The SOLAR QUARTERLY

The Complete Solar Magazine

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JAWAHARLAL NEHRU NATIONAL SOLAR MISSION
Realizing the dream

KNOWING AND CARING
For the operational needs of PV power plants

SOLAR TREE
An innovative concept for generating 'green power'

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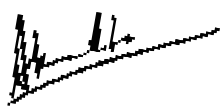
From the editor's desk...

The financial year is coming to an end. While we are waiting for a consolidated industry summary put together by some of the leading consulting firms to know the performance of the PV sector in 2009, indications are that it has performed fairly well. There was no oversupply of modules or redundancy in production capacity. In fact, most PV module manufacturers indicated an increase in the sales. India itself contributed to about 30 MW of PV last year. The other promising news is that, Germany itself consumed more PV in 2009 than the combined consumption of top 10 markets, according to *PHOTON International*. From 3000 to 3850 MW, it truly emerged as the world leader with Japan in the second position having installed about 500 MW. Other top rankers are the United States, Italy, and Czech Republic. With ambitious targets for the JNNSM, India hopes to place itself on the international map of top 10 PV markets.

There are challenges though. A large portion of the JNNSM's targets are sought to be met through off-grid small capacity systems, typically serviced by PV modules of capacities to 50 W or less. Going by the industry trends, this category of modules are becoming hard to find. The database of average power of modules compiled by a leading analyst suggests that modules with less than 100 W are relatively scarce; 200 W seems to be the industry standard. While this is good news for grid-connected PV markets which dominate the market share globally, it is a disturbing trend for small off-grid markets which would perhaps be forced to buy PV modules that are not produced by world leaders in PV manufacturing. The cost per watt which is important for large markets, is equally, if not more, important for consumers of off-grid markets typically present in developing countries. The challenge for JNNSM would be to ensure the steady supply of good quality modules at competitive prices to its millions of consumers that reside in far and remote locations of the country.



Akanksha Chaurey
Director, TERI

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LETTER TO EDITOR

Thank you very much for your encouragement. The editorial team of The Solar Quarterly will make every effort to make this magazine highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvement in terms of content and presentation.

Editor
The Solar Quarterly

I have recently started reading *The Solar Quarterly* magazine and have found it exstremely informative. I like the research based and technical articles in the magazine. I would like to subscribe this magazine on a daily bases.

The January 2010 issue was very interesting and had a good collection of articles. I really liked the mixture of articles. There were technical, research based as well as generic articles. I was perticularly impressed by the 'Lighting up Cambodia: the solar way'. It was a well written and a well presented article. I also liked the layout.

Keep up the good work and hope in future the magazine brings out more such informative and interesting articles.

Ankush Bhatia
Uttar Pradesh

I read the January 2010 issue of *The Solar Quarterly* and found it very interesting, knowledge-based, and Indianized. I have always been interested in the field of solar, and thus the magazine is a very useful resource for me. All the best to *The Solar Quarterly* team!

Neha Singh
Delhi

I am very thankful to TERI (The Energy and Resources Institute) for your quarterly magazine *The Solar Quarterly*. It is extremely encouraging to see such a magazine being published in India. The issue or topics taken up by the magazine reflect the state of renewable and specifically solar energy. At the same time, we are made aware about the recent developments in the technological front. I really like 'from the archives' section.

Ameesha Bhatia
West Bengal

I have been subscribing to *The Solar Quarterly* magazine since last one year. A lot has changed in the magazine. I appreciate the hard work that goes behind this magazine. Also, I am really happy that the number of pages of the magazine has increased. This helps us gather much more information on solar energy.

Anju Singh
Maharashtra

I have read the previous issue of *The Solar Quarterly* magazine. Few of the articles are really interesting. I like the expert speak section, and I think that you should increase this section. Also, the new section, titled, 'from the archives', is very interesting and gives access to article which otherwise are difficult to find at time.

Keep up the good work.

Gargy Mehra
Bihar

I have been following the magazine since its inception. Though, I love the content of the magazine, I feel that the editorial team should try to change the layout of the same. The magazine has too many pictures and it will be good if the pictures are decreased. Many pictures in the magazine are generic and can be done away with.

At the same time, I would like to write that I am really impressed by the content of the magazine. *The Solar Quarterly* has a good mix of generic and scientific articles.

All the best for the future issues of the magazine.

Rohit
Delhi

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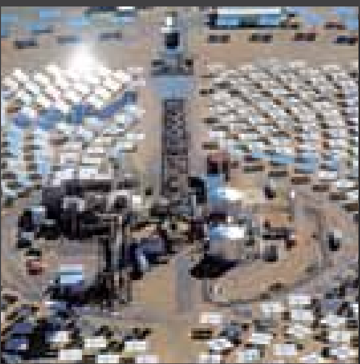
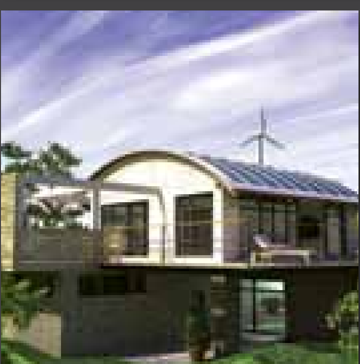




Google develops prototype mirror for solar energy

Google Inc. has developed a prototype for a new mirror technology that could cut by half the cost of building a solar thermal plant, Bill Weihl, the company's green energy czar recently said. He said that if, development and testing go well, he could see the product being ready in 1–3 years time. 'Things have progressed,' Weihl said in an interview. 'We have an internal prototype.' Google has been looking at unusual materials for the mirror's reflective surface and the substrate on which the mirror is mounted. In solar thermal technology, the sun's energy is used to heat a substance that produces steam to run a turbine. Mirrors focus the sun's rays on the heated substance. The Internet search engine company, which has been investing in companies and doing research of its own to produce affordable renewable energy, wants to cut the cost of making heliostats, the fields of mirrors that track the sun. 'There is a decent chance that in a small number of years, we could have a 2-X reduction in cost,' he said. Global companies are increasingly investing in green technology as the world grapples with global warming and governments strive to implement regulations that could limit greenhouse gas emissions. Google has invested in two solar thermal companies, eSolar and BrightSource, with which it has discussed the new mirror technology, Weihl said. He said the technology was not at a stage, where it could be tested externally, but he added that both eSolar and BrightSource were interested in it. 'If it works, it would absolutely be something they would use,' he said.

Source: The Economic Times

ABB wins a contract of $30 million for solar power plant

ABB, the leading power and automation technology group, has won a $30 million order from GA Solar, part of the Gestamp Corporation, to deliver a 13 MW PV (photovoltaic) power plant in northern Spain. Connected to the grid, the plant will supply up to 22.6 gigawatt hours of electric power a year, thus avoiding the generation of over 11 500 tonnes of CO_2 emissions, equivalent to the annual emission of over 4800 European cars.

Source: www.solarplaza.com

Analyst: solar installations rise, prices sink

PV solar installations are expected to soar in 2010, but erosion in average selling prices as seen in 2009 will continue to squeeze profits, and thus intensify industry competition, according to an industry analyst's report. Installations in terms of Watts of PV systems will increase by 64% this year to 8.3GW, returning to pre-2008-decline levels as the global recession recedes and demand reemerges in new segments and geographies, according to Henning Wicht, Senior Director and Principal Analyst for photovoltaic systems at iSuppli Corp, while summarizing a new report. 'A newly energized German market' leads the way as it recovers from a sluggish 1H09, though this could stall again by summertime if, the feed-in tariff gets trimmed by the Merkel government, he says. Growth markets are emerging (the US, Italy, and China, together 50% of the 2010 growth picture), though because of Germany's overwhelming influence (it accounted for 50% of total worldwide PV installs in 2009), 'collective PV demand accruing from other countries will not be sufficient to compensate for a German FIT reduction of 15% if, that were imposed in mid-2010,' he notes. Still, despite a general increase in demand this year, rampant price erosion that took hold in 2009 will continue in 2010, according to Wicht's calculations.

Source: www.photovoltaicsworld.com

First Solar signs 300 MW PPA with PG&E, Arizona

First Solar has signed a 300-megawatt power purchase agreement to supply Pacific Gas and Electric Company with electricity from a utility-scale solar photovoltaic power facility that First Solar is developing in southern California. The project's permit application has been fast tracked by the Bureau of Land Management and should come through in the next few months. The Desert Sunlight project, which is set to be built near Desert Centre in eastern

Riverside County, California, will have a total installed capacity of 550 MW. The other 250 MW portion of the project is already under contract to SCE (Southern California Edison). First Solar's power purchase agreements with PG&E and SCE are subject to the approval of the California Public Utilities Commission. Desert Sunlight brings First Solar's North American project pipeline up to 1.7 gigawatts. First Solar plans to build the Desert Sunlight project using its low-cost thin-film modules and the company said that it also plans to use its project development, engineering, procurement, and construction capabilities to bring the project to fruition. Construction on the project is expected to start by the end of 2010 and be completed as early as 2013, creating approximately 430 construction jobs over the three year period. The project's permit application has been tracked by the Bureau of Land Management and should come through in the next few months. First Solar is one of the few companies that have all the capabilities required to realize very large, utility-scale solar projects like Desert Sunlight. 'These are important in helping our customers and California reach the state's renewable energy goals,' said Rob Gillette, Chief Executive Officer, First Solar chief.

Source: www.renewableenergyworld.com

IBM's thin-film PV offers hybrid non-vacuum approach

IBM has a long history (going back to the 1970s) of working in solar photovoltaics, mainly with silicon-based solar cells. In the recent years, it has expanded to explore

thin-film PV, with one particular focus on low-cost solution-based approaches for depositing thin-film chalcogenide material. It is a perfect fit for David Mitzi, manager of PV science and technology at IBM Research in Yorktown Heights, New York. He has a background in solution processing for metal chalcogenides in other technologies, notably phase-change memory.

Focusing on the benefits of the thin-film PV hinge vs. silicon-based photovoltaics, Mitzi explained that silicon material has an indirect band gap, which complicates its ability to absorb solar radiation; tricks and enhancements such as light-trapping can help, but these also add complexity and costs. On the other hand, thin-film materials such as CIGS/CIS and CdTe possess a direct band gap, meaning thinner layers of them can absorb solar radiation. 'The physics points that using thinner layers of material,' he said. Thin-film materials also are less susceptible to 'grain boundaries,' meaning there is less efficiency-dragging recombination vs. silicon, Mitzi noted. IBM's use of a particular collection of earth-abundant kieserite materials (copper, tin, zinc, sulphur, and selenium) solves another issue. Materials such as cadmium and indium are not only scarce, but they are also highly sought after for other electronics applications. Limited supply and high demand makes them exceedingly expensive and adds to the overall PV cost.

Source: www.photovoltaicworld.com

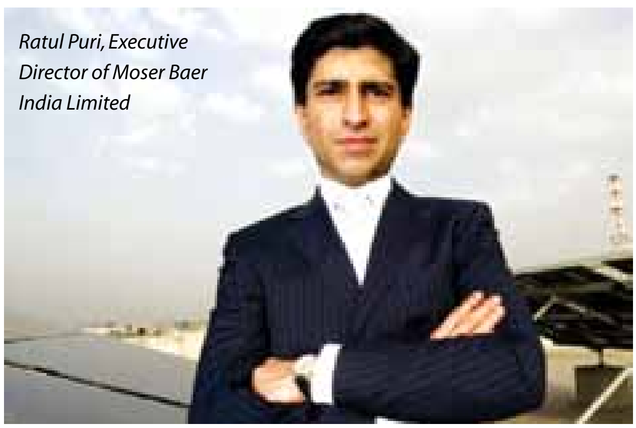
Moser Baer tips 7.3% efficient a-Si modules

Moser Baer says it has upped the conversion efficiency of its amorphous silicon single-junction thin-film modules from 6%–7.3%, which translates into a module wattage improvement of 400W/panel from 340W/panel (for full-size 5.7m^2 modules). Key to the improved efficiency is 'judicious optimization of multiple layers in the device structure,' which Ratul Puri, Executive Director of Moser Baer India Limited, called 'a game changer' in a-Si technology for solar farms that will help the company 'address certain sections of the market'. He also emphasized that the achievement is from an Indian company. Besides improving module efficiency and wattage, the upgrade offers a ~20% cost advantage. It has helped the company increase its thin-film capacity from 40MW to ~50MW, added Rajiv Arya, CEO of Moser Baer's PV solar business. Besides its thin-film segment, Moser Baer says, it also has about 80MW capacity each for crystalline solar cells and modules, and a few MW for concentrated PV.

