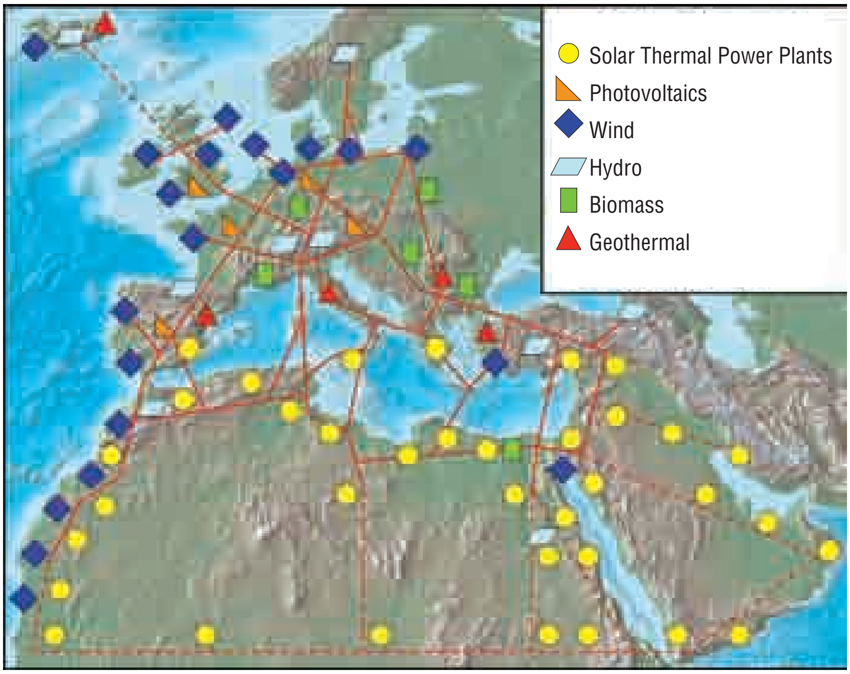
A “Supergrid” is a wide area transmission network that allows the trade of energy across great distances, usually countries endowed with different natural resources. A supergrid may also be referred to as a “mega grid”. The idea of trading in resources or transmitting them is itself not new, it dates back to antiquity, as is the trade of renewable resources. Sources cite trade in renewables back to Europe in 1912. The idea behind trading resources or transmitting them could be seen in dams and oil pipelines as well. Nevertheless, what distinguishes the supergrid from this traditional mode of trading or transmission is that it is associated with renewable energy resources. Unlike the traditional model, where richer countries could consume more, leaving the poorer countries poorer, there will be a lesser degree of economic exploitation here. This is, of course, because renewable energy resources are being traded. The other major difference is that this might limit the way the earth’s environmental resources have been exploited until now. Most supporters of the Supergrid, however, are sharply focussed on the trade aspects of the Supergrid as done necessarily by nations. The Friends of the Supergrid (FOSG), a group of international companies that supports the Supergrid, uses the economic concept of a supply chain to justify the profitability of the Supergrid.

The ideas behind Supergrids have a long and chequered career, of proposals from researchers and corporates, enthusiastic declarations from environmental activists, evaluations, projections, rejections, approvals and disapprovals from political quarters, and so on. The first successful attempt at a Supergrid-like structure, but within a set geographical area, occurred in Europe in as early as 1912, whereas in the US, it was proposed in the 1930s and saw fruition in the 1960s in California. It is called the Pacific DC intertie. The UK has had grids since the 1926 to cater to its needs (called the National Grid) and currently has both offshore and onshore networks to support its energy distribution. The transmission of electricity through high direct voltage current (HDVC) has been the most popular and functioning idea in all these early instances (a deviation from the even earlier AC mode of transmission, which was recognized as leading to wastage in long-distance transmissions). Recent proposals, however, have increasingly emphasized on the transmission of renewable energy resources, such as wind and solar power, across borders. This is a result of the general emphasis placed upon the usage of renewable resources, rather than non-renewable ones, given the fact that environmental resources have seen enormous



depletion and little restoration. The realization that we are faced with a global environmental crisis that threatens planet earth seems to have made the trade of energy resources across national boundaries more acceptable. However, the problem with using renewable sources of energy, as we have learnt since school, is that they are not sustainable. Sustainability implies the ability to meet the rate and nature of consumption. We may recall here the limitations and drawbacks of solar-run gadgets. Hence, the focus of the recent proposals for cross-border supergrids have been about linking renewable energy forms. For example, wind power can be used to run hydro turbines that produce electricity that is then transmitted through HDVC. There is also an understanding within supergrid proposals that renewable energy resources need to be supported by non-renewable energy sources in order to improve effectiveness, while we learn to not deplete non-renewables and move towards using renewables to the greatest extent possible. This is what the integration of large-scale renewable energy refers to.

There is also an understanding of what kind of energies are required to offer what kind of support to our current energy needs, an issue summed up by Dr Gregor Czisch of Kassel University thus: "I believe we would need 15 per cent hydropower, 17 per cent to 18 per cent biomass, two-thirds wind power, and 1.6 per cent solar thermal power."

