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Mahadevan Iyer

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> Out of renewable energy sources of 31,692 MW, solar is 2,631 and wind is 21,136 MW

We do have the fullest hopes in implementation of Modi's Plan 2022. Everyone was thrilled to the historic speech at New York for a persona, which creates cult and after analysis of it, which talks development, we feel that electricity dream to remote areas of India would be fulfilled. However, renewable energy focus is imminent.

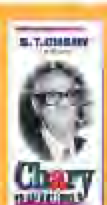
All India installed capacity as on August 2014 was 253,390 MW, of which Coal constitutes 152,310 MW hydropower 40,799 MW. Out of renewable energy sources of 31,692 MW, solar is 2,631 and wind is 21,136 MW. The recent verdict of Supreme Court regarding coal blocks is likely to impact sectors including power, steel and mining. The development will add to the shortage of fuel for power sector and requires reallocation with transparency. Further, a capacity addition of 90,000 MW assessed during 12th Plan, includes 30,000 MW of hydro power also.

India has made spectacular moves in expanding its ample solar power potential. Technologically India is well placed for the wide implementation of solar energy which is abundant discusses 'Solar –The Future of India'. And, government has committed to invest $20 billion in the next 10 years for the growth, development & implementation of solar energy in the country.

A methodology for the "Selection of Wind farm site and Wind Turbine /Electric Generator" based on the Technical and Economical analysis is well deliberated in an article 'Development of Wind Power Project'. All the more, the issue contains topics relevant to current trends on power sector and would like feedback from our patrons, readers, advertisers and subscribers.

Do send in your comments at miyer@charypublications.in

Mahadevan



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CONTENTS

Vol 54 | No 10 | October 2014

Departments

Interview

Wave of Reforms Mechanism in Power Sector

"Speedy reforms require timely action to manage the output"

Gopal Krishna Anand

As Modi transpired his conception during his speech at New York, concerning the development of the country, availability of electricity at optimum cost and optimum utilization of energy is the need of the hour to alleviate energy crisis. Government is committed to ensure affordable 24x7 Power for all. Speedy reforms require timely action to manage the output. We are simply not utilizing the full capacity of the existing resources and sources of power. When do we will have sustainable supply of power! All the more, focusing rural for upliftment and progress requires extensive investment and willingness.

Country has abilities and the campaign 'Make in India' launched by Modi, implies we have the manufacturing potential. The future investment in infrastructure growth would propel the economy to further heights. Reform is the key to shed the old traditions of generation and apply latest technology to the means of manufacturing and production. India is growing but power is required to grow, conserve and prevent excessive usage. Power sector is the largest consumer of coal in India. We need to strengthen our capabilities in keeping pace with new technologies in renewable energy sources and of course nuclear with all safety concerns would open an era of clean energy access and utilization with a purpose of increasing longevity of the global population on global scale.

Under changed regime at center, coal-based electricity generation from June to August 2014 grew by a record 21% than last year, indicating progress. CIL has given in-principle decision to purchase 250 additional rakes for Rs 5,000 crores to evacuate more coal. Power, Coal & New & Renewable Energy ministries integration is a one-in-all package for speedy decision in implementation. Working of these Ministries in an inclusive fashion is going to be the game changer in energy sector. Provision of adequate coal is necessary for Power Plants. Renewable energy sources could become driver of inclusive growth in remote areas. Specifically, situation needs be monitored very strategically as 214 coal block, cancelled by Supreme Court recently, will be crucial for power generation. Transparency in allotment of coal block in future is pertinent with overall energy sector reform to create options and innovative means for power.

Suzlon Group produces first blade for New S111 2.1 MW Turbine

Suzlon Group, the world's fifth largest* wind turbine maker, announced that it has successfully completed the production of its first blade for its best in class S111 2.1 MW turbine. The S111 is a technologically advanced product of the S88 and S97 2.1 MW family. This product has been specifically designed for Suzlon's next generation 2.1 MW turbine and is engineered to deliver a 20% increase in AEP (Annual Energy Production) at the same hub height compared to Suzlon's S97 wind turbine model. The S111 is built on the proven reliability of the S88 and S95/97 2.1MW family that has over 3100 turbines installed in fifteen different countries with over 68,000,000 operating hours. The blade is designed to harness the optimal available wind resources and deliver higher energy

productivity, which in turn ensures higher ROI to customers. Suzlon turbines are setting industry benchmarks across entire technology value chain by meeting new standards. Laurens van der Sande, Project Manager, S111/SB54 blade said, "The first SB54 blade is the longest and cleanest aerodynamic profile Suzlon has ever produced. This milestone has been achieved due to an effective integration between the product design, production unit and the tool design. The result is reflected in a shorter production timeline with a high yield product.This innovative product is a testament of our unique integral design approach and our rigorous New Product Development Stage Gate Process. We surpassed our last three power curves and expect the S111 to follow the same suit". Tulsi Tanti, Chairman, Suzlon Group, remarks company continues to leverage on technological edge and creates products that derive maximum energy yield. The S111/SB54 blade is based on previous Suzlon designs with innovative and optimized improvements.The turbine design makes it ideal for low wind sites in growth markets like the US and India.

Tata Power Solar commissions Phase II of solar power project for the Chennai Silks group

Tata Power Solar, India's largest integrated solar player, has executed five different solar power projects for The Chennai Silks group, constituting a total of 5.2 MW solar power plant. Total installed solar power capacity of the group comes to 7.2 MW. These five different solar projects, executed for different group companies of The Chennai Silks group, are located in Kangeyam of Tirupur district in Tamil Nadu and achieved power generation in 12 weeks. The five group companies include: Naachas Wind Energy Pvt Ltd, Space Textiles Pvt Ltd, KTM Jewellery (P) Ltd (1 MW each), SCM. International Impex (1.1 MW) and Sathy Silks Pvt Ltd (1.1 MW). Power shortage is a major issue in Tamil Nadu, with several manufacturing facilities in the region suffering from power shortage and relying on expensive diesel generators. For The Chennai Silk's group, venturing into solar power is a step towards making solar a mainstream source of power generation. "We installed these solar plants for captive consumption of power, as well as to avail of the accelerated depreciation benefits. The use of solar power in our retail showrooms has helped us reduce our energy costs while also enabling us to reduce our carbon emissions by 890 grams/kWh. Tata Power Solar's experience and capability in swiftly executing solar power plants have been the primary reasons to choose them, time and again." says N K Nandhagopal, MD, The Chennai Silks group. Tata Power Solar continues to extend job opportunities for the operations and maintenance of these captive power plants.