Source: www.photovoltiaicworld.com

Quick Cable introduces battery-containment systems

Quick Cable Corp., a manufacturer of products for electrical storage and connectivity, has released the Rescue line of battery-containment systems, battery racks and cabling systems



Ratul Puri, Executive Director of Moser Baer India Limited

in conjunction with the release of its new stationary power catalog. Designed to comply with the uniform fire code, occupational safety, health administration, and environmental protection agency regulations, rescue systems are constructed of industrial-strength materials to offer the highest level of protection for stationary lead-acid battery systems, the company says. Available in PVC or stainless steel, Rescue battery-containment systems are the complete turnkey systems that include PVC liner, absorbent pillows and socks, rails, corners, and clips. The company's new battery racks and cable kits are designed to be used in conjunction with rescue containment systems. The modular racks are made with sturdy steel construction and are powder-coated. They are available with two fixed shelves or one fixed shelf and one roll-out shelf. Complete cable kits are available with or without disconnect hardware.

Source: Quick Cable Corp.

Solar industry to hit $77 billion in 2015

As the books close on what was a turbulent 2009 for the solar industry, Lux Research said that the solar market will soon see the lopsided supply and demand that characterized much of the last year's return to equilibrium. According to the new report, *Solar's Shakeout: Europe Loses Leadership as China Rises*, 'strong demand growth in Asia and the US will push the market to 9.3 GW in 2010, hitting a dollar value of $39 billion. Building from there, continuing price reductions for all types of solar technology are expected to open new markets and help the solar industry reach $77 billion in revenue and 26.4 GW in capacity by 2015. A large portion of the growth is expected to come from China, which in the last few years has become a large manufacturer of solar modules and materials, but not yet a large buyer of the same. Lux said it expects China to be the world's largest solar market in 2015. The report underscores, however, that the renewed balance between supply and demand will arrive only after a wave of company failures and lower utilization rates.

Lux analyses economic competitiveness and other drivers for the industry's six major technologies, crystalline silicon, cadmium telluride, thin film silicon, copper indium gallium diselenide, high concentrating photovoltaics, and concentrating solar power. 'We found that solar's short-term pain will enable it to exceed growth expectations over the very long-term,' said Ted Sullivan, a senior analyst for Lux Research, and the report's lead author. 'The volume of solar installations will grow at a 23% annual rate from 2010 to 2015, but revenue will grow by just 14%, as prices fall due to remaining over-capacity. While current subsidies in China and elsewhere will help soak up some of that capacity, there will be widespread company failures throughout the value chain first.' The report updates earlier market size and demand forecasts, extends Lux Research's outlook through 2015, and adds three new geographies – Czech Republic, New Jersey, and Ontario – due to their high levels of subsidies and rapidly developing markets.

Amongst the key findings are the following.

- The supply and demand curves to move abruptly together over the next few years due to company failures.
- Demand will also increase in regions such as China, prompted by the government subsidies and other factors.
- Low-cost X-Si technologies will continue to dominate the marketplace, but thin-film and CSP will gain market share.
- As financing begins to return to solar in 2010, crystalline silicon players will continue to use low price as a weapon against new technologies that do not share its 'bankability' or scale.
- New technologies such as CSP, CIGS, and even HCPV technologies are expected to gain at the margins.

Source: www.renewableenergyworld.com

SOURCE: NREL/DOE

Solar power could provide 10% of the US energy

The United States could source 10% of its electricity from solar power by 2030, a report said. It has won the support from a US lawmaker, who wants to boost the number of US solar panels. The report, produced by the independent environmental group Environment America, was presented to Congress with backing from Senator Bernie Sanders who in February introduced legislation to install 10 million solar panels across the United States within a decade.

Sanders praised the report, which said the United States could get 10% of its electricity from solar power by 2030, up from just 0.1% in 2008, according to the Energy Information Administration. Sanders's bill, which has gained the support of several other Democratic senators, proposes 'rebates for the purchase and installation of an additional 10 000 000 solar roofs... by 2019.'

'At a time when we spend 350 billion dollars importing oil from Saudi Arabia and other countries every year, the United States must move away from foreign oil to energy independence,' opined Sanders .

Source: www.solarplaza.com

Toshiba, sun power take aim at Japan's home solar market

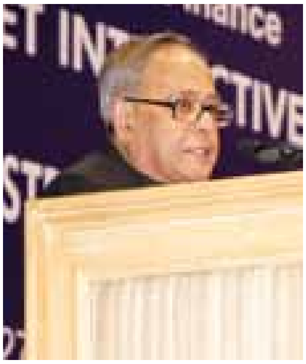
Toshiba is setting its sights on the domestic Japanese home solar system market, signing a third-party US panel supplier to help build the cornerstone of a new residential solar offering. Toshiba is linking up with Sun Power to procure 32 MW of panels with maximum 210 MW output. The company also plans to train about 3000 panel system installers in the next fiscal year. Estimates see the Japanese market for home-use solar power systems more than quadrupling to Yen 600 billion in the eight years from 2008–2015, of which the new partners hope to take a 10% slice, notes the Nikkei. In a statement, Sun Power CEO Tom Werner and Shoji Takenaka, chief technology executive of Toshiba's transmission distribution and industrial systems company, agreed that the deal's sweetspot is in offering high-efficiency panels. This is because Japan's new feed-in tariff 'rewards production of solar energy in excess of domestic consumption, but available roof area is typically quite small.'

Source: Photovoltaic World

Significant investment to flow into the solar sector

The announcements made in the Union Budget 2010/11 to promote the use of cleaner energy will direct significant investment into the solar energy sector, Moser Baer Group Chief Financial Officer Yogesh Mathur said. 'The government has been clearly consistent and has taken measures to support various technology and renewable energy sectors. The budget is a testimony to that as there is provision of clean energy fund, for driving investment towards clean energy,' Mathur told PTI. The clean energy fund could see several thousand crore rupees being mobilized on an annual basis and a significant chunk of this would go into promoting investment into the solar sector, he added. Finance Minister had also announced a concessional duty of 5% on equipment and appliances required 'for initial setting up of photovoltaic and solar thermal power generation' while exempting those from central excise duty. 'Overall, the custom duty reduction is to basically promote the sector and make it more competitive. Solar equipment maker Moser Baer expects that the sector will now see major investments for setting up large solar farms. The cost of solar energy per unit is still high as compared to conventional sources of energy but with advancing technology, that is coming down. With increasing investments in the sector and government support, it will become cheaper. The cost per unit in coal based power generation (base load) is approximately in the range of Rs 4–9, while the cost per unit in solar power generation is about Rs15–17.

Source: www.livemint.com



The Finance Minister of India gave a number of incentives to the renewable sector in the Union Budget 2010/11

Power regulator to offer sops for wheeling solar power

The CERC (Central Electricity Regulatory Commission) is expected to come out with new tariff rates for electricity generation from solar thermal and solar photovoltaic energy systems. To incentivize wheeling of power from the large-sized solar projects, the electricity regulator has proposed zero transmission access charge for use of the inter-state transmission system. CERC draft regulation on 'sharing of inter-state transmission of charges and losses' stipulates that solar-based generation would be

allowed zero transmission access charge for use of the inter-state transmission systems. Explaining the rationale, a senior official told, 'Given the fact that solar power tariff is higher than electricity from other sources, this has been proposed.' Currently, the open access charges levied in addition to high rate of solar power makes electricity from this source even more expensive. Open access envisages the possibility of any power generator getting to sell electricity to a consumer of his choice by getting access to the grid on payment of requisite transmission charges and a surcharge. Currently, the cost of electricity generation from solar thermal and solar photovoltaic energy systems is Rs 13.45 and Rs 18.44 per unit, respectively. 'Therefore, to ensure that high tariff does not become a deterrent this proposal has been mooted,' the official said. Most of the large solar projects are slated to come up in the states of Gujarat and Rajasthan. 'The proposed regulation will go a long way in facilitating the possibility of the developer of these projects selling excess power to the grid,' the official said. Meanwhile, the CERC is also expected to come out with new tariff rates for electricity generation from solar thermal and solar photovoltaic energy systems. This new tariff is likely to address the grievance of the industry that incentives should be technology neutral. While the regulator is addressing the issue of charges on transmission, the government has already flagged off a programme aimed at giving solar programme a boost on the generation side. The Jawaharlal Nehru National Solar Mission, launched in January 2010, envisages an investor-friendly mechanism that reduces risk and provides an attractive as well as sufficiently extended tariff for the solar power offtake. The mission targets the setting up of 20 000 MW of solar generating capacity by the end of Thirteenth Five-year Plan (by 2022).

Source: The Hindu Business Line

3 LED solar touch light

This new generation lamp is simple but effective. It is known as the POWER plus Spider. The Spider is a solar push light with three ultra bright LEDs (13 000 MCD) and integrated suction cups. Just place the Spider with the suction cups on the glass facing towards day- or sunlight, and the Spider will be charged by using solar energy. During night time, just push the Spider to get a powerful light or take the Spider with you, wherever you need light. The Spider can easily be mounted on glass or any other smooth surface thanks to the integrated suction cups. No screws, no tape, just place the Spider anywhere you want. It is quite effective for use at home, camping, car, boat, garden, and so on indicating easy, compact, and free lighting. This light uses a Nickel metal hydride battery of 40 mAh at 3.6 V. LED lifetime is estimated at about 10 000 hours. Use of ABS rubber coated material has been made for the purpose.

Source: Power Plus, Eco-Energy Products

Dongying, China: CNPV Solar Power signs module supply agreement with South Korea's Techbank

CNPV Solar Power SA, an integrated manufacturer of solar photovoltaic products from the production of ingots, wafers, and cells to the assembly of PV modules has entered into a long-term strategic partnership sales agreement with Techbank Company Limited, a South Korean leading photovoltaic company that develops and sells turnkey photovoltaic power plants.

Under the terms of this strategic agreement, CNPV will supply Techbank with a total of 36MWp of PV modules from 2010 to 2012, which includes 10MWp of scheduled delivery during 2010. The remaining 12MWp and 14MWp are scheduled for delivery in 2011 and 2012 respectively.

Myung H Oh, CEO and President of Techbank said, 'CNPV Solar Power is a leading supplier of high-quality, high performance solar modules in the Korean market. CNPV Solar Power modules are quickly recognized by our customers as a product with one of the best energy production ratios. We are very pleased to expand our strategic partnership with CNPV, which will allow us to provide long-term superior solutions to the attractive solar market in Korea, especially to our important local power utility customers.'

http://www.solarbuzz.com/news/NewsASCO562.htm

Berlin, Germany: SOLON SE signs 20 MW framework agreement

SOLON SE has closed a framework agreement for the supply of solar modules over several years with the solar distributor entrason from northern Hesse. The total quantity of the contract amounts to approximately 20 MW, or 90 000 modules, for the first year. Mostly, SOLON 230/07 Blue and SOLON 230/07 Black modules will be delivered nationwide to specialized retailers through the distribution network of the new SOLON partner.

SOLON SE is one of the largest solar module manufacturers in Europe and a supplier of solar energy system technology for large-scale, roof-mounted, and ground-mounted systems. Stefan Säuberlich, CEO of SOLON SE, stated, 'We are looking forward to a long-term partnership with a dedicated solar wholesaler, who not only requires premium quality and the ability to innovate, but also has the necessary specialized product knowledge...' 'Having SOLON SE in our portfolio means working with one of the leading premium manufacturers, who is known for high reliability and high standards of quality,' says Alexander Eysert, Managing Director of entrason gmbh. He adds, 'Our cooperation with SOLON places us in an even better position to meet the wishes of our customers.'

http://www.solarbuzz.com/news/NewsNAmerica.htm

Los Gatos, USA: Akeena Solar to provide installation services for Lowe's

Akeena Solar will provide residential installation services for Lowe's customers in 21 California stores. The announcement comes just a few months after Andalay AC solar panels first hit the shelves as part of Lowe's Energy Centre, making them the first grid-connected solar power systems to be sold by a major retailer.

'Akeena Solar has always focused on making solar power easy, thus more accessible for customers. Now that homeowners can see Andalay AC solar panels on the shelves at Lowe's, there is even more interest in installing solar for their own homes,' said Barry Cinnamon, CEO of Akeena Solar. 'Homeowners now have the option to install a few panels on their own or use Akeena's professional installation services available through Lowe's. Lowe's and Akeena Solar give homeowners the flexibility they need to get reliable solar energy and immediately decrease their electric bills.'

Akeena says Andalay AC panels provide homeowners with reliable, high-performing solar systems. The racking, wiring, grounding, and inverters are integrated into the panels, reducing the overall parts count by 80% and protecting against performance-threatening breakdowns that could happen with ordinary DC power systems.

By using built-in inverters, Akeena says Andalay AC panels produce up to 25% more energy compared to ordinary DC solar panels. Additionally, the Andalay AC panels' modular design allows homeowners to start small. They can purchase a few panels at Lowe's to install now and can easily add on later, unlike DC systems that require a complete redesign when adding panels.

http://www.solarbuzz.com/news/NewsNAC01098.htm

Hsinchu, Taiwan: Neo Solar Power to raise cell capacity to 800 MW

Taiwanese solar cell manufacturer, NSP (Neo Solar Power) recently announced that the board-approved capacity expansion plan of 200MW, enlarging the company's annual production capacity to 800 MW. The extra 200 MW is expected to be completed by the end of Q3 or early Q4. Upon completion, NSP's new capacity is expected to drive its revenue and profit to a new high in the near future.