The advantages of the Supergrid are as follows:

- Clean (carbon-free) energy that does not contribute to environmental degradation
- Cut in wastage of non-renewable resources through the use of renewable sources wherever possible
- Decreased burning of fossil fuels and other non-renewable resources, which would lead to the protection of the environmental balance
- Reduction of polluting greenhouse gases
- Limited global warming

The Supergrid, thus, is the result of revolutionary thinking. The European Supergrid and its recent proposals are an excellent case for studying the ideas associated with the Supergrid. Especially because the European Grid Declaration explicitly states as its objective 2.1.1: "Strive towards a high level of protection of Europe's biodiversity and natural environment". And also, as part of its Overarching Principles 3.1.2 Achievement of the European Union's 2020 biodiversity target, it states that it is committed to "halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss and the wider objectives of the EU Biodiversity Strategy."

The sharing of unequally distributed natural resources equally is a relevant plan when certain parts of the grid are well endowed, especially with say, seasonal winds, solar power, or water resources. Moreover, certain other parts face excessive cold weather, therefore, requiring electricity for heating purposes. Wind farms in Scotland and solar panels in Spain and North Africa, which provide for Europe's energy needs, are concrete examples under the proposed European Supergrid. This Supergrid plan also accommodates the distribution of surplus energy produced in one area to another that lacks it.

In their future avatars, supergrids could correct not only environmental imbalances, but also economic imbalances as found today, between the global north and the global south, quite clearly so, because Southern regions receive more solar energy. Economic downturns are said to have prompted countries into contemplating better energy solutions for the energy problems faced in current times. Recall here, President Obama's mandate on making America energy-independent in the recent presidential electoral debates. Thus, countries that seek to be energy independent will have to give serious thought to the principles behind the European Supergrid.

German scholar Dr Gregor Czish is said to be the first person to propose the European Supergrid, he has been working on it since 1997, all through his PhD project. This claim is challenged by Eddie O'Conner, CEO of Airtricty, who conducted a conference in 2001 where he proposed using wind energy to produce electricity, and is seen—in the opinion of some—as the first person to propose the Supergrid for Europe. In any case, the works of these two scholars have been reinforcing each other and shedding light on a number of aspects of the proposals made in favour of the European Supergrid. One important aspect has been the cost-effective nature of energy in the aftermath of the Supergrid and the possibility that it will create jobs. In fact, such possibilities are projected for India as well. According to a report jointly commissioned by Greenpeace, the Global Wind Energy Council, and the European Renewable Energy Council, 2.4 million jobs could be created in India by 2020. In an interview with the German Centre for Research and Innovation, Dr Czish says: "When I started these studies in 1997, many different technologies had already been developed to make use of renewable energy. But, there was no clear idea of how to combine all these technologies or how to achieve fully renewable electricity supply. To fill this gap, I wanted to search for a way to have a totally renewable electricity supply for Europe and its neighbours. Simultaneously, I wanted to look for for the cheapest solution. My main idea was to find an ecological method as well as an economical and socially responsible method to get our electricity exclusively from renewable sources."

Similarly, Airtricty also projects creation of employment opportunities through the Supergrid indicating the social and economic advantages of the Supergrid. According to EWEA, or the European Wind Energy Association, by 2030, the renewable energy industry will have created 800,000 new jobs. Moreover, according to Dr Czish, the price for power that Germany paid in 2005 is the projected cost of power after the construction of the Supergrid. Airtricity's financial allocations for the project mentions, the procurement of debt at subsidized rates as necessary. Other environmentalists see corporate funding as a stable source for the project since returns for this sector are high as well. It is estimated that competition in this regard will make power costs decrease further, making power affordable to all. Airtricity projects the reduction of prices in two phases. Here is what it says: "In the first phase, the price of 77/MW-hr is lower than that projected by ILEX for the UK out to 2025. It also fits within the current fixed feed-in tariffs in Germany and the Netherlands. The decrease in price of approximately one third in the second phase is due to the lower capital cost of refurbishment."

In the work of both Airtricity and Dr Czish, the harnessing of wind energy, specifically for producing electricity

comes across as filled with immediate possibilities and with least difficulties, although Dr Czish's work examines multiple scenarios that consider concentrated solar power (CSP) and nuclear power also. Geothermal and tidal energy are other renewables, but they seem to receive less emphasis currently. Airtricity, for instance, says: "Wind is infinitely sustainable—once constructed, wind farms can go on producing electricity indefinitely". In addition, Europe apparently has the world's richest wind resources. The emphasis on wind energy and the resultant electricity is because the technology involved here is not new. The areas proposed for the construction of the grid are those that receive high winds across time, onshore and offshore, specifically northern, and western coasts of Europe. However, the environmental advantage of concentrating upon the production of electricity is not meagre either, since in any case, "the electricity generation industry is the biggest single source emitter of CO_2".

The construction of the grid itself, however, is seen as time-consuming (several decades of construction) and financially non-feasible (the project costs about €100 billion, or about $127 billion, according to Poyry, a Finnish engineering and management consulting firm) by sceptics. It is, after all, the largest infrastructure to be ever built. Sceptics also believe that copper, the metal required for cabling is scarce, and its requirement in terms of hundreds of tonnes makes the project counter-intuitive. Greenpeace activists, however, insist that the lack of political will and support is what is stalling the progress of the Supergrid. Airtricity in its proposal also requests that "political risk must be removed from long-term off-take agreements for the project (i.e. through EU or state guarantees)".