BHEL wins contract for 800 MW rating Supercritical Power Project

Bharat Heavy Electricals Limited (BHEL) bagged a contract for setting up a supercritical thermal power project on EPC (Engineering, Procurement & Construction) basis from Gujarat State Electricity Corporation Ltd (GSECL). Valued at around Rs 35,360 Million, the order for setting up a 1x800 MW coal-fired supercritical thermal unit at Wanakbori in Kheda District of Gujarat, has been won by BHEL against International Competitive Bidding (ICB). With this, GSECL has reposed confidence in BHEL's proven technological excellence as also its capability in executing power projects of this magnitude on EPC basis. Significantly, this is the first ever project of 800 MW unit rating ordered in the country on EPC basis and is also the highest valued order placed by GSECL. This reinforces BHEL's leadership status in the execution of supercritical thermal power projects involving supply of state-of-art equipment, suited to Indian coal and Indian conditions. With this project, BHEL has now won orders for supply and installation of 33 supercritical boilers and 28 turbines of 660 / 700 / 800 MW ratings. With its vast experience in the design of boilers, BHEL has developed fuel flexible supercritical boilers capable of handling a wide variety of fuel blends of imported and indigenous coal. These boilers designed by BHEL are capable of operating the plant continuously at full load with fuel ranging from 100% imported to 100% indigenous coal. BHEL has a significant presence in the state of Gujarat with 78.3% share in the installed capacity of 9,653 MW in the state utilities of Gujarat for Coal, Lignite, Hydel and Gas based power plants.

Vishay Intertechnology, Inc.

Alternative Energy

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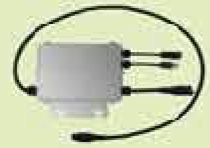

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An innovative solution reduces disruptions in Indian power industry

Power outage is a common challenge plaguing the power sector in India. Applied Materials, Inc. developed a technology and implementing this technology enables N+1 or N-1 redundancy, a more reliable transmission and distribution of power may soon be a reality in India. This promising technology is a superconducting fault current limiter (SFCL) which is designed to help protect the electrical grid from fault currents - or the sudden power surges that can damage expensive equipment and disrupt power transmission. Applied's SCFCLs have been successfully demonstrated at a number of sites, and most recently, a unit was successfully installed at a major utility in New York State, USA. In a country like India, with its growing economy and increasing demand for power, both public and private utilities may significantly benefit from this technology. For example, Applied's SCFCL can help these companies improve grid reliability; protect power system equipment from severe mechanical, magnetic and thermal stresses, and other undesired consequences of fault currents. Currently, one of the biggest challenge utilities face is in upgrading their systems for higher power capability or adding capacity to mitigate increased fault current levels. With increase in energy demand, and as more sources for power generation (e.g. such as wind and solar power) are being added to an already overburdened system, the fault current levels are likely to increase. SCFCLs may help the utilities overcome these problems.

Alstom-Bharat Forge joint venture to supply steam turbine islands for NTPC's Tandapower plant

Alstom Bharat Forge Power Ltd (ABFPL), the joint venture company between Alstom and Bharat Forge, signed contract worth 11365 MINR with NTPC Limited to supply two units of 660 MW supercritical turbine islands for the Tandacoal power plant in Uttar Pradesh. ABFPL's scope of work involves engineering, manufacturing, testing, supply, erection and commissioning of the two 660 MW supercritical turbine islands & auxiliaries for the plant. The equipment will be manufactured at ABFPL's new state-of-the-art manufacturing facility at Sanand in Gujarat, which will be commissioned starting October 2014. Set up over 120 acres of land this manufacturing facility will reach an annual capacity of 5000 MW and will be one of the largest integrated facilities for turbines, generators & auxiliaries manufacturing in the country. Alain Spohr, MD, ABFPL said, "This is another breakthrough for the joint venture after the two orders of Solapur and Nabinagar. This project reinforces our leading position in the supercritical steam market. We have been able to combine the technology and manufacturing skills of both partners (Alstom and Bharat Forge Ltd) to deliver a world-class product for the Indian market". Supercritical plants use steam with very high temperatures and pressure, resulting in a much higher efficiency than conventional sub-critical coal fired plants; it burns much less coal and generates less emission.

Rolta Power: installed capacity of 60 MW production line of PV modules

Rolta Power Pvt Ltd announced venturing in solar power sector with an installed capacity of 60 MW production line of PV modules. The company aims to manufacture A+ grade of solar photovoltaic panels and to work on a variety of ranges of solar power solutions like, solar EPC projects, rooftop solar projects (KW), solar water pumps, solar telecom tower and may more as per the requirement. The company offers comprehensive services for implementing enterprise-level applications, which is not limited to EPC formula only. It aims to go beyond EPC services, such as manufacturing, complete EPC (including basic design), owner operator solutions, operations & maintenance, backend paper work to claim subsidies, and getting government grants etc. on behalf of the clients. "Starting a new business has always appealed, says Dr. Aditya K Singh, Promoter and MD, Rolta Power Pvt Ltd. With the rise in demand for renewable energy, coupled with promising legislation and the need to enhance energy self-sufficiency, starting a solar energy business was an exciting opportunity for us." He further opines, "The nation is still in its infant stage of manufacturing cycle for supply-chain. Hence, with its proactive legislation, government grants and polices supporting this industry; there is a profitable backward integration opportunity available to be capitalize upon. Rolta Power Pvt Ltd is looking at making this contribution as per its expansion needs." With the increase in demand for solar photovoltaic in Asia-Pacific countries, India will continue to be one of the top countries to drive the regional demand. Though there is drastic fluctuation in panel prices, Indian manufacturers will look in advancing technical proficiency and increasing value chain and both forward and backward integration to distinguish their products from other dealers in the market. Further, Dr. Aditya K Singh adds, "The grid parity has been met more or less, as compared to thermal power or any other conventional power source in India. Hence, we do not see another recession in solar power sector, may be for some time."