In addition, NSP plans to conduct the capital-raising through one of the three options approved by the board, including equity offering, GDR issuing, or the private placement. The total capital raising is estimated to be approximately NT$3 billion and will take place concurrently with the syndication loan. However, the actual funding plan will be decided in accordance with the market conditions.

With the bullish outlook for the solar industry in 2010, NSP actively maintains its production capacity expansion in line with the customers' demand while reducing its manufacturing cost.

http://www.solarbuzz.com/News/NewsASMA289.htm

KNOWING AND CARING FOR THE OPERATIONAL NEEDS OF PV POWER PLANTS

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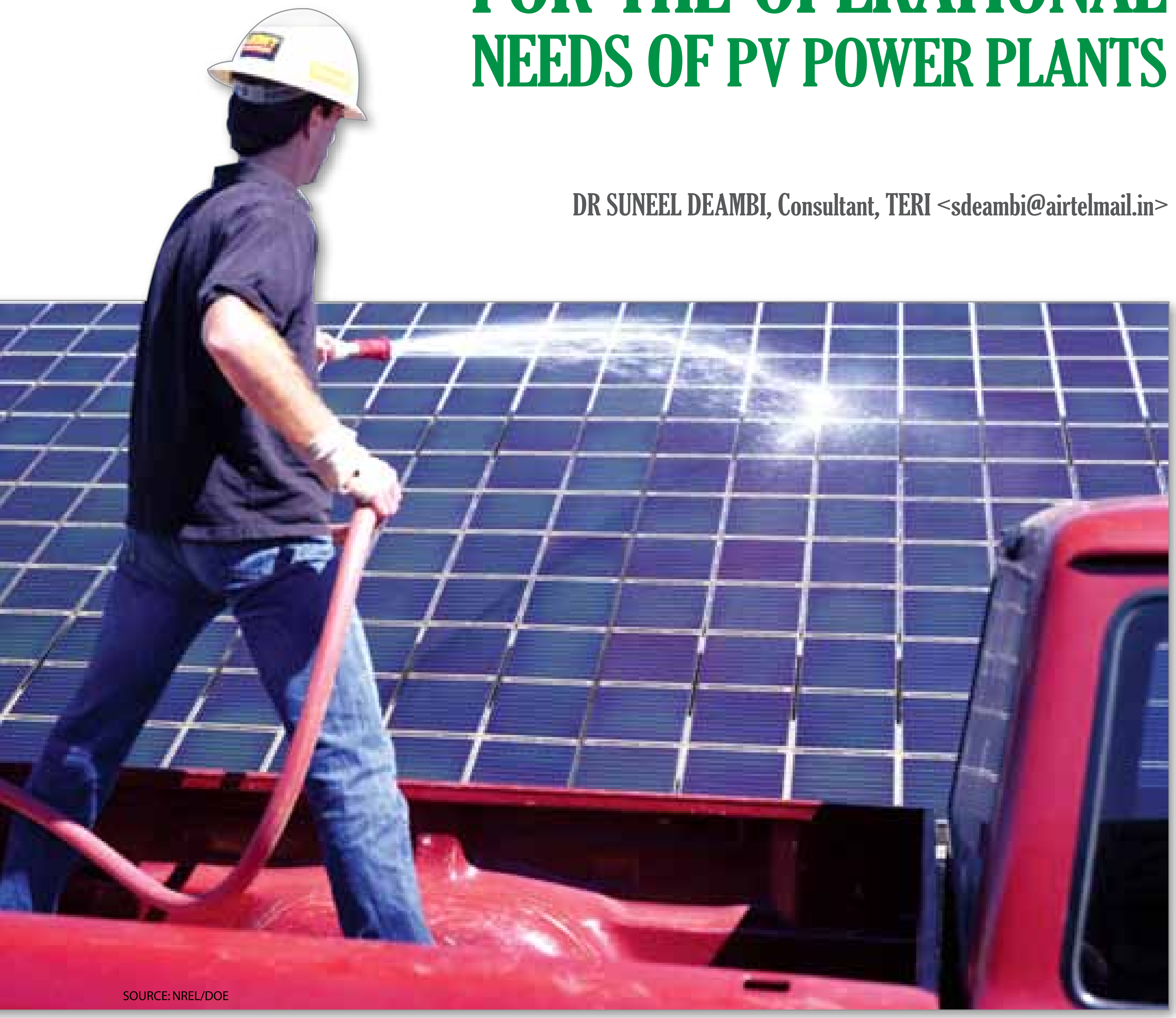

SOURCE: NREL/DOE

Background

Lately the solar PV (photovoltaic) technology utilization is being seen in a larger context than ever before. Most of the national and international forums are currently abuzz with deliberations related to cell/ module technology, policy, programme implementation, and financing-cum-marketing issues. So far so good, but there seems to be little consideration for an equally focused attention on the O&M (operation and maintenance) issues related to the large capacity PV grid-connected power plants. Often, the view that circulates around is that PV systems work entirely on their own without the need for any care or maintenance. It is definitely a marketing trick, which has been sold to quite a few clients if, not worldwide. Incidentally, PV panels and thereby a PV system is still very expensive to be left uncared for amidst the vagaries of nature. This can be easily compared to any household item that one takes care of to get the solution. Well, a solar PV system too needs routine O&M (operation and maintenance), which also calls for a certain budgetary allocation. This article attempts to address few selective issues related to this important aspect.

The beginning

MNRE (Ministry of New and Renewable Energy), India, undertook a country wide PV demonstration programme. It led this extensive programme from the front. Under this programme, a wide range of products were delivered to the end-users who were mostly drawn from the remote rural areas. In fact, solar street lighting systems were amongst the earliest systems to be tried in the field. However, these suffered from a few initial failures, which subsequently led to earmarking of a certain fixed amount as O&M charges to safeguard the interests of end-users at large. Such a consideration was later on extended to solar lanterns, home lighting systems, water pumping systems, the village power packs, and so on. The outcome on the whole has been positive as is evident from the increased field performance reliability of these products. However, the moot question is: only a mere allocation of budgetary support is necessary for an extended O&M support of the PV products or there is more to it than what meets the eyes? To begin afresh in this direction we first need to dispense with the very notion that PV system is totally maintenance free.

Being assumptive

One can make certain type of assumptions, which falls in the category of predictable and non-predictable issues. For example, temperature degradation and line losses are well known to occur in a PV system and can thus, be called as the predictable. Simultaneously though, soiling and downtime of a PV power plant are often not known. Therefore, this later issue can well be put under an unpredictable assumption. Quite often, out of genuine interest, one tries to estimate the daily, monthly, and/or yearly energy production, and this can also be in case of a PV grid power plant. These mainly include the actual monthly output and predicted monthly output, which can throw some light on an overall state of well being of a PV facility. However, there is a vital need to add some more tools to assess the system performance under the actual field operating conditions. Let us now try to look closely at the monitoring of various system components beginning with the inverter.

Monitoring of inverter

It is a very vital component of a PV system. Majority of the inverter manufacturers offer a menu-driven user interface mainly along the following few considerations

- Functional status
- Variable parameters
- Operating data

The inverter passes on some important information related to the following few parameters. It even exercises a self check on itself, which leads to problem identification of a definite nature as well.

- Amount of DC (direct current) power being fed into the inverter
- Amount of AC (alternating current) power being produced on the back end
- Efficiency of DC to AC conversion

Array monitoring

PV array is a source of DC power, which also means that one need to know the DC current that is being produced from sections of the array. Take the case of a PV array with a large inverter. A simple way to monitor the array performance is in terms of mounting DC current transducers on the incoming DC cables making their way to the inverter cabinet. These transducers are expected to pass on current flow information from various sections of the array into a DAS (data acquisition system). Following which, the plant operator can get reliable insights into the array functioning. However, in a large assembly of modules, difficulty may arise with regard to knowing the faulty performance of a single panel due to shading and so on. So, it may also be of interest to check for any such shading through a physical inspection. The likely incorporation of a small inverter with each solar module is expected to be more advantageous than a centrally designed inverter. It is mainly due to the following few considerations.

- Mismatch losses from the panel are eliminated
- Loss of a single panel will not impact the output from the surrounding panels
- AC wiring from the inverter to inverter does away the DC wire losses
- DC current is measured at each module
- Data is sent to a communications hub-via-the AC conductors thereby avoiding the need for parallel communication lines

However, it is still a costly affair to adopt the practice of attaching individual inverters and also that it is not sufficiently field tested.

Power conditioning

Its use is akin to the micro-inverters in the sense that these are mounted behind every panel in an array wired to a string series. This makes the performance monitoring of individual modules easy in addition to keeping the array design simple. The additional benefit comes via the elimination of panel mismatch problems. It is important to mention here that power conditioners perform the maximum power point tracking or simply the MPPT (maximum power point tracker) at the panel. The resultant outcome is by way of improved system efficiency and so on. However, yet again, the DC power conditioning makes the system more expensive and may have to wait for an opportune moment.

Preventive maintenance

Let us now take a close look at what is usually known as the preventive maintenance. In general, it deals with the following few issues.

- Cleaning of panels
- Servicing of inverters
- Maintenance of trackers
- Inspection of the balance of system

It is of definite interest to evolve a regular O&M routine for undertaking such work(s). The solar panels can be wiped clean as and when needed. However, a strict regime needs to be put in place for checking the other system components such as inverter and so on. Ultimate objective of preventive maintenance is to enhance the system efficiency, which in turn may lead to an extended life span of the system as well.

Specific maintenance tasks

PV modules are aesthetically pleasing in undeniable terms. However, a PV system is at times considered to be an inert system going unnoticed in its operation, should any one even closely pass by a PV installation. The balance of system components can generally be put down as the following.

- Junction boxes
- String combiners
- Conduit runs
- Fixed mounting structures
- Disconnects
- Communications equipment

A daily inspection of the above mentioned items may not be required as against a certain preference for either an annual or a bi-annual check. The all important task is to find out any corrosion, loose connections, and so on. A manual touch may lead the sensitive field personnel to know if there are any loose mechanical connections. It is also of a vital importance to detect any presence of rust and water seepage inside the enclosures. In contrast, any weak electrical connections occurring in the combiners and junction boxes may come to light via thermal imaging. Further, it is of an increasing important to ensure a clean and dry environment besides tight wire connections for the communication equipment.

The solar PV panel is the core element of any PV system. Any amount of dust accumulation on the panel will reduce the efficiency level. Regular maintenance is required to keep the efficiency level high.

Cleaning the solar panel

The solar panel is the core element of any PV system. It absorbs the incoming solar radiation and converts it into electricity. Quite obviously, the surface of module needs to be kept as clean as possible all through the year. Any amount of dust accumulation and so on will result in a reduced passage of radiation through the glass surface. Thus, lower power output is obtained from the same panel under two different conditions. The key objective is to optimize the energy production while keeping the component failure at a bare minimum. There is a more pronounced way of knowing about a right time for undertaking system cleaning. To arrive at that, we have to take actual energy production as measured at the metre and adjust it by using the ratio of actual solar insolation to the expected solar insolation for the solar system. Thus, the value obtained is then to be compared to the projected degradation as adjusted for degradation over a period of time. The net result obtained is the system efficiency.

Seasonal effects on the solar panels

India is a land of diverse geographical regions and climatic conditions. During some parts of the year, the weather is completely dry or rainy. Some agricultural areas where a PV system is at work may get exposed to the pollen problem. The windblown dust gets collected on the module surfaces in the dry season. Likewise, a huge gathering of birds is witnessed at some time of the year rather than in the remaining parts of the year. This may result in enhanced bird droppings at times. A module is exposed to the hot summer all day long, which makes it quite hot. It is not prudent to sprinkle cold water over it due to the threat of thermal fractures looming large over it. Surely, rain may be a naturally occurring choice when it gets too hot. It will wash away any dust or bird droppings on the panels as well as help to keep the module cool. Solar modules can be put up either on ground or mounted on the flat roofs.

Thus, it may be easy to clean these by using a locally available water jet. In contrast, it is always a tricky affair to clean the surfaces of tilted roof mounted solar arrays. Overseas, it is a common sight to see the use of mechanical lifts when it comes to, say for example, the cleaning of elevated arrays.