Related positive developments have included the North Sea offshore grid for which an MoU has been signed in 2011. The North Sea Grid Initiative involves Germany, Denmark, Norway, Sweden, Belgium, France, Luxembourg, and the United Kingdom. This consists of undersea and onshore networks. The 260-km Britain-Netherland interconnector was developed at a cost of £500 million ($807.9 million). Close to 100 gigawatts (GW) of offshore wind are set to be channelled throughout Europe. The offshore or undersea transmission lines, we are told, run along the coasts of these countries and connect to a robust onshore network. It is projected to remove intermittent power supply (as was seen in the London Blackout in 2003) and cater to Europe's power needs. According to Airtricity, "Europe's dependence on imported energy has risen from 20 per cent in Monnet's time to its present level of 50 per cent and is forecast to reach 70 per cent by 2025." This does mean that Europe is severely energy-challenged. Furthermore, if Europe has to meet its G8 commitment of reduction of greenhouse gases by 2050, it has to work on a plan, such as the Supergrid, to prepare itself. Airtricity also claims that the Supergrid will facilitate Europe's goal of 20 per cent renewabilization by 2020. Perhaps the best way to determine the worth of the Supergrid is to proceed phase-by-phase, recording its success and cost-effectiveness at each phase, and then constructing the other larger connections envisaged. There is a supergrid conference in Brussels in March 2013, and as such we will have to wait and see the latest on the Supergrid's inspiring philosophy.

Airtricity says: "A meshed system will be necessary to allow trading between national markets". However, the European Supergrid does propose to connect European countries and those on its borders, such as North Africa, Ukraine, Kazakhstan, and other countries in the Middle East. Perhaps it is not too much to hope that as a result of sharing the earth's resources, political and cultural relationships too will see brighter days, helpful winds, and safer waters, ending the exploitation and hegemony of excessive modernization and developmentalism.

Besides the arguments in favour of the Supergrid, introduction of new technologies is restricted to primarily solving non-technical and technical issues, such as political support and leadership, harmonization of grid codes, regulatory procedures and revenue models that will create strong market growth and technology push. ■

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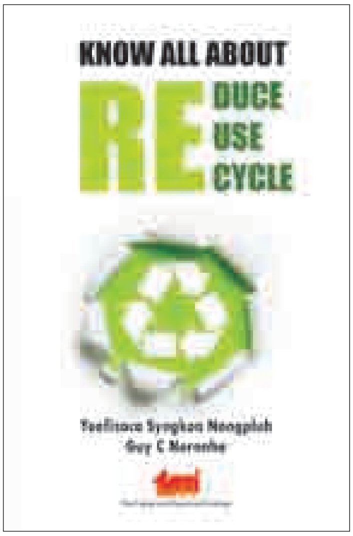

KNOW ALL ABOUT
REDUCE REUSE RECYCLE

Yoofisaca Syngkon Nongpluh
Guy C Noronha

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We live on a rich, colourful and diverse planet. Whether we care or not, understand or don't - our everyday actions have far-reaching consequences.

Know All About: Reduce Reuse Recycle is a fresh attempt to engage you in a global problem. The book is informative and meant to help lay persons to come to grips with an all too familiar phenomenon – garbage.

The book traces the history of waste and its generation - from the earliest civilisations till today - and the various efforts to find solutions. It is no technical treatise but told in a simple way. It has information, guidelines and tips on how you can help to reduce the problem that at times seems to be overwhelming us.

Know All About: Reduce Reuse Recycle is, hopefully, a signpost for you along the way to cleaning up our beautiful planet and keeping it so.

Key features

- Never-seen-before tips on reducing, reusing, and recycling waste.
- Illustrated and visually appealing.
- Complete with data and diagrams.
- Written in a simple and lucid style to appeal to the general reader.

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Tesla, the electric car

Electric cars have emerged as the looming symbols of an energy efficient future with features ranging from lithium ion batteries and mileage of 2.5 km per mega joule. *Pratik Basu* takes a closer look at Tesla, the Tarzan among electric cars and provides a glimpse into a supersonic tomorrow.

A pioneer of sustainable transportation and a rage among car owners, the Tesla Model S was awarded Motor Trend magazine's Car of the Year award for 2013, to add to its awards from Automobile magazine, Time, and Popular Science. Tesla Motors has been known to sell high-performance and durable electric vehicles; in addition, the company also owns a unit that manufactures power train components. Over time, Tesla has been putting a lot of effort into manufacturing durable, efficient, and safe battery systems for cars. In the coming years, they hope to come up with an unbeatable idea for manufacturing efficient, battery-powered cars. The vision of a cleaner commute, where gasoline-powered vehicles are replaced with economic and environmentally friendly electric cars, is the driving philosophy behind Tesla. Tesla's previous sports car, the Roadster, reportedly consumed 110 watt-hours of electricity per kilometre, and offered a mileage of 2.5 km per MJ (mega-joule). The Lithium ion battery employed in the car is similar to ones found in laptops and is estimated to be 86 per cent efficient. Tesla cars also have the highest well to wheel energy efficiency (i.e. , energy efficiency throughout its entire life cycle), and lowest carbon dioxide emissions when compared to cars of other categories, namely, diesel, gasoline, and hybrid. The biggest advantage of using an electric car is the fact that the electricity can come from any source. Thus, the Tesla can be powered by electricity generated from fossil fuels or greener sources like geothermal, hydroelectric, wind, biomass, or solar energy. Another advantage offered by the electric car is the torque. The torque offered by electric cars is much more than what one gets from gasoline cars, which helps keep you on the road in sharp turns and helps you get off to a quick start.