Starting a solar energy business


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Sterling Generators endorses CPCB II Compliant Gensets with 10KVA to 1000KVA DG Sets

One of the largest Manufacturer of DG Sets in Asia, has always been CPCB II ready with its 10 KVA – 1000 KVA range of Gensets, that comply with the new Environmental norms for DG Sets. Sterling Generators is known to have provided its customers with CPCB II compliant Gensets even before the new Legislation on Stringent Emission Norms came into effect on 1stJuly 2014.In view of the powers conferred by sections 6 and 25 of the Environment Protection Act 29 of 1986, the Central Government has recently amended the Environment Protection Act. Sterling Generators strongly believes that the latest CPCB II Emission Rule is a breakthrough legislation which will certainly help Indian engines to compete with those worldwide. Sterling Generators is managed by a group of

Mr. Sanjay Jadhav, President, Sterling and Wilson Powergen Pvt Ltd.

best minds in the Industry who bring in a Solutions-Oriented approach and the latest in Technology to their customersand are backed by a state-of-the art manufacturing facility at Silvassa. Commenting on the new Environment Protection Rules, Sanjay Jadhav, President, Sterling and Wilson Powergen Pvt Ltd says, "Sterling Generators are in an advantageous position as our product offerings were always most fuel and emission optimized, meeting International emission standards and will need only minor product alterations to meet the new norms in India. The implementation of these norms will certainly help control release of polluting gases into the atmosphere and result in overall healthy living." Sterling Generators, enjoys the trust and excellent relationships with their customers, operating in India through four Regional Hubs and 17 Branch offices and have opened offices in Dubai, Nigeria and Australia as they foray into the Exports market, which will be the focus area for the company in near future. It has a Pan India Network of trained Service Engineers across the country who are responsible for providing uninterrupted power to their customers and are available 24*7.

SunSwitch India launches range of Solar Powered Products for Indian market

SunSwitch India, a full service provider of solar energy solutions, today launched a new range of solar powered products to strengthen its foothold in the rapidly growing solar sector to cater to the needs of both urban & rural markets in India. As a part of their business and growth strategy in solar business, the company has introduced unique

and innovative products which are modular Solar Home Lighting Systems (HLS) and Solar Retrofits for Home Inverters. SunSwitch India Pvt Ltd - the innovative start upin solar energy solutions is offering solutions that shall enable rural electrification through innovative products that are cost effective and durable supported by the large after sales service network.SunSwitch will introduce the new range of solar products in a phased manner across the Delhi NCR/UP region. As a part of its marketing drive, the company is planning to add many new dealers and distributors to increase the footprint. With the launch of the new range of solar powered products, SunSwitch India is targeting to reach revenue of Rs 10 cr in the solar business by FY 2015. Abhinav Gupta, Founder & CEO, SunSwitch India, said, "We are delighted to launch these environment friendly and efficient products. We intend to address critical areas of unending power deficit. Keeping in mind the deprivation of availability of power in the sub-urban as well as rural India, SunSwitch India has developed solutions to address these problems by developing AnantUrja (12 V) and Surya Dhani (3.25 V), our two Solar Home lighting systems based on Li-Ion battery technology. These are modular systems, wherein the customer can invest in pieces and add components to his system over a period of time, as and when his budget allows.

Innovative business models on renewable energy

Business Strategy Development Competition, the finale of 'India-Sweden Innovations' Accelerator (ISIA)' programme concluded on August 30, 2014 at WeSchool,

Mumbai, where teams from WeSchool and Institute for Future Education, Entrepreneurship and Leadership (iFEEL) presented future-proof business models and strategies on renewable/green energy that can be implemented especially in the energy starved rural India. The business ideas designed by students' teams were evaluated by an external jury panel comprising of Ludvig Lindstorm, Country Director- India, Swedish Energy Agency, Dr Anjali Parasnis, Associate Director- Western Regional Centre, TERI, Srikant Illuri, Executive Director & Country Head Investment, Business Sweden and Dr Christer Nygren, Professor of Innovation at Malardalen University, Sweden. The winning team presented a business plan for Exeger, a Swedish company that produces dye-sensitized solar cells. These cells can be affixed to the massive glass frontages of skyscrapers for garnering and storing solar energy which can be used by the building thereby not only creating solutions towards sustainability and saving of costs but breaking new grounds. The WeSchool team provided a detailed roadmap for Exeger, thereby developing the best business solutions to enter the Indian market with their product.

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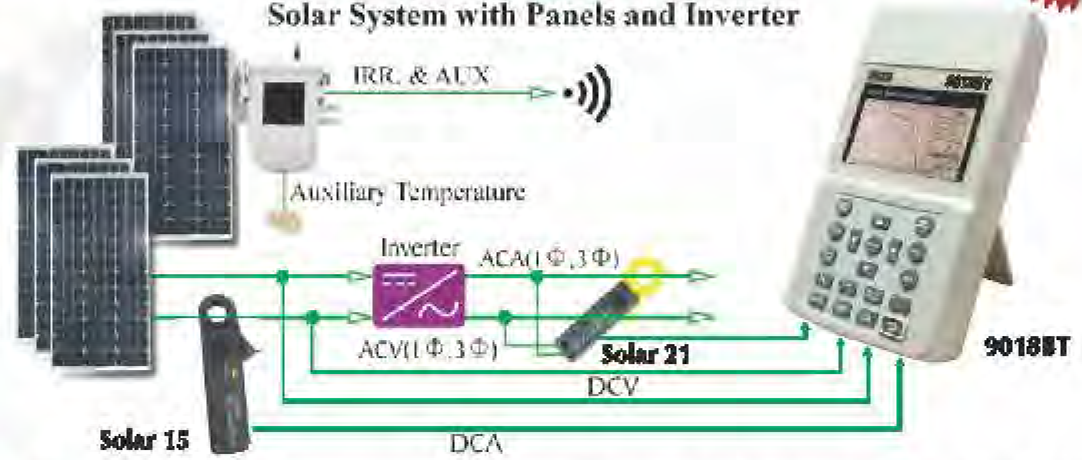