Few other issues

One needs to always be on a lookout for broken cells, affected wiring, and any discolouration of cells. It is also important to identify any broken glass surfaces that may be prone to water ingress or other elements. It is obvious that every maintenance related activity incurs some cost or the other. As per the available estimates, it should not cost more than $.0025/watt to clean (based on the value of dollar in 2009–10) the ground mounted and flat rooftop mounted systems. One of the commonly available procedures to clean panels is to use weak vinegar solution in the proportion of two tablespoons per gallon of water. Vinegar is made by a chemical change commonly known as the fermentation. This solution breaks the surface tension of water thus, causing it to shine from the glass without spotting. A soft bristle brush can then be used to mechanically remove any soil prior to the process of a thorough rinsing by water. In case of a large array field, it may be necessary to use a water pump capable of forcing large volume of water at some distance(s). However, one needs to take proper care so as not to break any panel seals. Having said so, it may be of an equal interest to know the amount of time taken to clean a 100 kWp array field. Assuming the use of 150 Wp panels, there would be about 666 of these at work. A team of 3–4 people may perhaps be able to undertake the panel cleaning in about two hours or so. These days, customized designs of solar sprayers are also available, which can do the same job much more meticulously and speedily.

Inverters

When it comes to the actual use of a solar PV system, inverters are no less important. In a grid connected system, it may account for as much as 10%–15% of the total system cost in accordance with the type chosen for the purpose. The routine maintenance of an inverter also depends on its capacity rating. In general, following type of measures is quite necessary so as to ensure the well-being of an inverter.

- Making the contact tight
- Ensuring no water ingress
- Cleaning and replacing of air filters
- Lubricating the moving components (fans, handles and disconnects)
- Electronic diagnostics
- Knowing the hot spots via thermal scanning


SOURCE: NREL/DOE

The all important goal is to keep the inverter in a good running condition and enhance its life as well.

Tracking mechanism

Majority of the PV systems especially those deployed in remote locations do not involve a tracking system. It is a motion filled activity as against the static nature of remaining PV components. So, there is a likelihood of wear and tear of friction components, motors, sensors, cables, gearboxes, and so on. It is quite important to undertake regular checks of controllers and sensors for any loose connections, alignment, and so on. The setting in any corrosion may well be avoided at all costs.

The growing need for O&M measures

India is slowly but surely waking up to the reality of encouraging the use of megawatt capacity solar PV power generation as against the deployment of kWp size power plants until recently. There is now a heightened emphasis on taking the PV grid power capacity from almost a stagnant value of 2.5 MWp to a very sizable capacity of 20 000 MW (includes solar thermal power) by 2020. Thus, in the course of time, we will witness the installation of several large capacity PV grid connected power plants. However, the mote question at the core of such a massive demonstration is whether we are adequately equipped to take care of such facilities. Prior to answering it, let us take a brief look at our experiences of dealing with small capacity power plants, even though of a standalone nature.

O&M experiences with small power plants

Our early experiences (that is of chief editor and author of this article) during a MNRE supported project on, 'Performance Evaluation of Small Power Plants' in the state of Uttar Pradesh at The Energy and Resources Institute led to some interesting field observations. A total of 17 small PV power plants in the capacity range of 2–10 kWp were monitored in terms of their performance under actual field operating conditions. The routine care ranged from a physical


SOURCE: NREL/DOE

Large PV power plants need proper maintenance. However, many a times, proper maintanence is not done due to budgetary constrain and lack of awareness.

inspection of the PV array followed up by a regular monitoring of the battery bank condition. A member of the village community was found to be well trained for the purpose in most of the cases. In lieu of that, he received a very modest contribution out of the monthly charges collected from the village community itself. Following were his routine key O&M duties.

- Cleaning the dust/bird droppings on the solar modules
- Looking out for any loose connections in the panels
- Ascertaining if any junction boxes are open
- Checking for the battery terminal corrosion
- Measuring the specific gravity of the cells at regular intervals
- Reading the array current and array voltage from the control panel

However, it is obvious that the same level of skills will not be sufficient for taking care of the new breed of megawatt capacity solar power installations. It is equally true that PV-grid interactive systems avoid the drudgery of maintaining an expensive battery bank, which has often been deemed as the weakest link in a solar PV system. With GBI (generation based incentive) mechanism coming to the fore, the need is to maximize the power output from the PV array. This calls for a still more stringent operation and maintenance requirement by the personnel specially trained for this purpose. It is also because of the issues related to the smooth functioning of power conditioning unit and so on. The interfacing issues of PV with grid also bring with it some kind of complexity, which needs a regular attention.

Budgetary considerations for O&M

The box below gives a quick insight of the cost involved in the O&M of a 1 MWp Solar PV power plant. In this case, the annual operation and maintenance has been previously assessed at 1%–2% of the total system cost. However, more recently, the CERC (Central Electricity Regulatory Commission) has indicated an O&M cost of Rs 9 00 000 per MW for a solar PV grid interactive power plant. It is equivalent to about 0.5% of the total PV power plant cost, which means a definite reduction in such cost considerations. Further, if, seen in per Watt terms, it comes to just about a rupee.

Capital investment (Rs 20 crores per MW)
Debt-equity ratio: 2:1
Financing cost: 7-12%
Estimated generation: 1.5–1.9 million units/year
O&M costs: 1%–2%
Return on equity: 9%–14%
Cost of solar PV electricity: Rs 15 per kWh

Emerging trends in PV power plant monitoring

The global PV industry is fast maturing, which may also mean a growing recognition for standard practices related to the performance monitoring procedures of large size PV installations. Lately, the value of kWh generated is gaining prominence owing to the presence of feed-in-tariffs or simply FIT's. From the advent of small capacity PV power plants to the present era of megawatt capacity power generation, there have been many challenges for the solar professionals too. Until a few years back, a PV system operator had no other choice but to visit the site in order to ascertain whether the PV system was actually supplying power to the grid or not. He would then have to take a look at the metre connected to the AC output of an inverter for the stated purpose. Given that there are several types of inverters, some of these put up a single-line LCD (liquid crystal display) to show voltage and instantaneous AC output. To put it in a clearer perspective—the remote control capabilities depend on the use of both customized hardware and software packages. These facilitated the viewing of data at regular intervals followed by its transmission to a server in daily uploads. It was quite a routine affair in case of utility scale systems and large capacity commercial systems with a clear intention to know the variation between the rated and expected power outputs.

Equipment used at the site

Pyranometer is the most commonly used instrument used at the site to measure the amount of sunlight available in Watts per metre square (W/m^2) in addition to the sensors for the recording of ambient temperature. Anemometer is the instrument that is used to measure the wind speed and direction. The collective purpose is to know the environmental conditions at a given site, and thus to enhance the reliability of projected output from a power plant. A downside of this approach was seen in terms of an added expense for an average user and an overall complexity of understanding the whole process. Also thanks to the internet era, it has prompted a few companies to develop the web-based tools for connecting to inverter output. In this way, one gets a clear access to the current and historical data of any given system in an easy to analyse manner. That is not all, as some systems are also equipped to transmit the automated alerts in case of run-down condition of either an inverter or system as a whole for that matter. As of now, several inverter based companies provide some kind of near-real time web based monitoring for their systems. Likewise, some installation based companies make available a monitoring and performance package for an operator to know the field status of a system by a simple log-in.

Case specific example

The management of PV array is of vital importance. The modern day intelligent systems enable better safety feature, while working with a PV array producing power during the day. For example, take the case of a traditional PV array deployed in the United States. When there is bright sunshine, the DC voltage of a string can run from 375 V to 600 V as against 1000 V in utility-scale and European applications. It is not possible to prevent the flow of electrons by disconnecting the DC at the inverter. In other words, we have to physically shade the modules from the sun or disconnect them from each other so as to bring down the string voltage. The way out for

a trained operator working on the system is to disconnect the string of modules or the complete array on-site or via the use of customized software so that working with the PV array becomes safe.

Caring for the positive attributes

Let us now take a look at yet another interesting issue to understand how much profitable a PV power plant facility can be for any intended owner. With the recent announcement of generation based incentives and an accompanying need for the PPA (power purchase agreements), even in the Indian context this issue gains importance. The PPA has a strong bearing on an optimal production of the system for a positive-cash flow consideration. That simply means any increase in the uptime or the number of units produced can turn a marginal system into a successful venture. To put it in the real context, it involves building a certain capability to identify trends at the module level in terms of possible problem areas.

A follow-up measure could then be quickly initiated so as to enhance the uptime of a system. A quick example may be that of a problematic module or a string. The desirable trend is not to de-activate a complete array, but just that one problematic string. The immediate purpose is to keep rest of the array in a performing mode. There are several other situations too, which may not always be possible to detect in a large array field of a megawatt capacity power generation facility. These relate to the already touched upon issues like the presence of dust, debris, bird droppings, or even a broken module, which often result in lower array efficiency. The most recent technique can make use of an instant alert service for those responsible with the system upkeep to repair it within the shortest possible time.

Summing up the O&M initiative

It is quite essential to disseminate information on the field data obtained from the PV power plants of varying capacities irrespective of their off-grid or on-grid configuration. The underlying purpose is to develop a crystal clear understanding on the type of problems encountered in case of system components under the actual field operating conditions. With megawatt capacity power plants on the brink of large scale deployment, such a need seems to be all the more acute. After all, it is now a matter of dealing with larger array fields in conjunction with sensitively placed electronic and electrical controls. The larger effort must be to generate a large amount of on-site data for a meaningful and long-term analysis with a clear objective of maximizing the gains from a PV power generation facility in all possible ways. The climatic variations and their accompanying effects on the functioning of key system components across different geographical regions would be an area of broad based study for all those involved in the furtherance of these new generation power units.

Solar thermal system components

Optimizing the size for industrial process heat

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Introduction

With increase in fuel costs and environmental pollution, there is a race to find alternate sources of energy—both renewable and non-renewable. World over, the major focus has been to generate electricity through alternate resources. However, a major part of industrial energy consumption is in the form of thermal energy, a large fraction of which is needed in industrial processes below 250 °C. This need can be met using the solar collectors available in the market. The design space method as introduced by Kulkarni and others, is used to design and optimize the SIPH (solar industrial process heat) systems.

This article is based on author's Master (M.Tech) thesis. The basic goal of the project is that for a defined industrial process heat load and location, to find the size of main components of solar thermal system (solar collector field, pressurized hot water storage, and heat exchanger) so as to reduce the annualized LCC (life cycle cost) of the SIPH system. Many industrial systems with different load patterns have been analysed in the project with one of the cases presented in this article.

The underlying challenges

The sizing of a solar thermal system is important due to its high initial capital cost. To meet the process heat demands of a given industrial system, many system sizes are possible. Hence, it becomes important to choose the best option as per the optimization criteria. It needs to be stressed that the design of a SIPH system is a multi-constraint problem. Under designing the system affects its performance, while over designing would incur a higher capital cost. Additionally, the choices available for the solar collector and the intermittent nature of solar radiation make the computational problem very challenging.

Going solar

As previously mentioned, a large part of the industrial process heat required is at temperatures lower than 250°C, and hence can be supplied using the solar thermal systems. These solar thermal systems which can meet the industrial thermal needs are referred to as SIPH systems. The major components of SIPH systems are – solar collectors, energy transport system, and the controls-cum-instrumentation. Solar collectors may essentially be thought of as heat exchangers, which transfer heat of the Sun rays to a working fluid. Due to a wide range of process temperatures encountered in the industry environment, many different types of collectors have been proposed. For the needs of process heat concentrating collectors are required, as they can provide higher temperatures, and thus work more efficiently.

The energy transport system includes the entire setup required to transport the energy absorbed by the collectors to the proper location in the process system. This mainly includes the following few components.

- Piping
- Pumps
- Valves
- Heat exchangers (thermal energy) storage components along with the heat transfer fluid.

Water, the best heat transfer fluid

Water is the most popular heat transfer fluid as it is non-toxic, inexpensive, non-flammable, and has excellent heat transfer characteristics. Storage of thermal energy is important if, solar energy is to meet a larger part of process load. Sensible heat storage is the most common technique available commercially. It can be in the form of rock bin storage (for hot air), pressurized hot water storage, or steam accumulators. PCMs (Phase change materials) can store more heat on a volume basis comparison. Tamme and others reported the work, which has been done in developing PCMs for solar thermal power plants and for high temperature process heat.

The control scheme for the SIPH system has to balance out energy collection, energy storage, and process load usage. When the energy from the collectors is unable to meet the load, the control system should activate the use of an auxiliary system or the thermal storage, it may even supply the heat to low temperature energy needs. The instrumentation in SIPH systems is standard and includes flow metres, level switches, pressure transmitters, and thermocouples. The process data would be usually transmitted to a PLC system to relate alarm and status conditions, and can be forwarded to a data acquisition system so as to enable performance evaluation of the system. Solar insolation and wind data would also be required to be monitored for performance evaluation.

The selection of SIPH components depends on the form in which energy is to be used in the process. In the process industries, energy requirements are mostly met by hot air, hot water, and steam systems. Thus, based on the form of energy usage, SIPH systems may be classified as hot air, hot water, and steam based systems. Apart from these, it is also possible to use pressurized hot water and thermic fluids as the heat transfer mediums.