In recent years, numerous electric vehicles have been developed as a solution to the energy and environmental crises caused by the massive usage of internal combustion engines in our society. Many of these vehicles have already been put in use to establish their importance in recent times. However, the most remarkable advantage of using an electric vehicle still remains unutilized. In electric cars, the torque can be controlled with enhanced precision and swiftness as compared to internal combustion engines. For example, the property of adhesion between road and tire of the vehicle is greatly affected by controlling traction. This directly implies that the safety and stability of the car can be improved substantially by an improved torque control. Tesla has emerged as one of the first electric cars to achieve sales on par with the sales of commercial cars. The company is already booked for more cars than the 20,000 cars manufactured per year; the waitlist for the highly acclaimed Tesla Model S ran in at over a year until December 2012.

For a relatively new automotive enterprise in the market, Tesla Motors has done an excellent job to obtain the unusual tag of a Silicon Valley carmaker. However, there are few reasons so as to why the company still sells its cars only from company-owned stores and has a limited service-centred model. There are many aspects that would make it easier for Tesla to pursue the traditional and commonly used franchise dealership model, which can save a lot of money for the company spent on the account of constructions and help the cars gain widespread distribution within a short time span. There have been many arguments and discussions on the topic, which can be highlighted as:

Gasoline versus electric

Current franchise dealers hold certain fundamental conflicts of interest over whether they should sell gasoline cars, which constitute the majority of market interests; or electric cars, which are relatively new in the market. It becomes difficult for dealerships to undermine their traditional business of selling gasoline cars and understand the advantages of electric cars. These conditions leave the electric car at a disadvantage since it does not get a fair opportunity to explain its stance to the unfamiliar public. However, the people who have had an experience of driving the Model S understand very well the difference between this car and others. The car is designed with the aim of making it the best car currently available, and not only in the electric segment. In spite of its purely electric functional engine, the car has faster acceleration to 100 kph than BMW's top of the range high-performance sports sedan, the M5, and yet it can drive up to long distances without any problem. The supercharger-enabled Model S can travel up to distances of 300 miles (480 kms) on a single full battery. The Tesla Model S holds has the largest automotive touchscreen among all cars in the world. The system also has the ability to add the latest features and upgrade them wirelessly, similar to a smart phone.

Reaching people in time

When they decide to buy a new car, most of the people head towards their local dealer with a prior decision as to which car they want to buy. The new car is usually the same company as their current car. At this point, the distance between them and the car is just that of price negotiation. Tesla, being a relatively new car in the market, thus has rare opportunities to educate the buyers about the advantages of getting Model S against traditional gasoline cars. For this reason, the company has taken steps to position its stores and galleries in areas known for high foot-traffic areas or at high visibility retail venues, for e.g., malls or popular shopping avenues. This strategy allows people to increase their interaction with Tesla products before they make a decision about their new car. Tesla product specialists are well

versed and capable of answering a wide range of questions regarding the electric vehicles. The company has a policy to not pay commissions to their employees; therefore, there Tesla sales representatives do not pressure customers. The sole reason of the strategy is to provide an enjoyable and knowledgeable experience to the potential buyers, so that they look forward to visiting the store again and feel drawn towards the car.

However, the product specialists cannot sell any car now under any circumstances, as the Tesla Model S has been sold out already and the customers have to wait for several months before they can have their hands on the new model. All they can do at the given time is to place a reservation for the new car. The Tesla stores have been designed to provide an interactive and informative experience to the customers in a delightful way, which is quite different from traditional dealers that have several hundred of cars in the inventory to be sold by the commissioned salesperson. Tesla cars have a different technology, a different point of view, a different car, and different sales and marketing techniques.

Fairness and franchising

For over 100 years or so, the US automotive industry has been employing the same method for selling cars, and there are many laws governing this sector. Tesla does not seek to change these rules and has a lot of concern for them. They make sure that there is not any act conducted by the company that falls contrary to these rules even once.

Service coverage

Last, but not least is another issue that is very important to the company. Tesla believes that obtaining the best possible service is a top priority for every customer. In the beginning 2012, the company had 10 stores, 9 service centres, and 1 Gallery in the United States. The company plans to have 19 stores, 26 Service centres and 3 Galleries by the end of 2013. This means, that the company is concentrating on opening more service centres for the benefit of its customers as compared to the stores and galleries. The service centres are being opened in the cities where the store is even not present, to allow access to the necessary services to more and more people. This ensures that all customers of the specific region have access to the Tesla certified engineers and technicians, even when there is no store in the immediate area.

The company has a vision that by the end of 2012, almost 85 per cent of the reservation holders of the Model S in North America would be within a 50-mile radius of a Tesla service centre, and 92 per cent of them would be within a radius of 100 miles.

Tesla believes that electric cars are the future of automobiles. The revolutionary Roadster was the first giant leap from the company in this direction. The uncompromised approach in designing and engineering the car exhibited that an electric car can surpass gasoline cars in aspects like performance, durability, or plain driving fun. After buying Tesla cars like the Roadster or the Model S, the company claims that their customers simply cannot go back to their older cars. The sales team of the company realizes the fact most people are still reluctant to buy an electric car. With an aim to provide them with the experience of driving an electric car, the company has announced Tesla Motor Leasing, which provides people the opportunity to drive Tesla cars and experience the design and performance. The benefits of owning electric cars, like the relative low cost of electricity as compared to petrol, and low maintenance demands of the car (its engine only has one moving part) are some expected benefits that would lure potential customers towards the brand.