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Applications

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ACME's Lithium-ion based Energy Storage Solution

ACME, the leader in energy management and innovative solutions for alternate energy sector,announced the completion of one year of Lithium-ion Based Energy Storage Solution at telecom sites since their deployment in last August. This is first of its kind achievement in the field of energy storage solution which demonstrates true potential of the technology to eradicate diesel based back-up. Manoj Kumar Upadhyay, CMD, ACME Group said, 'This is a remarkable achievement and marks the success of LIB based Energy Storage Solutions in India. We at ACME strive to eliminate the inefficient energy systems that pollute the environment and bridge the demand-supply gap through green energy solutions. Through the LIB technology, ACME is taking major steps forward to solve this challenge of the energy industry by having the right storage solution from Kilo Watt to Mega Watt class. As ACME continues to change the industry standards for cost, ease of installation, reliability and higher uptime, their Lithium-ion Based Energy Storage Solutions are poised for hyper charged growth.' The Lithium-ion Based Energy Storage Solution enables Telecom Site to meet 21st Century challenges by radically reducing its dependence on environmentally degrading fuel sources while delivering benefits on cost and decrease on carbon footprints. The company's Lithium-ion Battery Solution has been consistently providing savings of up to 60% on Diesel and Maintenance expenses over a conventional solution to Off-Grid and On-Grid Sites. ACME's Lithium-ion Based Energy Storage Solution is a game-changing technology and this will also help utilities to schedule their renewable energy generation as per the demand.

REI 2014 sets growth charter for Renewable energy sector in India

UBM India concluded Renewable Energy India 2014 (REI 2014) at Noida, the three day expo and conference with a consensus; the need of the hour is to drive the Indian renewable sector, optimizing its potential with support of Public-Private interplay. The event witnessed an overwhelming industry response with a 30% increase in attendance over last year. The event witnessed an industry congregation of the renewable energy sector, both, with national and international representation. The initiatives taken by the new government towards expansion and growth in the renewable sector have led to a growing interest in the Indian market, attracting global attention and investment. The increasing international interest in the Indian market was highlighted by the presence of 35 countries at the exhibition. Japan, China, Canada, US, Italy & the European conglomeration were represented by key industry players. The Government's participation was represented by presence of Anil K Jain ,IAS, Adviser (Energy), Upendra Tripathy, IAS Secretary, MNRE Govt of India, BN Sharma, Joint Secretary (Distribution) Ministry of Power, GM Rao, Director IREDA and SK Bhargava, Director IREDA. The platform proved to be a catalyst of dialogue and action amongst the industry players & policy makers, The various sessions highlighted potential in the wind sector which is growing exponentially and demonstrated innovative technologies in energy conservation efficiency along with Geothermal energy as a realistic option for energy security. The key themes were discussed and presented by international experts.

Emerson named automation contractor for replacement project at Longview Power plant

Emerson Process Management has been named main automation contractor for a comprehensive, fast-track controls replacement project to improve reliability at the Longview Power plant in Maidsville, W.Va. Under the contract, Emerson will remove the existing plant controls and I/O, and engineer and install its Ovation™ control technology. Commissioned in 2011, the 695 MW, coal-fired supercritical unit serves Morgantown and surrounding communities. "This is our first collaboration with Emerson," said Stephen Nelson, Senior Vice President - Plant Rehabilitation, Longview Power. "We based our decision on their experience managing large, complex projects; successful track record automating supercritical units; and ability to be an open and responsive partner."

Another critical consideration, according to Nelson, was Emerson's ability to complete the project in an accelerated 13-month timeframe, with commissioning slated for June 2015. Projects of similar scope and complexity typically take 18 to 24 months to complete. Since it was commissioned three years ago, the unit has suffered frequent, costly plant trips that have weakened plant reliability. Under the contract, Emerson will replace the Siemens T3000 system currently controlling the Foster-Wheeler boiler, Siemens turbine, air quality control system, burner management system and other balance-of-plant equipment and processes. Providing a more integrated control strategy for the boiler and turbine on a single, unified platform is expected to stabilize the unit and greatly enhance reliability. In doing so, Longview Power will gain the ability to bid into the regional grid operator's ancillary services market for such functions as automatic generation control and synchronized reserve, making it possible to capture additional revenue. Emerson will also provide HART smart instrumentation, including its Fisher FIELDVUE Digital Valve Controllers, Rosemount Guided Wave transmitters and a number of wireless devices - all of which are inherently compatible with Ovation I/O.

9000X High-Performance Variable Frequency Drive from Eaton

Power management company Eaton is offering the marine industry a broad range of air and water-cooled frequency inverters. The 9000X family of variable speed drives comprises efficient devices for applications with ratings from 0.55 to 2,750 kW. Due to its compact and modular design, quick-start wizard, high degree of communication flexibility and extensive range of configuration options, it offers users a vast number of possibilities. The SVX9000 series can be used in both simple and also complex applications. With ratings from 0.55 to 160 kW it is suitable for example for fans and pumps, offering protection to IP21 and IP54. The SPX9000 series with IP21, IP54 and IP00 protection comes in a considerably higher rating range up to 1,800 kW. It has been designed for applications, where high performance, reliability and dynamic behaviour are crucial, such as in crane applications on ships or for anchor and mooring winches. Here, the variable frequency drive ensures precise motor control and can generate on start-up up to 200 per cent torque. The units also support the synchronisation of multiple motor units, positioning applications as well as the control and synchronisation of winding systems. In addition to these air-cooled frequency inverters, Eaton also offers a water-cooled variant. The LCX9000 series features the same functionality as the SPX9000 but offers ratings up to 2,750 kW. The benefits of water cooling are particularly apparent in shipping applications as it provides: space saving thanks to the elimination of fans, a clearly inexhaustible supply of water, and the elimination of fan grills through which salty air could otherwise penetrate and cause corrosion. The variable frequency drives also offer a high degree of flexibility. Optional I/O and communication cards enable the individual adaption to customised requirements through the use of five available slots. Due to the various communication protocols available, the 9000X product family can be connected to a wide range of automation systems based on protocols such as Modbus/TCP, Modbus/RTU, Profibus DP and Ethernet/IP. Thanks to its compact design, the frequency inverters are ideal for use in places with limited space such as those frequently found in the ship building industry where space is at a premium. The modular separation of power and control units not only offers installation benefits but also reduces spare parts requirements.