Simulating the effort

It is observed that a lot of effort has been directed to develop such computer programmes, which can assist in designing of the SIPH systems for example, SOLIPH. These tools take into consideration many practical issues such as row to row shading losses, overnight thermal losses, and so on. However, these tools have two main disadvantages. Firstly, they are expensive, time consuming, and need expertise in programming to be used. Secondly, they are uneconomical for

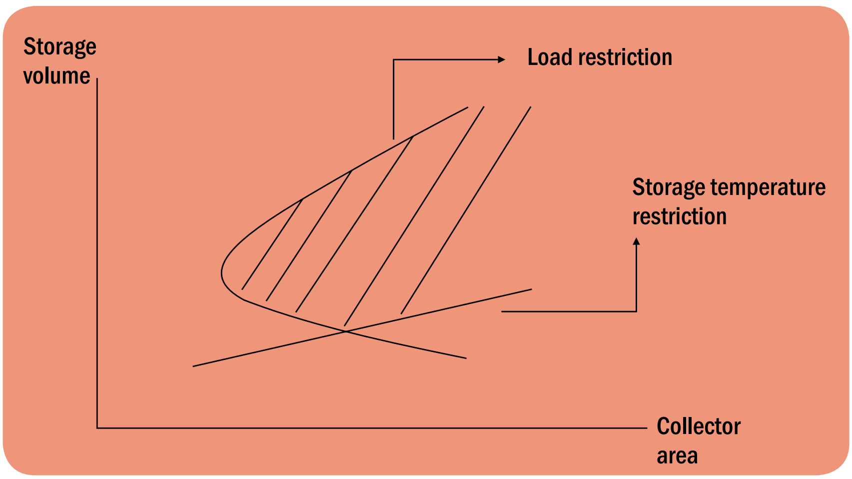

Figure 1 Design space

designing of small systems. For the growth of the SIPH industry, it is important that simple design procedures are available to select and size the various components. To develop such a procedure, some of the first steps were taken by the SERI (Solar Energy Research Institute) Colorado, USA. SERI developed a design procedure, which involved calculation of parameters using the graphical plots. These plots were generated using correlations developed from hour by hour runs of SOLIPH. However, the method can only be used for systems to be installed in the USA, as the correlations and the plots have been prepared only for the USA territory.

Another common approach for modelling has been detailed simulation of all the system components, and hour by hour simulation runs. This method, however, is very laborious. The SIPH system installed at Frito Lay plant in Modesto, California,USA, has been designed using this method.

Design space method

A new approach known as the 'The Design Space Approach' is presented by Kulkarni and others for the design of solar hot water systems. The core approach of the method is to use the design constraints to identify all the possible designs or a 'design space' on a collector area versus storage volume diagram. The design space as shown in figure1 is represented by tracing constant solar fraction lines on the collector area versus storage volume diagram. The design space in itself refers to the region bounded by constant solar fraction lines in a plot of collector area versus the storage volume. Since design of a solar thermal system is dependent on multiple parameters, it seems appropriate to first identify all the feasible points and then attempt optimization in the feasible region identified. The design space method also helps the designer to visualize the effect of variation of different parameters on the collector area and the storage volume required.

Whilst other methods identify a single optimum design by optimizing a particular objective function such as payback period, internal rate of return or annualized life cycle savings; design space method identifies a pareto-optimal region. Since the design of the solar hot water system is dependent on time varying variables such as insolation, fuel costs and so on; instead of a single system size (which may not be meaningful), a region of possible system sizes is identified. For example, an optimum collector area of 100 m^2 is not meaningful if, in reality only a space of 80 m^2 is available. Thus, the method offers flexibility in system sizing on basis of desired performance and economy, constraints such as maximum allowable storage volume or limitations for collector area can be easily incorporated in the design. The design, however, is specific to a configuration.

Mathematical modelling of the system

Figure 2 shows the typical configuration of a solar thermal system for industrial process heat.

The solar energy is converted and transferred as useful energy in the collector. The hot water is stored in a pressurized hot water storage tank, which has a limiting upper temperature constraint for some safety reasons. During the process load period, hot water from a storage tank is pumped through the heat exchanger. On the cold side of the heat exchanger, the cold process fluid enters and is heated after passing through the heat exchanger. In case, the required load temperature is not met after heating in the heat exchanger, the process fluid is passed through an auxiliary heater so as to heat it to the desired temperature.

Energy conservation feature as considered by Kulkarni is briefly presented here. Conservation of energy is central to the mathematical modelling of the system. Consider a storage tank of volume V_{st}, at temperature T_{st}. The energy balance over the storage tank over a time step t, assuming it to be well mixed yields:

$$(\rho C_p V_{st})\frac{dT_{st}}{dt} = q_s - q_{ls} - q_{stl}$$

q_s = useful energy collected
q_{ls} = demand met
q_{stl} = storage losses
ρ = density of heat storage medium
C_p = specific heat capacity of heat storage medium.

The useful energy collected for collector area Ac is given by standard Hottel-Whillier-Bliss equation, where $F_R\eta_0$ and $F_R U_L$ are characteristics of the solar collector. I_T and T_a are the solar flux incident on the plane of collector and the ambient temperature respectively.

$$q_s = A_c[I_T F_R(\eta_0) - F_R U_L (T_{st} - T_a)]^+$$

The storage losses are given by

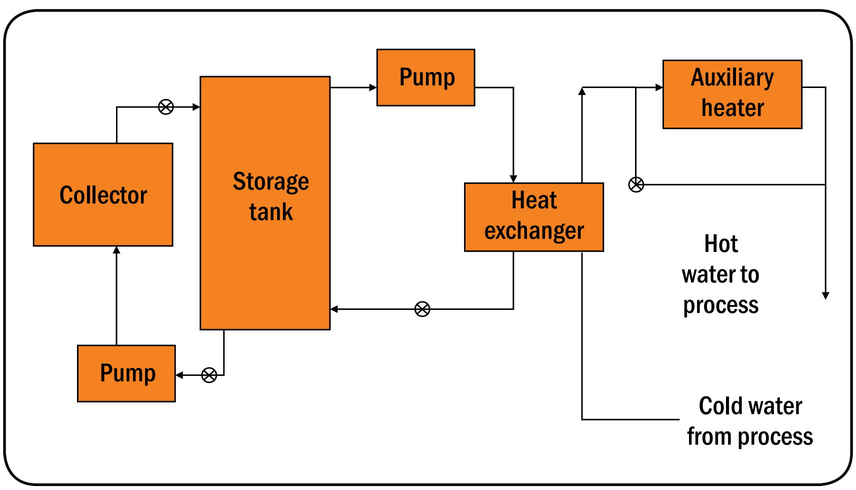

Figure 2 Block Diagram of a typical SIPH system

$$q_{stl} = U_{st} A_{st} (T_{st} - T_a)$$

$U_{st}A_{st}$ = UA loss coefficient for the storage tank.

The load met by solar energy is given by

$$\begin{aligned} q_{ls} &= m_{st} C_{ph} (T_{st} - T_{ho}) && \text{If } T_{comin} > T_{ho} > T_{ci} \\ q_{ls} &= m_c C_{pc} (T_{comin} - T_{ci}) && \text{If } T_{ho} > T_{comin} \\ q_{ls} &= 0 && \text{If } T_{ho} < T_{ci} \end{aligned}$$

T_{comin} = minimum cold fluid outlet temperature (desired temperature of process fluid) T_{ho} = outlet temperature of the storage fluid entering the heat exchanger

T_{co} = cold fluid outlet temperature m_c = cold fluid flow rate

T_{ho} can be calculated using effectiveness of the heat exchanger (P), number of transfer units, N, and the heat capacity ratio, R.

$$N = \frac{UA}{(m_{st} C_{ph})}$$

$$R = \frac{(m_{st} C_{ph})}{(m_c C_{pc})}$$

$$P = \frac{(T_{st} - T_{ho})}{(T_{st} - T_{ci})} = \frac{(T_{co} - T_{ci})}{(T_{st} - T_{ci})}$$

Assuming the load to be uniformly distributed, T_{comin} is given by equation below with the knowledge of total load Q_L and load hours n_L

$$T_{comin} = T_{ci} + \frac{Q_L}{n_L t (m_c C_{pc})}$$

If $T_{st} < T_{comin}$, then auxiliary heat is to be supplied which is given by,

$$q_{aux} = m_c C_{pc} (T_{comin} - T_{co})$$

Thus, substituting and rearranging all the equations we get,

$$T_{stf} = T_{sti} + \frac{t}{\rho C_p V_{st}} \left[\begin{array}{l} A_c [I_T F_R (\eta_0) - F_R U_L (T_{st} - T_a)]^+ \\ - q_{ls} - U_{st} A_{st} (T_{st} - T_a) \end{array} \right]$$

which can be used to calculate the temperature at the end of the time step t.

So the storage temperature variation over the entire time horizon can be calculated, and it is seen that after a number of such 'consecutive time horizons', the storage temperature reaches steady state in the sense that the variation becomes cyclic, and it does not change from one time horizon to another. Hence, the maximum storage temperature obtained decides the thickness of the storage tank, tt given by the hoop stress equation

$$t_t = \frac{p D_{st}}{4\sigma_d} + t_{ca}$$

Solar fraction for the given system size can be calculated using the following equation.

$$F = \frac{Q_L - \sum_{timehorizon} q_{aux} . t}{Q_L}$$

Design space and its generation

The design space as seen in Figure 1, is bounded by two curves – one dependent on the load to be met through the solar system (solar fraction, F), and the other decided by the maximum storage temperature (T_{max}) restriction. For a given collector area there is a maximum storage volume and a minimum storage volume both of which satisfies the 'Load to be met' and 'Maximum storage temperature restriction'. The other parameters affecting the design space are size of the heat exchanger (UA) and the maximum storage flow rate (m_{st}). The design space is also affected by the solar collector used ($F_R \eta_0$ and $F_R U_L$), insulation material (k), location of the system (insolation, I_T , and physical properties of the heat transfer fluid used, but these parameters are usually decided before hand.

Thus, for optimization of the system subject to a given load, the parameters of interest are – solar fraction, heat exchanger size, maximum storage temperature, maximum storage mass flow rate, collector area, and storage volume (V_{st}). Additionally, the thickness of the storage tank and size of the auxiliary heater also add to the cost and are hence important in optimization of cost. To generate the design space, one has to systematically search for the range of possible collector area and storage volume combinations (after fixing all the other parameters). Any collector area-storage volume combination is evaluated for its feasibility by calculating the storage temperature profiles over a time horizon, for all time horizons over a year. If for a combination, all the temperature profiles meet the desired load and maximum storage temperature restrictions – the combination is selected as a feasible system size. Due to the large computation involved, a simple computer programme was formulated to generate the entire design space. Subsequently, once the design space has been identified, optimization can be carried out by applying the optimization criterion to this design space. The computer programme was designed to optimize the systems based on their annualized life cycle costs.

Diary with a difference

To be able to design SIPH systems visits were planned to many industries in Mumbai, Udaipur, and Delhi. A survey based questionnaire was prepared to enquire about the process and economic factors prevailing within the different industries. For designing a SIPH system related to a particular process, the first step is to characterize the process energy requirements.

Table 1 Data for dairy plant

Industry	Dairy
Application	65 000 liters (l) of milk pasteurized with 10 000 l/hr pasteurizer Duty Cycle: 6 hrs/day
Present setup	Boiler Capacity - 600 kg/hr Temperature, Pressure - 170°C, 15 kg/cm² Feed water - 720 kg/hr @ 55°C Makeup water – 5000 kg/hr @ 30°C
Fuel	Type – LDO Cost – Rs. 35.41 Consumption: Per month – 3240 l Per hour – 18 l

1. The dairy starts its daily operation by 6 am and goes on to normally finish it by 1 pm
2. The milk is to be heated to a temperature of 72°C, for about 15 seconds.
3. Calorific value of fuel – 10700 kcal/kg

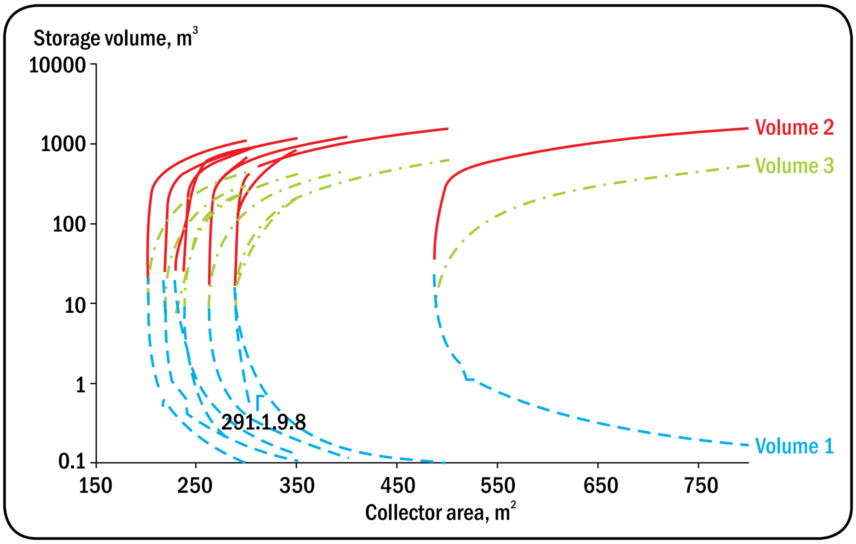

Figure 3 Design space data for parabolic trough collector, unity solar fractions for non-monsoon months

The primary data for a dairy is presented below. The closest solar insolation monitoring station is Pune, thus the insolation data used for sizing is that of Pune. Since this region receives little insolation during the monsoon months, the analysis has been done only for the non-monsoon months. Figure 3 shows the design space generated for parabolic trough collector for unity solar fractions corresponding to different non-monsoon months. Here, volume 1 and 2 refers to the upper and lower limits on the feasible volumes possible for a given collector area. Volume 3 refers to the minimum volume required to maintain temperatures in the storage tank below the pre-decided upper limit (for safety reasons). Thus, the feasible region is bounded by Volume 3 and Volume 1, for a given month.