Tesla is an example of business incorporating the ideas of sustainable energy, to ensure that the transition to a green economy does not come at the cost of the standard of living that we in the twenty-first century have come to take for granted. ■

Pratik Basu is a freelance writer based in Kolkata. The views expressed in this article are those of the author and are not endorsed or supported by The Energy and Resources Institute (TERI) in any way, shape, or form.

Will offshore wind power form a significant part of the future energy generation mix?

Jyothi Mahalingam attempts to answer the question as it emerges as one of the most important issues on the future energy horizon.

Introduction

Global Trends In Renewable Energy Investment 2012, a report published by the Frankfurt School – UNEP Collaborating Centre for Climate and Sustainable Energy Finance, mentions that worldwide investment in renewable energy power generation increased by 17 per cent in 2011, and is now to the tune of $257 billion. The advanced countries have shared 65 per cent of the investment while the developing countries have contributed 35 per cent. Another factor that necessitated such massive investment and growth is the rapid development in related technologies and consequent fall in the components cost. The report also mentions that in the year 2011, the renewable energy sector has accounted for nearly 44 per cent of the new energy added to the grid globally.

Among the various green power generation alternatives available, producing power using wind energy leads the table along with solar. However, onshore wind power generation is still considered to be economical in the long term, the problems in finding suitable large-sized construction sites, the proven negative influence due to the bigger size and the created noise pollution, makes offshore wind farms a viable alternative for them.

The unexploited potential of offshore wind power generation makes it one among the front-runners in global renewable power generation. The comparatively large level of energy yield (1.5 times greater than a similar land-based installation) and the possibility to build utility-scale

power generation facilities, makes offshore power production, a potential contender for green energy revolution.

Global scenario on offshore wind power generation

Over 90 per cent of the present offshore wind power production facilities exist along the coastal lines of the UK, Germany, Denmark, and Belgium. Denmark, has installed the first offshore wind farm Vindeby, a 5-MW power generation facility in 1991. The country then added an additional 400 MW from 2001 to 2003. As of June 2012, the United Kingdom leads the global offshore wind power generation with 2,500 MW. It has plans to add another 1,000 MW in the coming years. It is expected that Europe, with an estimated yearly investment of around $10.76 billion, will reach 40,000 MW offshore power-generation capacity by the year 2020.

Among the Asian countries, China is ahead with 260 MW offshore wind power generation. It has unveiled its plans to add 5,000 MW by 2015 and increase it to 30,000 MW by the year 2020. Currently, Japan generates 25 MW power and it is in the process of installing a 16-MW floating power generation facility close to the Fukushima coast. South Korea is planning to generate 2,500 MW of offshore wind power by the year 2019.

Surprisingly, the USA, though endowed with a long and strong windy coastline, is yet to have an offshore power generation facility. It generates around 51,630 MW wind power from wind farms located inland. Right now, the country is in the process of installing offshore wind production facilities at Massachusetts, Rhode Island, and New Jersey. Similarly, India, gifted with a 7,516-km long coastline, has thus far not even developed a policy for offshore wind power generation.

Offshore wind turbine structure

Typically, an offshore wind turbine will include a tower, nacelle, hub, and blades. The packed fabrication of the blade and hub is known as the rotor. The turbine tower is placed over the already installed transition piece of the sea floor foundation and bonded to it. The nacelle part is fixed over the tower and the rotor is connected to the nacelle. The offshore wind turbines are available with power generation capability ranging from 2 MW to 10 MW.

The tubular constructed steel tower holds the turbine assembly at the top. The other components, such as transformer are placed at its base. The tower provides access to nacelle using a ladder or a similar feature. The diameter of the rotor and its clearance over the water level decides the height of the tower construction. Currently, the offshore wind turbine towers stand a height of 70 m to 90 m over the foundation that is above the sea level.

The nacelle includes a mainframe and a cover that holds gearbox, generator, and a break. It will have features to supervise communications and control the ambient temperature within it. This large-sized and heavy unit of a wind turbine decides the type of vessel needed for installation.

The hub of an offshore wind turbine is made of cast steel. It guides large measure of wind to the nacelle from the blades and incorporates a low-speed shaft to transfer the rotational power to the gearbox. It is one among the most used parts of a wind turbine and houses motors to control the blade movement.

The blades of the wind turbine are manufactured using reinforced plastics. They react to the air movement and rotate. The blades are fixed to the hub either on shore or at the offshore location.

Calculating the power generation efficiency of offshore wind turbines

The power production effectiveness of a wind turbine is often based on its key figure known as the harvesting ratio. The ratio is nothing, but the energy it generates when compared to the energy required for its manufacture. When compared to the 40:1 energy harvesting ratio of onshore wind turbines, the energy demanding concrete and steel used in constructing the offshore wind turbines brings down its ratio to 15:1.

Continuous research is taking place for the use of composite materials in constructing the tower in order to cut down the use of concrete and steel and to improve the harvesting ratio to 25:1. Researchers are trying to improve the ratio further to 32:1 by deploying guyed towers manufactured using composite materials. Furthermore, the proposed use of composite materials will help to increase the working life of such installations up to 60 years from the present 20 years.

Steps in the construction of an offshore wind farm

To its advantage, the offshore wind development uses a number of technological features already established in the offshore oil and gas production constructions. However, unlike the bigger sized oil and gas production platforms, where the weight is evenly distributed, the heaviness of the wind turbines and its vertical structure makes its construction more difficult.

Choosing the location

Ideally, an offshore wind farm is best located in places that are close to headlands, have access to lochs, large harbours and bays, narrow straits, and shallow waters with high-level marine current for optimal performance.