CG wins $25 million Contract by Ministry of Electricity, Iraq

Avantha Group Company CG announced a $25 million new contract win for design, construction and delivery of 16 mobile substations. The order was placed by the General Directorate for Transmission, Upper Euphrates Region, Ministry of Electricity in Iraq. The key deliverables are engineering and supply of 16 mobile substations containing 31.5 MVA transformers delivered by CG's Power Transformer factory in Hungary, auxiliary/earthing units manufactured in the Distribution Transformer factory in Belgium and control and protection equipment provided by CG's Automation arm ZIV. Integration and assembly work for the project will be concluded at the CG factory in Belgium. The suite of mobile substations will be flexibly deployed throughout Iraq for utilities and industries to provide interim grid connections and temporary power supplies. CG's short-track delivery of mobile units allows flexible use in the Iraqi grid. Delivery is expected to be completed by September 2015. Ministry of Electricity in Iraq selected CG to execute this project on account of an enduring business trust and in recognition of CG's high quality, reliable T&D products. CG has a successful track record of providing reliable mobile substations and conventional (Gas Insulated Switchgear/Air Insulated Switchgear) substations to the Middle East region and has the reputation of being one of the leading manufacturers of mobile substations, worldwide.

Alstom to supply 75 MW Francis turbine toThac Mo hydropower station

Alstom has been awarded a contract worth around €13 million from Electricity of Vietnam (EVN) for the extension project of the Thac Mo 75 MW hydropower plant in Vietnam. The aim of this project is to increase peak load capacity to support the existing 150 MW Thac Mo power station with 75 MW of additional power. Alstom's scope of the contract includes design, manufacturing, testing, supply, erection and commissioning of electro-mechanical equipment consisting of one vertical Francis turbine of 75 MW, generator, control systems and electrical balance-of-plant equipment. Jerome Pécresse, President of Alstom Renewable Power said, "This project showcases our technological leadership in the hydro sector and reaffirms the confidence that our customers have in our ability to deliver world class products and solutions in different regions and geographies." The main turbines and generators will be manufactured at Alstom's state-of-the-art Vadodara facility in Gujarat, one of the company's largest hydro manufacturing hubs worldwide. Electrical and mechanical balance-of-plant items will be supplied from various countries including Vietnam.

Data Center Power Market worth $23.67 billion by 2019

Markets & Markets broadly segments the data center power market by solution: power distribution, power measurement and monitoring, UPS, generator, power storage and cabling infrastructure; by service: consultation, professional and system integrator; by vertical: Telecom and IT, BFSI, government, healthcare, energy, and others; by region: North America (NA), Europe, Asia-Pacific (APAC), Middle East and Africa (MEA), and Latin America (LA); by end user: cloud provider colocation provider, and enterprise. The power usage is one of the major operating expenses in data centers. This is driven by the demand of efficient power solutions which are capable of performing functions reliably and efficiently. The power quality maintenance is also an essential function of power system in data center, such that electricity supplied to IT components is free from any fluctuations. All the equipment should be monitored in order to protect them from overloading. Organization needs their data center available around the clock to avoid monetary losses in their businesses due to power shortage. The major equipment for backup solution in data center are UPS, battery and generators. The green data center power solutions provide efficient transmission of electricity to data center critical equipment. All the power solution providers are broadening their offerings to meet the business requirements of customers. MarketsandMarkets forecasts the data center market to grow from $15.19 billion in 2014 to $23.67 billion by 2019, at a CAGR of 9.3%.

Jinko Power Signs Agreement for 100 MW PV Power Plants

Jinko Solar Holding Co Ltd (Jinko Solar) a global leader in the solar PV industry, announced that JinkoSolar Power Co Ltd ("Jinko Power"), a subsidiary of it signed project investment agreements with the local government of Hengfeng county in Jiangxi Province to develop totally 100 MW PV projects. Jinko Power will own the projects and will manage the project investment and EPC as well as operations and maintenance. According to the agreement, Jinko Power will invest approximately RMB 800 million for the projects, and the project will receive subsidies of RMB1.2 per kWh. Construction has begun in the third quarter and is expected to complete in the fourth quarter of this year. After the completion, those projects will generate around 110 million kWh electricity annually, generating approximately RMB132 million revenue per year. "Our power plant development has traditionally been in northwestern China but is now gradually moving towards China's southern and eastern coasts resulting in a more balanced geographic mix," commented Xiande Li, Chairman of JinkoSolar.

Taiwan, China solar firms boost overseas production

More than a month after the US International Trade Commission's (ITC) anti-dumping and countervailing duties ruling against China's and Taiwan's solar makers, the effects of that decision continue to shape those firms' business strategies. Amidst trade disputes with the US and EU, Chinese solar manufacturers have begun moving production offshore over the past two years, said Jason Huang, a research manager at EnergyTrend, a subsidiary of the Taiwan-based market intelligence firm TrendForce. For instance, the solar manufacturer CSUN has set up factories in Turkey while ReneSola, also a Chinese solar firm, is using OEM models in Japan, Korea, India and Poland to sidestep trade barriers and unfavorable taxation rates. With a new round of anti-dumping and countervailing duties expected, JinkoSolar will build its 100-120 MW modules in South Africa. Yingli Solar and Suntech Power may also increase production capacity overseas. Taiwan producers are also ensnared in the latest round of anti-dumping investigations in the United States. While the duty rates may ultimately change, combined pressure from declining sales and rising prices will compel Taiwan vendors to gin up overseas manufacturing. Currently, Tainergy Tech has established cell and module production lines in Vietnam. Solartech Energy has built a solar cell production line in Malaysia. Other vendors plan for upstream manufacturers to build module production lines in Thailand. Cell manufacturers also have plans to develop solar cell or module capacity in the Americas in the 100 - 200 MW range. While overseas production may help Chinese and Taiwanese vendors negate the effects of trade disputes and taxation, those firms are also considering weaker economic conditions and an increase in local labor costs as they continue to move production offshore. Producers are weighing the needs of the local market as well as their organizations' global strategy, Jason Huang said, adding: "But costs remain paramount for most solar manufacturers. Emerging markets are certainly catering to that focus on costs by offering tax breaks and other perks to attract foreign investment. Whether the solar industry can truly develop in those markets, however, remains open to question." Cells produced by Korean and Malaysian manufacturers, who have not been hit by the US anti-dumping and countervailing duties, are currently priced at US $0.40-$0.42, about 20.5% higher than those made by Taiwan firms. That gives Taiwanese firms leverage to negotiate with customers.