Similar exercise is repeated for different solar fractions, Table below presents the optimum data at different solar fractions. Thus, in this case, it can be seen that the system has an optimum at unity solar fraction hence, it is feasible to employ a solar hot water system in this case as against the conventional boiler system being used. The annualized LCC at unity solar fraction can be compared favourably against the fuel price for a year (Rs 35.41 × 3240 litres/month × 12 months = Rs 1 376 740). Here, it should be noted that the fuel is subsidized as against cost of the solar thermal system has been calculated without any subsidy.

Showcasing the economic viability

Economic feasibility for some industrial systems was demonstrated in the project. A flexible module based computer programme was designed to aid the computational process of design space generation and subsequent optimization. The key observation was that the economic feasibility of the system depends on the fuel already being used, and requirement of thermal heat– or in other words, the time of load requirement. The size of the SIPH system is found to be governed by the month of lowest insolation. Also since generation of design space is dependent on the weather data available, it is important to analyse the effect of uncertainties in weather data. This would result in more reliable systems, and hence provide much better comparative opportunity (with conventional systems) from an economic viewpoint. Further, the design space approach has been applied with an assumption of a well mixed storage tank. Future work may be focused on the study of effects of stratification on the design space.

The author is thankful for the guidance of Prof Shireesh Kedare and Prof. Santanu Bandyopadhyay during the project. Due to limitation of space, a full fledged discussion was not attempted. Interested readers can contact the author for an e-copy of the thesis report.

Table 2 Optimum data at different solar fractions

Solar Fraction	Annualized life cycle cost	Optimum						
		Collector area	Storage Volume	Size of heat exchanger	Auxiliary Size	Thickness of storage tank	Storage Temperature	Flow Rate
–	(Rs./yr)	(m^2)	(m^3)	($W/(m^2K)$)	(kW)	(mm)	°C	(kg/s)
1.0	987640	291.1	9.8	5500	0.0	22.3	160	12
0.9	1067940	261.8	7.8	5000	48.0	22.3	160	6
0.8	1204390	236.8	6.2	5000	153.4	22.3	160	12
0.7	1282761	215.2	5.3	5000	153.4	22.3	160	12
0.6	1298710	174.3	4.0	5000	153.4	22.3	160	12
0.5	1398882	156.9	3.3	7000	147.6	22.3	160	8

SOLAR TREE AN INNOVATIVE CONCEPT FOR GENERATING 'GREEN POWER'

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Background

Recently, solar PV (photovoltaic) system has got lot of attention and considered as one of the viable renewable-energy based power generating options. While current trends and future projections of solar PV technology with its costs seem to be promising, it has to be utilized very efficiently in order to make it more affordable. The efficiency of a solar PV array, and thus the energy output, is highly sensitive to solar radiation. So the solar PV array should be installed in a shadow-free area. With moderate power density of solar module – Watt/m^2 – generally a large shadow-free space is required for installing large scale power plant.

Although the installation of large scale solar PV based power plants are encouraged through various initiatives, with rapid urbanization, it might be a challenge to obtain enough open space.

The solar tree

Understanding the space constraint in installing medium or large-scale solar power project, an innovative concept – the 'solar tree' – has been evolved. This innovative concept of 'solar tree' gives flexibility in design, while meeting the stringent site condition. In this design, the solar photovoltaic panels can be installed on the 'solar trees' as shown in the figure 1.

It has a very good application in big campuses, farm houses, shopping malls hospitals, and so on. The additional cost involved in constructing the structure

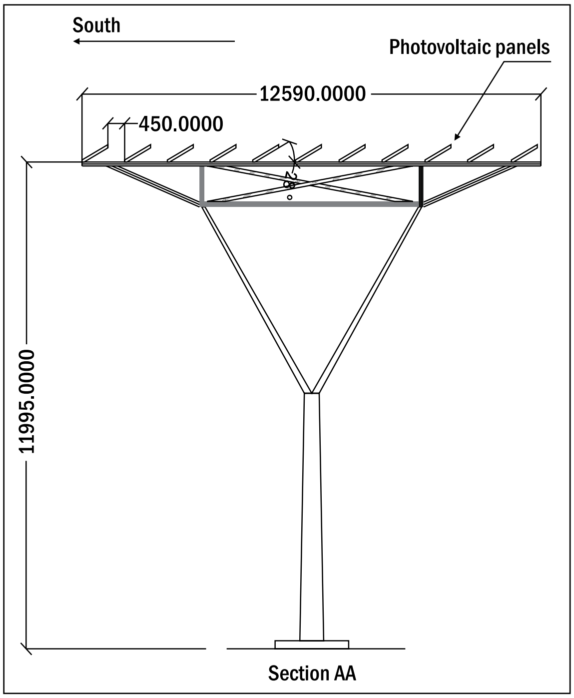


Figure 1 Solar tree arrangement, typical section.

would not be much and in many cases can be adjusted with the structural design of the buildings.

Photovoltaic system comprising of solar trees

As mentioned earlier, the efficiency of a solar PV array depends on the exposure of the solar PV modules/panels to solar radiation. Hence the design and sizing of the solar PV array using this solar tree concept has been done judiciously using computer simulation and considering all parameters which have the influence on the performance of the solar PV array. A detailed description of the solar PV array design comprising of solar trees is included in this article.

Creating a solar tree

Here, a typical tree type structure taller than a fully grown natural tree is built. This was done, so that the natural trees do not cast shadow on the solar trees.

The tree structure has a platform for mounting solar PV modules. In this case, each solar tree is proposed to be about 12 m in height and has a platform of about 12 m × 12 m size on the top. This platform has an octagonal shape as shown in figure 2. This platform is to be used for mounting solar PV modules to create a solar tree. Several such solar trees can be created depending upon the energy requirements and site conditions.

Solar module orientation and mounting on a solar tree

Solar modules orientation and mounting is one of the most important aspects of any solar PV system. It is important that the solar module receives sunlight throughout the day time in order to maximize the energy output.

In the proposed design, the modules are mounted on the solar tree in the horizontal plane facing south direction with an inclination equal to the latitude of the location. This orientation optimizes the solar energy falling on the surface of the modules throughout the year. The siting of solar modules with preliminary design is carried out using ECOTECH and RETScreen© softwares. ECOTECH software is used to optimally site and design the solar array on the top of the solar tree, where as RETScreen© software is used to find out the total energy that can be generated from the solar array which is optimally designed by ECOTECH.

Keeping the space constraint into consideration, a detailed analysis is carried out by using ECOTECH to decide upon the spacing between different rows in each solar tree. The distance between the rows of solar modules is to be kept in such a fashion that the modules do not cast shadow on each other, even on 23rd December from 10:00 am to 3:00 pm. It may be noted that the sun's elevation in the sky is lowest on 23rd December, and hence it was selected as the design date. The dimension of the solar module is to be finalized before carrying out the above mentioned exercise. Considering the tree dimensions and dimensions of

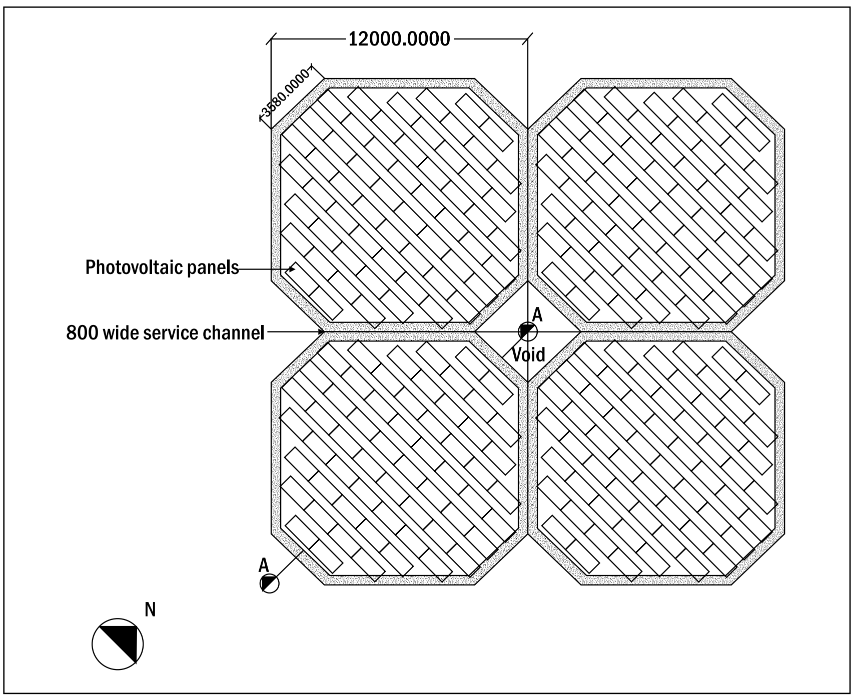


Figure 2 Solar tree arrangement, plan showing four solar trees together

various modules available in the market, a detailed and exhaustive exercise is to be carried out to get the installed capacity of the proposed solar system. The calculations are to be carried out for modules of various capacities using various solar cell technologies so that a judicious and scientifically correct design can be considered. For this, it is recommended to select the most efficient, commercially available solar module with maximum W/m². For example, 185Wp solar module is considered in this design. Since the solar PV technology is changing very fast, more compact and efficient solar modules are available, it is always recommended to do a market survey on the availability of solar modules and their features such as dimensions, power output, and so on prior to the simulation in ECOTECH.

Figure 3 and 4 shows the simulated position of the sun in the sky and shadow of modules at 09:00 am and 10:00 am on 23rd December. This simulation was carried out using ECOTECH software. As can be seen, the modules are free from shadow from 10:00 am onwards. It is observed that the modules would be free from shadow from January–November, from 10:00 am to 4:00 pm. However, in the month of December, the solar modules would be free from shadow from 10:00 am to 3:00 pm. The solar radiation levels on horizontal and inclined surface of the solar modules towards south orientation are calculated using RETScreen software. This analysis is carried out to optimize the inclination and orientation if the solar tree is located in New Delhi for example, where latitude of the city is 28 °North.