Usually such increased level offshore wind source is preferably found on both the sides of the bigger-sized islands with a difference in the speed of the tides that run through its sides.

A meteorological mast or tower is used to assess the wind-power generation potential of an offshore wind project site. The tower comprises a substructure, a platform with a boat-loading feature, piloting and marking lights, and the needed equipment. The tower will gather the wind details at its various heights and use an anemometer to offer weather forecasting at the project site. Sensors are used to gather information on vertical profiles of wind direction and speed, degree of hotness or coldness of wind, ocean current speed, and direction and place temperature.

Logistics for offshore installation

Supply and transport of components of an offshore wind farm is more time-consuming than an onshore installation. Use of special type of vehicles and road strengthening to drive such vehicles is needed to transport the huge wind turbine components to the nearest port. The port must have features to accommodate bigger-sized installation ships and support features for offloading and loading of the turbine components. At ports, where adequate port parking facility exists, turbine parts, such as hub and blade assemblies are assembled to avoid weather-related delays during offshore installation. Helicopter services substitute the ship transportation of components during rough weather conditions.

Selecting and installing proper foundation

Selecting the right foundation technology plays a crucial part in an offshore wind turbine installation. Remote sensing technology is used to assess the geologic and bathymetric features of the chosen place. Details, such as surf attributes, height of waves, undersea currents, water depth, and the maximum speed of the wind at the site also are taken into consideration. The profiles and properties of seabed soil and the subaquatic current plays a major role in deciding the construction of the under-the-water sea structure.

Currently, four basic types of underwater base structures, such as gravity foundation (concrete structures), tripods, jackets, and monopoles are used. A floating foundation is used for the installation of a single demo turbine. The gravity and monopile type of foundations

are normally used in shallow locations that are up to 90-ft deep. In locations that have depth of more than 180 feet, jackets and tripods are used. The floating type of wind turbine is installed in deep waters with depth of more than 180 feet using tension legs and guy wires.

On completing the foundation erection, for the purpose of making the platform in level condition, a transition piece is kept over the foundation. Such transition pieces penetrate most of the water feature of the foundation, and do not go to the bottom of the seabed. To protect the foundation against scour, concrete pads are placed around or mixed-sized rocks are dumped. The protection methods used will differ with the type of foundation used and the installation location.

Collection and transfer of generated electric power

Offshore wind power generation uses two types of cables to generate and connect the power to the grid. An inter-array cable will link the wind turbines positioned offshore to the offshore-located substation. The transformers are fixed to increase the low-level voltage produced by each wind turbine. The inter-array cables buried underneath the soil is linked with the transformer of the next turbine. A similar procedure is followed to link all the turbines at the site. Connecting of more turbines will automatically increase the generated power. During every stage of connectivity, connecting cables of the right size are used to bear the increased level of power load.

Substations are used for increasing the voltage level of electricity collected from the wind turbines and to bring down the transmission loss. The substation located within the wind farm normally weighs around 500 tonnes or more and uses a similar foundation that is used for the wind turbine. The substation will be big enough to incorporate a backup power generator with fuel tank, switchgear, voltage transformers, and will have the facility to accommodate fewer people. Designed with precise power rating (MVA) to match the project power generation capacity, the substation increases the collected voltage power to the higher required level to match the point of interconnection (POI).

The power collected at the offshore transformer facility is transported to the onshore transmission facility by using buried export cables of medium or high voltage range. The medium voltage cables are designed to carry from 24 to 36 kV and the high voltage cables carry 110 to 150 kV. The power carrying export cables comprises three layers of construction and use galvanized steel wire as a shield.

Development of installation standards

The offshore wind power generation as such do not have full-fledged and prescribed standards to follow in installation. There is no enforcement mechanism to monitor the progress. Currently, European Wind Energy Association (EWEA) and the American Wind Energy Association (AWEA) are involved in the process. AWEA, has developed best practices for offshore wind, jointly with the US Department of Energy's National Renewable Energy Laboratory (NREL) and released the document in October 2012 at a conference held in Virginia Beach, USA.

A typical example of offshore installation

Currently, Global Tech I (GTI)—a joint venture involving HEAG Sudhessische Energy, Nordererland Projekt, Stadtwerke München, Esportes Offshore Beteiligungs, EGL Renewable Luxembourg Axpo, and Windreich—is constructing a 400-MW offshore wind farm off the coast of the North Sea in Germany. The wind farm is located around 180 km from the northeast shoreline of Bremerhaven Emden.

The project set out in August 2012 with an estimated investment of 1.6bn ($2 billion) is likely to be completed by the end of 2013. On completion, the wind farm is expected to generate around 1400 GWh electric power per year, to meet the energy requirement of nearly 445,000 homes in the region.

The wind farm built in 38 m to 41 m water depths will install 80 numbers of AREVA M5000 wind turbines with a rated power production efficiency of 5 MW each. Each turbine will feature a 116-m diameter rotor, a 90-m height hub, and will stand a total height of

148 m. The wind farm has pressed into service a jack-up vessel named INNOVATION to carry and erect the turbines at the offshore location. The vessel built with a fully automatic crane is capable of lifting up to 8000 tonnes of weight. It can simultaneously carry nine 60-m-long poles and three tripod foundations to the construction location.

The installed turbines will be interlinked with each other by using a 33-kV inter array cable. BorWin Beta, an offshore substation established within the wind farm will convert the generated power to 155 kV and transfer it to Diele, an onshore substation using high-voltage under-the-sea cables. Then the power will be carried to the grid for distribution.