Micro-Inverters/Module Integrated Inverters for Solar PV Applications - A Review

Renewable energy sources are becoming a more and more important contribution to the total energy consumed in the world. Because of their independence from limited fossil and nuclear fuels and their low impact on the environment they will become the only crisis-proof and reliable energy supply within the next decades.

- Dr.L Ashok Kumar

Today the contribution from photovoltaic (PV) energy compared to the other renewable energy sources is very low, but due to decreasing system prices the market for PV systems is one of the most stable and fastest growing in the world. If this trend continues, PV will be one of the most important energy sources in the future. To maintain the further spread of PV systems, it is important to decrease the cost and at the same time improve the efficiency and reliability of these systems. Valuable improvements can be made on the side of inverters for PV systems. These inverters account for approximately 15..25% of the system cost and are still a bottleneck for system reliability. Therefore it seems to be a well spent effort to have a close look at the inverters, their topologies and control.

Solar photovoltaic (PV) based systems are among those renewable energy systems that are now at the top eco-friendly renewable energy solutions for power generation. From powering up a compact fluorescent lamp, the world's leading economies have installed solar PV systems that produce power in the Mega Watt (MW) range. Solar PV systems are based on semiconductor wafers and are available in variety of sizes for various applications. The basic solar cell when combined forms the solar array which is basic unit for solar module/solar panel. Solar systems have low efficiency and are used in assistance with the power electronics based systems for efficient energy harvesting. They can be installed on ground or on roof. In roof top installations they offer good results as far as the energy saving is concerned.

Over the years the researchers have seen tremendous potential in PV technology. From the Log Cabin Systems (LCS1) to Urban Home Systems (UHS2) there have been a variety of technical arrangements. However, if the solar panel gets shaded due to nearby fence or by some tall building, the working of solar PV module is compromised. Therefore, this issue of partial shading forced engineers to design another category of systems with individual DC–DC converters followed by only one main inverter. Here, the DC–DC converters are connected to each panel and are connected to a common DC bus which forms the input to the inverter. It should be noted that for this system there is only one inverter, therefore in case of failure of inverter there is no alternate of energy transfer. But, in case of failure of the inverter in such systems, there is no alternate arrangement for energy transfer. For resolving this issue the idea of string inverters was proposed and implemented. Therefore, instead of having a common DC bus, in these types of system the AC is coming from each panel to a common AC bus. The output of various panels is synchronized with each other for proper operation. This provides better stability and safety against the failure. But here also the problem of partial shading degrades the performance by lowering power output and if the connection is in shunt then it lowers the input voltage to the converter. Therefore for ensuring stable operation, Maximum Power Point Tracking (MPPT) is recommended for each and every module. Even with string inverters, a PV system was not suitable as a plug and play device for domestic applications. Therefore, it was considered desirable to design systems that have inverters inside the PV modules. This type of design was initiated in early 90's under the name of OK4 and is also termed as Micro-Inverter (MI), Module Integrated Converters (MIC) or AC module. One researcher defined an MI as "An AC module is an electrical product and is the combination of a single module and a single power electronic inverter that converts light into electrical alternating (AC) power when it is connected in parallel to the network". Although the concept of MI is not new, the latest developments in this field classify it as a new concept. With the use of a micro inverter each PV module produces its own AC power. Therefore in case of failure of any individual module the power can still be supplied without any interruption. The average life of MI based systems is about 25 years because of low rise of internal temperature and elimination of bulky electrolytic capacitors. Such systems have a better physical and economical scalability as compared to the string inverters . One important advantage is the saving in term of space, noise and heat in contrast with large string inverters. They also offer a highly efficient battery-less PV system using individual tracking of maximum power. They are low cost due to decrease in balance of system, have increased reliability due to easy installation, and, reduced risk of arcing because of the use of standard AC wiring. Some researchers claim that MI is the best choice for building integrated environment

> ***One With the use of a micro inverter each PV module produces its own AC power. Therefore in case of failure of any individual module the power can still be supplied without any interruption. The average life of MI based systems is about 25 years***

because the procedure for their installation is simple. Protection functions are integrated within the electronic control of the inverter. However, MI do have some disadvantages as an obvious cost of the above mentioned benefits. The direct exposures of power electronic devices to extreme environmental conditions like humidity, temperature, lighting etc. reduces the Mean Time to Failure (MTTF). The stiff environmental conditions may have a wide temperature range from - 30^{O}C to 70^{O}C and from dry to very humid environment. If an MI system develops a fault as a result of the environmental or technical issues, repairing it can be very difficult. Though the cost is low for an MI system, at mass levels the cost per watt is higher as compared to a string inverter of the same size. MI being a home for tens of components in a compact space it becomes obvious that each and every component is a possible point of failure. MI systems are mostly designed for power rating between 200 & 700W. For better matching of inverter and PV module they are incorporated with MPPT as the output power of a typical MI system increases by 11% annually if proper MPPT technique is employed. Most of the MI systems have either a single stage or multi stage power conversion process. In the single stage configuration the inverter is designed to make sure of MPPT and in the multi-stage configuration the use of DC–DC converter is usually employed to ease the implementation of MPPT. Transformers are also used in some multistage configurations for stepping up the voltages. Mostly, MI systems are designed for operating at grid voltages with a desirable power factor of 0.9 & Total Harmonic Distortion (THD) limited in accordance with the IEEE regulations.

Micro-inverter research

The first MI was designed during the 90s, yet the research in this field has opened new horizons for power electronics engineers. This section deals with the general design objectives of an MI system followed by various energy conversion configurations proposed by the researchers. It also gives a glimpse of the MPPT techniques employed by the researchers.