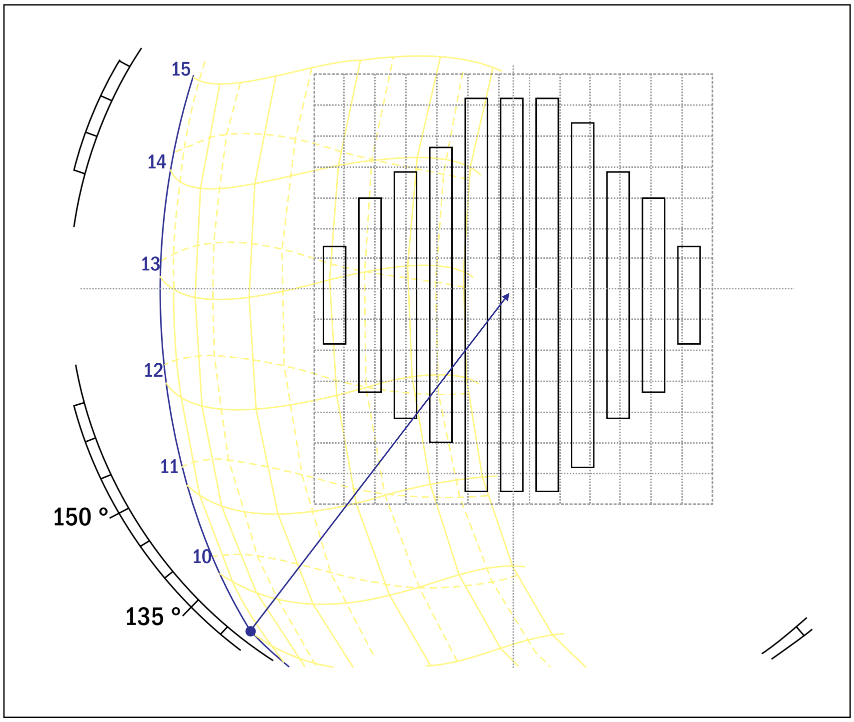


Figure 4 Adjacent PV panels under shade at 09:00 am on 23rd December

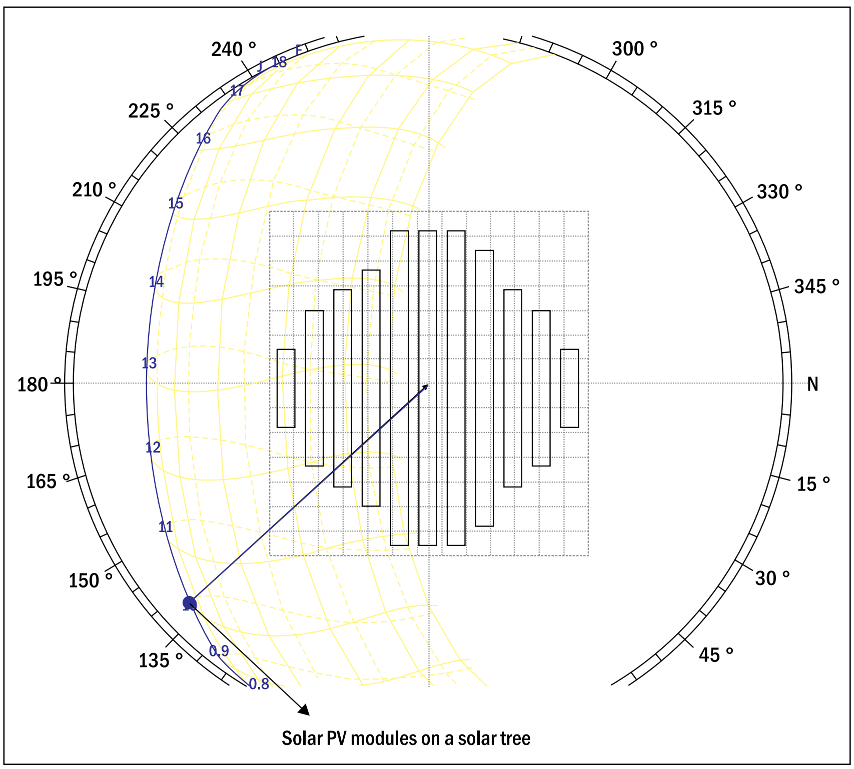
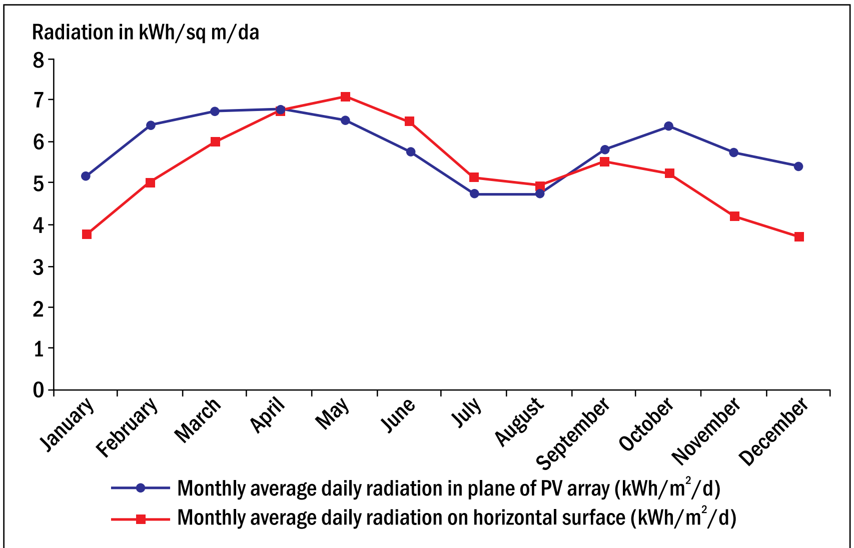


Figure 3 Simulated position of the sun in the sky and shadow of modules at 10 AM 23rd December
January–December, no shadow on adjacent PV panels, from 10:00–15:00 hrs
January–November, no shadow on adjacent PV panels from 10:00–16:00 hrs

Power generation by solar tree

Once efficient modules are selected along with selected orientation, inclination, and distance between the rows of solar modules, an efficient solar tree can be fabricated and installed. In the proposed design, after leaving space for walk way, services, and so on about 114 m² areas is available on each solar tree for installing solar PV modules.



		Annual
Solar radiation (horizontal)	MWh/m²	1.94
Solar radiation (tilted surface of module)	MWh/m²	2.13
Average temperature	°C	25.1

Figure 5 Monthly average daily solar radiation levels on horizontal and tilted module surface

Considering that there are 54 185Wp solar modules, after optimizing orientation, inclination, and distance, each tree can produce 9.9 kW of output power and each tree can produce about 16 MWh of energy per annum. The proposed configuration is completely modular, and thus offers a wider choice for solar modules.

Advantages of solar tree

The proposed design is modular in nature and the innovative concept of solar trees, as explained in the earlier sections, gives flexibility of modular design while meeting the stringent site conditions.

Usually, there are space constrains for installing solar PV panels on ground or on terrace of a building. If the same system is installed on the ground, without any shade of neighbouring buildings or trees, then same area will be required. This may result in wasting huge land. Thus, the innovative technology of a solar tree which requires ground space equivalent to the bark of a tree is taller than the tree to take advantage of shadow less clear sky to achieve maximum efficiency. At the same time, the space beneath the solar tree can be used for other important purposes. A solar tree could also be integrated within the column structure of buildings, with the architecture of the urban space that could act as a shading device for open spaces below. Shaded courtyards could be created in building complexes that provide advantage of shade and also generate green power.

Synergizing solar trees as per the architectural design

These solar trees can be constructed in any open space and will tall enough so that the space beneath the tree can be used for other purposes. In addition, wherever possible, the structure can be integrated to the architectural design.

To ensure this, a system of solar trees, which raises the arrays to the level of the height of existing mature tree is proposed. This grid of trees could also coincide and double-up as the structural system of the building to which the tree grid gives shelter. Solar trees could also be integrated with already existing natural trees, but should be taller than them.

This design was first developed by TERI in one of its PV design projects. The design involved here is the subject matter of the patent rights which have been applied for by TERI, vide patent application titled 'An Elevated Tree-mounted System For Solar Power Generation and its Method of Working'. Hence, TERI is the deemed rightful owner in respect of the above-mentioned IP.

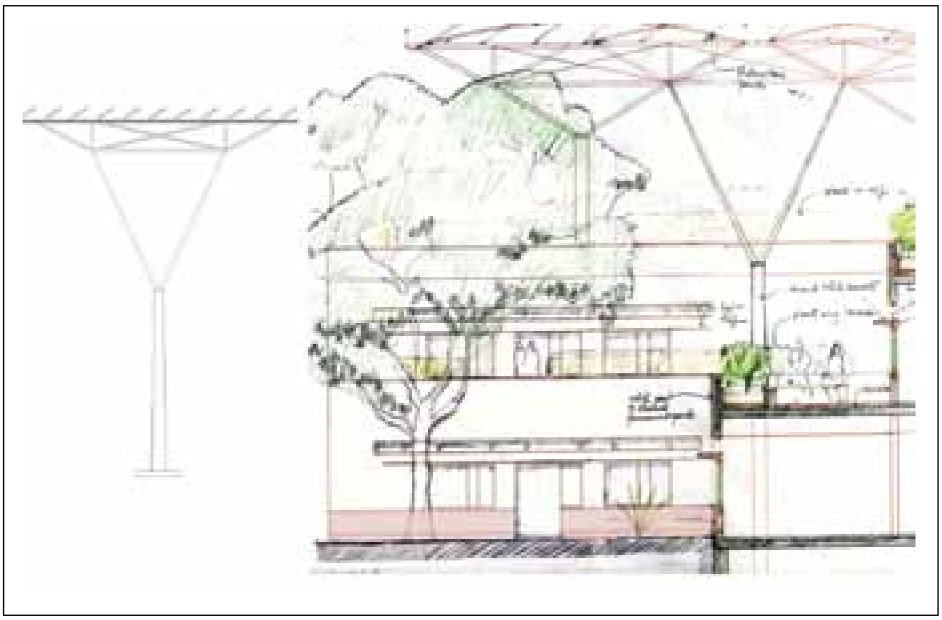


Figure 6 Array of PV panels mounted over a frame structure that forms the solar tree

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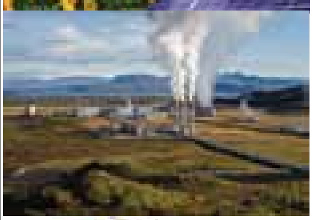

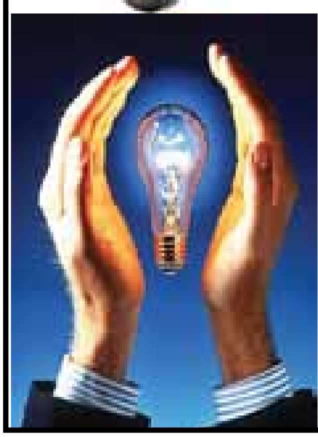

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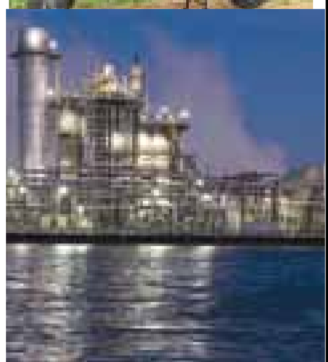
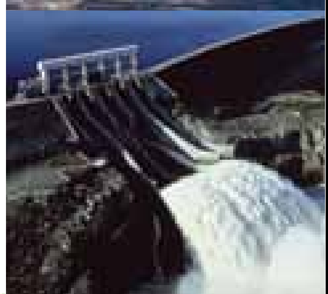

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UNDERSTANDING FEED-IN TARIFF
A CASE STUDY OF GERMANY

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Background

Locations rich in solar insolation are often been regarded as ideal spots for large scale deployment of solar PV (photovoltaic) systems. However, Germany is one such country which scores very low in terms of solar insolation, but has been successful in deploying large scale solar PV systems. The German 1000-Roofs-Programme comprises of about 2100 PV systems built from 1991–1995. All of these were installed on the rooftops of private residences. The programme was extensively monitored wherein all the system owners had to provide monthly yield data and logbook reports. As part of this exercise, about 100 systems were subjected to an exhaustive monitoring with the help of remote data acquisition systems at a sampling rate of five minutes. Following which, a special investigation was done to analyse the poorly performing systems. A quick insight into some 200 systems offered enough experience in the long term functioning of the system hardware—the system components. The total installed power was 5.3 MWp, average nominal power was 2.6 kWp, and typical power values were 1.6 kWp, 1.9 kWp, 3.2 kWp, and 4.8 kWp. This distribution was caused by the power rating of available inverters. Thus began a country programme, which subsequently overtook rest of the PV programmes in various parts of the world. Subsequently, the

FIT (feed-in tariff) became popular across the world.

Understanding FIT

A FIT is an incentive structure to encourage the adoption of renewable energy through government legislation. The regional or national electricity utilities are obliged to buy renewable electricity (electricity generated from the renewable sources, such as solar PV) at the above-market rates set up by the government over a period of 20–25 years, from the day the system is connected to the grid. In turn, the utilities are authorized to pass on this extra cost, spread equally, to all electricity consumers through their regular electricity bill. This means that the feed-in programme works independently from the state economy at an extra cost. In turn, such a cost is realized from the electricity consumers with a clear cut objective to increase the share of renewable energy in the national electricity portfolio. A unique attribute of FIT is that this financial burden on the individual consumers turns out to be extremely small. That is reason enough for the populace to derive a sense of satisfaction in using the green energy technologies like solar PV.

Immense power of FIT

PV systems have a high initial capital cost, though these come loaded with multiple advantages in terms of operational ease, an extended life span, and so on. However, it is quite clear that without the support of suitable instruments, the expansion of the global solar electricity market will not be able to move forward at a fast pace. In order to pick up the pace of our electricity supply system, it is necessary to implement few selective powerful and efficient tools supporting the use of solar electricity. Over the years, the premium feed-in tariff has proved its power and efficiency in developing the new markets. Often, people are surprised by the fact that Germany, a country which is not one of the sunniest places in the world, has developed the most dynamic solar electricity market. In turn, it has shaped up a booming PV industry. How could this happen? Various types of programmes have been tried in many countries in the past, in order to accelerate the PV market. The hard fact is that none has been as successful in such a short period of time as the FIT in Germany.

The easy replication

After Germany's success, the idea has been adapted for use in other states of European Union. Each country within the Union has adjusted the system according to their specific needs. The EPIA (European Photovoltaic Industry Association) has shouldered the responsibility to promote the uptake of solar electricity in Europe taking a strong cue from the highly successful FIT regime in Germany. The simplicity of the concept, and its low administrative costs, mean a definite advantage on several fronts. It is no doubt a highly effective tool for boosting the contribution of solar electricity in national energy mixes. In short, the producers of solar electricity reap the following few advantages.