The construction company HOCHTIEF is engaged to construct the vital foundations and install the wind turbines. AREVA will supply the required wind turbines and provide the needed maintenance for the farm. ABB has been chosen to supply the medium-voltage frequency converters essential for the project. Siemens and Prysmian will erect the offshore cable connectivity to the BorWin Beta offshore station and the local grid operator TenneT will manage the linking of power supply to the grid.

Environmental impact

The research performed at some of the existing offshore wind farm locations has found that the turbine foundations provide a kind of artificial reef to new species and offer food supply to the fish population. A study conducted on a wind farm located at Windpark Egmond aan Zee, close to the north coast of the Dutch sea, did not unearth any negative impacts on biodiversity. It established that the calm offshore location actually encourages the growth of sea organisms, such as crabs, anemones, and mussels. It also found that the wind farm did not affect the local bird population.

A study of potential climatic impacts of offshore wind turbines conducted by the Massachusetts Institute of Technology's Centre for Global Change Science and Joint Program of the Science and Policy of Global Change, has found the reasons for surface cooling at the place where offshore wind turbines are installed. After using a range of simulation tests, it concluded that when compared with the land-based wind farms the offshore wind farms cause less disturbance to the global climate. The institute has also suggested further research.

Offshore wind turbine manufacturers

The leading offshore wind turbine manufacturers include Enercon, Repower, Siemens, Sinovel, Alstom, Areva, Bard, XEMC, Gamesa, and GE.

Conclusion

Offshore wind power production is growing at a quicker pace. It has immense potential to meet the rising energy demands using non-polluting green energy. Presently, researchers are trying to cut down the amount spent on fabrication, erection, and upkeep of offshore wind turbines. They are trying to introduce orderly and logical grid management procedures to accommodate the increased level of power generation from offshore wind turbines. It is anticipated that in a few years offshore wind power generation will form a significant part of the energy generation mix. ■

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Mirror, mirror

What was once hailed as an endless source of desert electricity has now fallen by the wayside in the profitability race. Is concentrated solar power condemned to remain a niche player in the energy market? *Jürgen Heup* reports.

The tale of concentrated solar power (CSP) can be told from a number of different angles. There is the historical approach, which begins with the story of Johan Ericsson, the Swede who built a hot air engine and the first solar collector in 1873. This shows just how long engineers have been trying to make practical use of CSP. At the time, Ericsson's discovery was no match for the coal-driven steam engine. However, he predicted that in the future, industries would relocate to the world's sunniest regions around the equator, where they would be able to use CSP plants to harness incredibly cheap energy.

Another approach might be to look at the potential of CSP. The red square drawn years ago by some clever PR person on a world map, in the middle of the Sahara. In fact the square measures 300 by 300 km and shows the area which, if completely filled with solar collectors, could generate enough electricity to meet the energy needs of the entire planet.

Yet another angle would be to list the technical possibilities, which seem to make CSP so unbeatable: mirrors capture the sun's rays and focus them on a receiver, creating temperatures of 400 to 1,000 °C— enough to heat a heat transfer medium consisting of oil, salt, water or gas. The transfer medium is conveyed to a power plant where it is used to heat water, which evaporates and drives a turbine, powering a generator to create electricity. In order to generate electricity when it is needed, it is also possible to store the heat in a molten salt storage unit, from where it can be recirculated to the power plant at night when solar energy is no longer available. Alternatively, excess heat can be used as process heat for desalination of seawater in neighbouring industrial installations.

A wealth of possibilities—all enabled by a technology that seems to be a perfect match for the centralized energy structure of a great number of countries today. Indeed, it is a technology, which deserves the support of major energy companies because these companies have the necessary expertise (they operate gas and coal power plants, which work on the same principles) and because CSP plants can even be combined with conventional energy sources in the form of hybrid power plants. What is more, with optimal plant capacities

of around 100 to 200 megawatts (MW), CSP can easily be scaled up by connecting several blocks in parallel to form a gigawatt-plant. Investment costs for CSP are somewhere between 5,000 and 9,000 per kilowatt (kW). Not a trivial figure, but it could be financed by the energy market's major players.

Over 70 per cent of projects cancelled

However, the story can also be told from a very different perspective, starting with the fact that over 70 per cent of plans for the construction of CSP plants announced in recent years never made it off the drawing board. Of the over 7,400 MW of planned worldwide capacity for 2012 listed in a study by Greenpeace four years ago, just 2,000 MW are online today. Why such disappointing results? Why, with its unparalleled versatility, is CSP unable to hold its own?

The main reason is that CSP continues to suffer from the same problem as it did 140 years ago: it is too expensive. "The industry just cannot lower the costs fast enough," explains Dominik Foucar of consultants A T Kearney. With the help of the learning curve theory, which describes the cuts in production costs enabled by economies of scale, researchers from the German Aerospace Center (DLR) have announced a 13 per cent reduction in the cost of CSP plants for every doubling of installed capacity. As a result, they calculate that CSP plants could be producing electricity for under 0.04 per kW by 2050—provided over 400 gigawatts (GW) of plant capacity has been installed by then.