The design of an MI must be such that it is easy to install and can be fitted on the rooftop for domestic applications. To enhance its acceptance in the market it is necessary to make its use feasible for home based installations. The basic challenge is to convert the low voltage output of a solar module to a level compatible with the utility with highest possible efficiency (typically above 90%). The inverter must also be capable of current shaping making it as close to a sine wave form as possible. The inverters used for the MI must inherit high conversion efficiency with better optimization for output power, low profile electronic design and multiple AC connections. They must be able to convert even at 5% of the rated power. Furthermore, it is also desired that they inherit the property of "Islanding" in a worst case scenario. Islanding techniques are discussed in. Class II isolation for providing special safety measures for PV modules is also a requirement. Galvanic isolation is also recommended in case of utility interfacing for solving the grounding issue. It can either be provided in the form of a high frequency transformer connected with DC–DC converter; or, with the grid side in the form of low frequency bulky transformer. The MI must be tested in accordance with international standard tests for safety compliance. In case of MI interface with grid, the requirements for current/voltage harmonics and under/over voltage protection must be ensured. The high frequency ripple due to switching must not pose EMI3 problems in the system. Planer magnetic4 is recommended for a slim design. The cost of the AC modules should be less than the string inverter or central inverter based systems and it is a good option to have an integrated monitoring system. Based on the temperature profile of the solar PV panel during a sunny day, an MI must withstand a max temperature of 80^{O}C. It should be noted that the famous Arrhenius law tells us that the life of the device becomes double if temperature decreases by 10 K. This means that thermal modeling can enhance the life of the MI and it can increase the life of device. Therefore, as a design objective, proper thermal modeling is also required. The reliability and life of a MI is mainly dependent on the life of the components utilized and if there is no other issue they can reach a life of 20 years.

Designed topologies

The circuit arrangement and design in MI is a promising field as far as research and design aspects are concerned. Technically an MI is composed of the following components in general as shown in Fig. 1 (Next Page).

- DC–DC converter
- Inverter
- Control circuitry
- Protection scheme
- Utility interfacing transformer.

Control chips like dsPIC DSC, TMS320C31 UCC28956 TI MSP430F1232, TI TMS320F2812eZ DSP kit, DSP TMS320F28027/2407, DSP1104 from dSPACE and MSP430F147 are generally used to control the power switches and the implementation of the protection schemes along with MPPT. Moreover, surface mounted inductors, fast recovery diodes and low ESR capacitors are generally recommended. The topology of the inverter deeply affects the efficiency. A lot of work has been done based on the inverter topologies and circuit arrangements. For maximizing the efficiency of the system often the designers incorporate MPPT either by a DC–DC converter or by modifying the inverter switching algorithm. First one is known as multi stage design & the latter as single stage design.

Single stage micro-inverters

Fig. 2 shows a fly back inverter based MI of 300 W power rating was designed using Digital Signal Processing (DSP) chip, that yielded in 89% efficiency. Another fly back inverter type 100 W MI was proposed taking into consideration the high atmospheric temperature. The efficiency reported by them was very low due to the low input voltage rating. However, this topology (Fig. 3) enables the use of ceramic capacitors thus boosting the useful life of the system. A 300 W single stage inverter topology based on Z source 5 was presented by Z. Chen et al., as depicted in Fig. 5.

Despite the inherent instability during the zero states, the measured Total Harmonic Distortion (THD) of their system was less than 4% (Chen et al., 2007). Jain and Agarwal (2007b) designed a single stage 300 W MI using DSP with THD less than 5% as shown in Fig. 6 (Jain and Agarwal, 2007b). Another design was presented by B. Sahan et al., which is a purely single stage MI with a power rating of 250 W and managed to obtain an efficiency of 96%. The solar PV panel was connected directly to the Current Source Inverter (CSI) as shown in Fig. 7. Sahan also did the thermal modeling of the system for fully integrating the PV MI module (Sahan et al., 2007, 2008). Similarly, single phase transformer-less design is presented in (Vazquez et al., 2009). Current hysteresis band control is used here. It is important as the current controlled PWM6 is very easy to implement in practice. Yu Fang et al., presented a single stage MI that is also a transformer-less system, and is based on coupled inductors and two half bridge inverters as shown in Fig. 15. The system output is taken across the output of bridges and it has a THD of less than 3% while maintaining a power factor of 0.99. The overall efficiency of the system is reported to be 97.5% (Fang and Ma, 2010). Multi stage micro-inverters The early MI were based on a multistage configuration, when in the mid of 90s a team of researchers presented an integrated power processing system with PV and called it an AC module (Wills et al., 1996). Their power rating was 250 W. Following the work by Wills et al. (1996), Kusakawa et al. (1998) presented the concept of transformer less MI in late 90s. Their design was two staged and with the inverter connected directly to the PV module followed by a buck/boost converter as shown in Fig. 8. This provides low input voltage to the switching devices; thus MOSFETs can be used without having much conduction losses.

To reduce the conduction losses and to increase the efficiency of the inverter M. Andersen and T.B. Alvesten designed a two stage MI based on Zero Voltage Switching (ZVS) inverter (Andersen and Alvsten, 1995). Their MI has a design rating of 200 W as shown in Fig. 9. S. Yatsuki et al., designed a cycloconverter based low power MI based on impedance admittance conversion theory. Their 2 stage conversion process has an inverter followed by a cycloconverter via immittance7 conversion circuit as shown in Fig. 10 (Yatsuki et al., 2001). S. Kjaer, presented a work based on two stage 160 W MI. He connected the PV module directly with an inverter. The output of the inverter is stepped up, rectified and then converted into AC using a single phase bridge inverter (Kjaer, 2005) as illustrated in Fig. 11. B.M.T. Ho et al., published their design work for a two stage MI using a buck/boost converter and a single phase inverter. It is a verter and obtained an efficiency of 92% (Li and Wolfs, 2007). C. Rodriguez et al., presented a design with the main aim of attaining long life of the inverter. Their design is three stages and uses soft switching technique. The output stage is based on current source in 30 W MI with an overall efficiency of 90.2% as shown in Fig. 12 (Ho and Chung, 2005). Zero Voltage Switching (ZVS) has been employed for low switching losses for a 150 W MI by G. Walker et.al., as shown in Fig.4. The efficiency attained by them is 94% (Walker and Pierce, 2006). Q. Li, presented a 2 stage 140 W MI using a boost converter (CSI). Their system design can deliver a maximum power of 150 W with an efficiency of 89% (Rodriguez and Amaratunga, 2008). A multilevel topology of inverter that does not inject DC in the grid was proposed by (González et al., 2008). Their topology (Fig. 13) is multilevel and transformer-less. Researchers have proposed two stage MI that uses the full bridge configuration for DC–DC conversion stage and instead of having a pure DC in the DC link a rectified they produced rectified sinusoidal waveforms. These waveforms are then converted into AC by using a full bridge inverter with square wave control (Jiang and Pan, 2009). Choi et al. (2009) presented a novel DC–DC converter for MI applications. Their system has two transformers and provides better conversion ratios as shown in Fig. 14. The proposed scheme is two stages and was tested for a 260 W MI.