- Have the right to feed solar electricity into the public grid
- Receive a premium tariff per kWh of power generated thus, reflecting the benefits of solar electricity
- Compared to electricity generated from the fossil fuels or nuclear power receive the premium tariff over a fixed period of time

On the basis of the available information, it has been an uphill task, at least in the initial stages, to implement the FIT programme. For quite a few years, the power utilities did not grant an access of the input solar electricity into the available grid. With the result, significant effort was put in by the solar lobby to convince the utilities about the wholesome gains by shifting to this type of FIT mechanism.

Support mechanism for PV in Germany

Since 1991, Germany had a feed-in law in existence. However, the current feed-in law that is the Renewable Energy Sources Act has been in existence since 2000. In fact, it was preceded by a 100 000 PV roof programme in 1999. Specific goal of this programme was to ensure a total installation of 346 MW through a 35% subsidy of PV systems at 0% interest loan rates. Such a subsidy allocation was terminated in 2003 with an installation of 346 MW at a cost outlay of about € 1 billion. Following are the specific attributes of this programme.

- Rates guaranteed for a period of 20 years
- Differentiated as per the size with a € 5 cents bonus for façade integrated systems
- 5% annual degression rate for rooftop and façade installations and 6.5% for the ground based systems

- No cap on system size
- No cap on programme

As on 6 June 2008, the German Parliament passed the new FIT for 20 years, and the annual degression rates became applicable from 1 January 2009. Table 1 sums up the tariffs for the new installations in 2009.

Table 1 Tariffs for the new installations in 2009

Tariff for new installations in 2009	• System size < 30 kW: 0.4301 €/kWh • System size 30 to 100 kW: 0.4091 €/kWh • System size 100 kW to 1 MW: 0.3958 €/kWh • System size > 1 MW: 0.33 €/kWh
Annual degression rate increase for new systems	• System size < 100 kW: 2010 – 8% • System size > 100 kW: 2010 – 10% • From 2011: 9% for all system sizes

In addition, there is a build in increase or decrease of the degression rate if, the installed capacity is above or below certain values in the previous year. In order to monitor all this, the new systems, which became operational after the 1 January 2009, has to be registered under a central PV system register.

The planned cut in FIT

Particularly in the last few years, the German PV programme has been on a fast track growth. The prime mover has of course been the FIT which the government has now resolved to reduce by about 15%. The plan envisages to cut the subsidies to the solar power providers by this much amount. This one time cut is due for implementation by April 2010 in case of rooftop installations and by July 2010 for the open-field projects. Furthermore, the environment ministry has indicated that an additional FIT reduction will be implemented for the farmland installations. However, a good sign is that the FIT for the solar power usage in a personal capacity may be enhanced. It is important to mention here that if, the country's newly installed PV capacity exceeds 3.5 GW during the current year a subsequent cut of 2.5% will be added. The threshold for the 2.5% reduction was previously expected to be 3 GW. A further 5% reduction in the FIT may be implemented if, the cumulative installed capacity tops 4.5 GW this year.

Impacts on the country programme

The newly announced FIT may well be seen in the light of the following few observations made by various market analysts.

- A significant rush to install PV systems prior to any change (in practice) in the existing fit may be followed by a dramatic fall in demand
- The projected installations are expected to be 1000 MW in the first quarter, which may drop down to about 50 MW by April 2010 accompanied by a constant figure of 100 MW for May and June 2010 as per a reputed market analyst
- The cumulative installation figure for the current year may be in the range of 2700 MW spurred partly by an expected reduction in the module prices during the year
- The new proposal is still to be treated as benign keeping in view the fact that internal rates of return or simply the IRR can be maintained for the rooftop systems
- There is no cap on the new installations, which augurs well for the industry as against a cap of 400 MW to 500 MW set up under the Spanish fit programme

SOURCE: NREL/DOE

- The pressure on the German PV industry is, however, will increase owing to the tightened cost situation
- It may result in a short-term run on the photovoltaic equipment and thus, lead to false price increases
- The manufacturing units are expected to face the upheaval on this account mainly over the medium term
- The impacts on the local production are an expected area of concern that one needs to watch

Technology improvements versus FIT

It is of genuine interest to know the installation capacity that was realized in Germany during 2009. As per the estimates available, it is between 3000–4000 MW. Total installed PV power may touch the 10 000 MW mark by the end of 2010 and thus, account for about 2% of the country's electricity production in 2011. There is a line of thought that the FIT in the country should be brought down further keeping in view the drastic reduction in the cost of solar PV. The key concern for climate change phenomenon has increased the need for adopting solar PV and the FIT has no doubt made that happen.

However, it also sounds logical to arrive at a realistic cost estimate of PV and not keep it artificially high. The main intention is to ensure an enhanced social acceptance of this fast emerging technology. After all, new production capacities have been created for the solar modules worldwide and economies of scale are not hard to attain by in the renewed context. The moot question is if, with a further expected reduction in PV technology costs, the FIT should be further lowered further? It is equally true that the Government of Germany decreased the FIT by about 10% at the start of 2009. If we go by the constant drop in the prices of PV modules, it is expected that the German PV market will overtake the Spanish market yet again.

Market growth assured through FIT

The German PV market accounted for nearly half of the global market in 2007. It goes largely to the credit of FIT, which required the utilities to pay customers a guaranteed rate for the solar power that they feed into the grid. Table 2 presents the installed PV capacity in the country in the following manner.

Table 2 The installed PV capacity in Germany

Cumulative installed end 2008	5722 MW
Cumulative installed end 2007	3862 MW
Cumulative installed end 2006	2863 MW (99% grid connected)
Cumulative installations growth rate	
(2005/2006)	+49.9%
(2006/2007)	+34.9%
(2007/2008)	+ 48.2%
Annual installations growth rate	
(2005/2006)	+ 10.1%
(2006/2007)	+ 19.1%
(2007/2008)	+ 86.2%
PV per Capita	46.8 W (Population of 82 million)

Source www.globagreen.org

In Germany between 1997 and 2007, the huge increase in the capacities has increased the cost of the PV installed system. There is a perceptible optimism that PV has the potential to meet Germany's electricity demand by as much as 25% by 2050. The current installed capacity of solar PV in the country is equivalent to 8000 MW, whereas the thermal capacity is about 13 million sq m of collector aperture areas. These figures point to an appreciable penetration of solar energy technologies in this country. Table 3 summarises the baseline solar targets, key points, and key policies of the German programme from several key considerations as given under.

The cumulative PV capacity that is required by 2020 to meet the stipulated target is 39 500 MW. In Germany, more than 56% of the EU-27 installations are located. There is one more issue of interest here, which is basically connected with a fiercely competitive market presence in Germany. Presently, there are too many companies competing against one another. Positive fallout of this has been that the cost of solar modules has fallen from $4 per Watt to $2.20 per Watt peak. The system integrators are busy rushing to complete the PV installations and one can see a lot of urgency among the customers.

Table 3 Baseline solar targets in Germany

Solar target	Baseline target
SPV Target	7% of electricity needs from PV by 2020
CO_2 reduction equivalent	30 million (metric-tonnes CO_2-equivalent)
Jobs potential from PV target	1 00 000 (FTE)*
Solar thermal (heating and cooling target	4.5% (in buildings) of energy needs from solar thermal by 2020
CO_2 reduction equivalent	16 million (metric-tonnes CO_2-equivalent
Job potential from solar thermal target	50,000 (FTE)*
Key policies	Feed-in Tariff, Renewable Energy Standard, Solar Buildings obligation

Source JRC

The final un-metered tariff plan

As of now, intensive parleys are taking place amongst various groups to halt the newly announced tariff cuts. The issue meriting an active consideration is to deal with a fairly well balanced arrangement between the support actually needed and the perceived degree of affordability. After all, any support mechanism is not entirely functional on its own but derives strength from a few elemental mechanisms. Germany has no doubt come out as one of the strongest in the solar energy sector, and now it is the turn of countries with high solar insolation such as India to display the presence of solar systems on every possible rooftop.

JAWAHARLAL NEHRU NATIONAL SOLAR MISSION

REALIZING THE DREAM

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Introduction

India is a tropical country, where high intensity of sunshine is available for longer hours per day. Solar energy, therefore, has great potential as a future energy source on a sizable magnitude, given our concerns of energy security and environment sustainability. It also has an added advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level. In view of the stated facts, GoI (Government of India) has now provided a major thrust in promoting solar power by announcing the JNNSM (Jawaharlal Nehru National Solar Mission). The National Solar Mission is being launched under the brand name 'Solar India'. The aim of the mission is to enable India to become a world leader in the solar energy area, and thus promote ecologically sustainable growth while addressing India's energy security challenge. The heightened impetus of this mission is to create conditions leading to rapid scale-up of capacity and technological innovation so as to drive down the cost of the solar power towards attaining the much needed grid parity. The mission aims at achieving grid parity by 2022 and parity with the coal-based thermal power by 2030. In fact, it focuses on promotion of both grid-connected and off-grid solar applications for promoting energy access in the rural areas. The mission aims to feed 20 000 MW by 2022 with an initial investment of Rs 4000 crore under three phases of programme implementation. The first phase will last until 2012/2013, Phase-II will be from 2013-2017, and Phase-III will be operational between 2017-2022.

Table 1 Phase-wise targets of National Solar Mission

S. No.	Application	Units	Phase I (2010-13)	Phase II (2013-17)	Phase III (2017-22)
1.	Utility grid power (including rooftop)	MW	1100	4000–10 000	20 000
2.	Off-grid solar applications	MW	200	1000	2000
3.	Solar collector area	Million sq. mt.	7	15	20

Source Jawaharlal Nehru National Solar Mission Statement, November 2009

Solar Mission: the true worth

Solar energy is being looked at with a great deal of interest across the globe and efforts are being made to improve the system efficiencies to reduce the cost of solar power. Thus, JNNSM specific thrust to this fast emerging energy form at this time may help in reducing costs extensively. It may provide a base for meeting the future energy needs in a sustainable manner. The relevance of the mission comes from the impact that it would have on technology, costs and environment, and so on.

1. Solar power technology related costs are currently high in absolute terms as compared to not only the conventional sources of power such as coal, but vis-a-vis other renewable energy sources such as wind, biomass, and so on. These costs are expected to come down only with large scale diffusion of technology, research, and development efforts in improving efficiency, and transfer and/or indigenization of technology. Thus, the mission scores in building a policy scenario, wherein large scale and rapid deployment of solar power can be achieved. In addition, off-grid solar applications particularly for meeting the rural energy needs, which are already cost-effective, mission provides for their rapid expansion.
2. Scalability: About 5 000 trillion kWh per annum energy is incident over India's land area with most parts receiving 4–7 kWh per sq. m per day. Hence, there is a huge potential for solar, which can be effectively harnessed. This also provides huge scalability and future expansion of solar power in India.
3. Energy security: From an energy security perspective, solar is the most secure amongst all other sources, since it is abundantly available. With a crippling electricity shortage and increasing fossil fuel price in the international market, solar energy can very well provide the energy security on a long-term basis
4. Environmental impact: Solar energy is environment friendly and has zero emissions associated with it, while generating electricity and/or heat.

Mission targets

As mentioned above, JNNSM targets to achieve 20 GW of grid connected solar power in addition to off-grid applications and solar collector area for various thermal applications. Table 1 summarizes the phase-wise mission targets.

Mission strategy

The mission adopts a three-phase implementation approach. The strategy proposed for each phase is as follows.

Strategy for Phase I (2010–13)

- The focus in first phase is on capturing of the low hanging options in solar thermal, promoting off-grid systems to serve remote areas without any access to commercial energy and modest capacity addition in the grid-based systems.
- In case of grid connected solar power, focus is to achieve 1000 MW (connected to grid at 33 KV or more). A solar power purchase policy with NTPC's (National Thermal Power Corporation) NVVN (Vidyut Vyapar Nigam) as the designated nodal agency has been formulated to achieve this near term target. NVVN will aggregate the solar power generated by independent solar power producers and the cheaper unallocated power generated by NTPC stations accompanied by its sale to the utilities at the existing rates as determined by the CEREC (Central Electricity Regulatory Commission). Utilities will be able to meet their respective RPO by purchase of this solar power.
- The mission proposes separate RPO (Renewable Purchase Obligation) for the power utilities. The purchase obligation will increase and tariff fixed would decrease over a period of time. RPO for solar power purchase for state utilities will start at 0.25% during 2009/10 and go up to 3% by 2021/22.
- Also solar based REC (Renewable Energy Certificate) may be allowed to help the utilities and solar power generation companies to buy and sell certificates so as to meet their solar power purchase obligations.

Strategy for Phase II and III

- In the second and the third phase, capacity will be aggressively ramped up, after taking into account the experiences of the initial years, to create conditions for up scaled and competitively placed solar energy penetration in the country.

Strategy for the rooftops installation

- To promote grid connected rooftop solar PV applications for replacing the