Unfortunately, it is now clear that the rate of expansion predicted in previous years was overly optimistic. CSP is not living up to its potential. The Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg recently announced the electricity production costs of CSP; at 0.18 to 0.24 per kilowatt hour (kWh), they remain far higher than other forms of renewable electricity. "With barely 2 GW of installed capacity worldwide, CSP technology is just not in the same market phase as the more mature technologies of photovoltaics and wind," says Florian Zickfeld of the Desertec Industrial Initiative (DII), explaining the price difference. However, CSP plants were around long before anyone had thought of solar cells. In this sense, CSP should actually be regarded as the more mature technology in comparison to other renewables. However, with just over 70 GW of installed capacity worldwide, in practice, photovoltaic (PV) technology is streets ahead. Plus, its 20 per cent learning curve suggests that its lead in terms of cost reduction is unassailable.

The researchers at ISE put the electricity production costs of PV solar farms at just 0.10 per kWh in regions with insolation levels of 2,000 kWh per square metre per year, such as those found in Spain. In desert regions with over 2,500 kWh per square metre per year, where CSP plants really come into their own, production costs for PV electricity are already under 0.10. For 2020, the researchers predict values of around 0.07 for PV—close to the cost of conventional power plants. In the same year, the cost of CSP will be down to 0.11 at best, but probably closer to 0.16. These figures are already matched by PV systems, even in countries, such as Germany. At relatively modest insolation levels, electricity from solar panels in Germany has already achieved grid parity, meaning that production costs are below the retail price of power from the grid.

Eighty per cent of CSP power plants are in Spain and US

To date, the driving forces behind CSP technology have been Spain and the US. Australia, despite its enormous solar potential, is not exactly a trailblazer for CSP. Its plans for plants totalling 250 MW have failed to materialize for four years. India and China's commitment is equally doubtful, says Foucar. Over 80 per cent of the world's CSP plants are located in Spain and the US, but even these two countries are hitting the brakes. "Spain was too optimistic," says Foucar in reference to the developments of recent years. Thanks to a relatively high feed-in tariff, over 1,000 MW were installed in the Iberian Peninsula. This is the largest CSP capacity in the world. However, the associated high costs and the financial crisis engulfing the country led the government to suspend the feed-in tariff at the start of this year, ruling out payments for new plants.

Meanwhile, the US witnessed a steep decline in PV panel prices, causing many developers to switch from CSP to PV in order to capitalize on the lower investment costs. A case in point is Solar Millennium: plans for what was once the German solar company's showpiece, a 1,000 MW CSP plant in Blythe, California, were suddenly altered, with half of the capacity to be generated by PV. Then the company became insolvent. American CSP plant manufacturer SES was another casualty of developments in the PV field. The company used to offer a highly promising technology: the Sun Catcher. Rather than large plants, the company concentrated on small units with a tracking system and dish-shaped mirrors to focus sunlight on a single point. Instead of a receiver, the units were equipped with a Solar Stirling motor, which uses the heat directly to generate electricity. The Stirling cycle meant the plant achieved 31 per cent efficiency, putting it streets ahead of PY. SES received orders totalling over 1.5 GW. But, as it subsequently found out, higher efficiency is not everything. The low prices and operating costs of PV plants led to the cancellation of

solar dish projects, and yet another manufacturer was forced out of the market.

It is a market, which continues to be dominated by US and Spanish companies, thanks to domestic demand in those countries. According to Florian Zickfeld, its major players include companies, such as Bright Source, Solar Reserve, and Abengoa Solar. Solar Millennium's fate notwithstanding, German companies retain a strong position both as general manufacturers and component suppliers, with names, such as Siemens, Schott Solar, and Flagsol. In particular, high-tech components, such as receivers and mirrors are a key strength of German companies. The decline in the overall number of CSP technology manufacturers is cause for concern

for Foucar: "Production has stagnated, so there is insufficient downward pressure on prices."

However, high production costs could actually be an opportunity for CSP. Following the collapse of the market in the US and Spain, all hopes now rest on the Middle East and North Africa, which are known as the MENA region. In these countries, energy supply is firmly in the hands of businesses owned by, or close to, the state. This means that support for energy technology depends less on production costs and more on industrial policy—that is, on creating jobs and added value in the country in question, referred to as local content. In the Estela study, "Solar Thermal Electricity 2025", AT Kearney's European solar team points out that 100,000 jobs could be created in the MENA region, and that only a low proportion of the components of CSP plants are genuinely high-tech products, which need to be imported from leading countries, such as Germany, the US or Spain. This means that it would be cheaper to produce collectors or plant components locally, enabling factories to be established and kept within the MENA region—unlike PV technology. The study also claims that the power plants would create permanent jobs. Furthermore, in arid regions with gas and oil deposits, CSP plants that use gas at night, known as hybrid plants, would be more efficient than PV technology. At the moment, hybrid plants of this kind certainly appear to have a better chance than CSP plants, which aim for round-the-clock operation using molten salt storage. In either case, CSP offers grid stability, which is a major advantage, especially for countries with low grid coverage.

Saudi Arabia: 20 GW of CSP planned

Foucar is, therefore, positive about the volume of orders for construction of CSP plants in North African countries. What is more, he has spotted a new star in the skies of CSP. The frontrunners of the CSP market have been joined by Saudi Arabian solar specialist ACWA Power, and Saudi Arabia has announced plans to build CSP plants totalling 20 GW. ■

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JAPAN

LAND OF THE RISING SOLAR BOOM

Post Fukushima, policy-makers in Japan decided to embark on a "renewable" journey almost instinctively. But is it the solution to Japan's—and the world's—energy woes? *Dharmesh Vinod Rajan* takes a look at the dawn of a new energy era in Japan.