The efficiency attained was 97% and this was mainly due to the use of Zero Current Switching (ZCS) scheme. Franke et al. (2010a) presented the control methods using a 2 stage

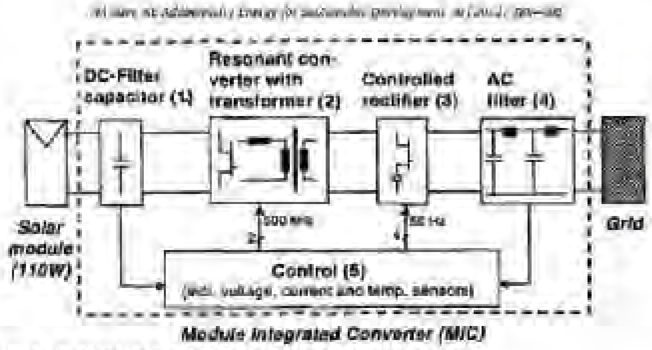

Fig. 1: Typical micro-inverter (Meinhardt et al 1999)

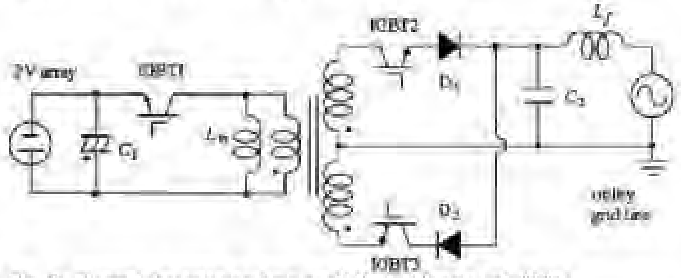

Fig. 2: Flyback inverter by Nobuyuki Kasa (Kasa et al. 2005)

transformer less system and adopted a three phase H bridge inverter for grid interconnection. His work is based on high voltage solar array and a transformer-less system is considered for implementation of different algorithms. His work gives a useful conclusion by showing that the current control PWM causes lower losses than the PI controller in DQ reference. The power quality is however poor as compared to the DQ method due to variance in switching frequency. Trujillo et al. (2010, 2011a) designed a two stage MI based on push pull converter and single phase bridge inverter. By avoiding the bridge topology, though, the number of switches reduces to two but they have to bear extra voltage resulting in higher rating requirement. This helps in a relatively simpler control circuitry. Their efforts on MI result in a reconfigurable control scheme for a MI. For that scheme the MI works as a current source & for island mode it operates as a voltage source. This control was achieved using droop schemes (Trujillo et al, 2011b). Krishnaswami (2011) presented his work with a high frequency

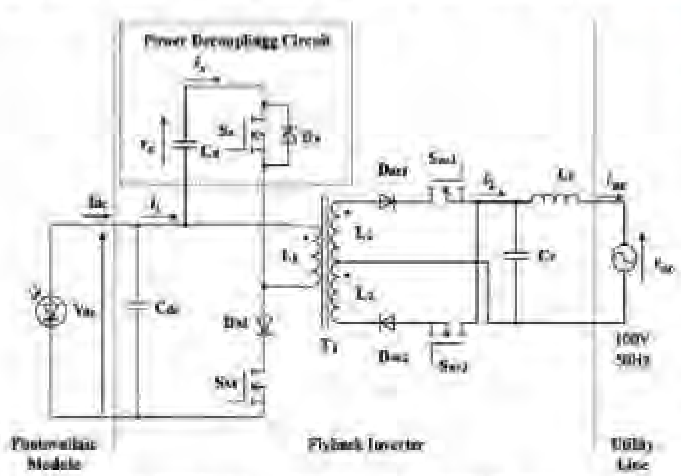

Fig. 3: Flyback inverter by T. Shimuzu (Shimuzu et al. 2006)

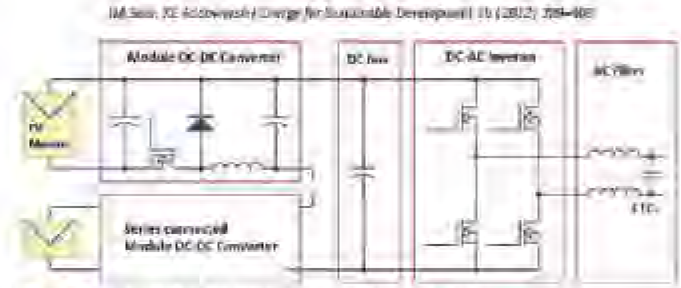

Fig. 4: Design of Walker (Walker and Pierce, 2006)

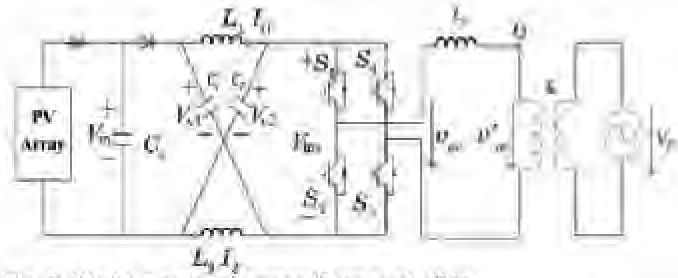

Fig. 5: MI with Z source inverter (Chen et al., 2007)

link using ZVS and high frequency transformer as shown in Fig. 16.

His topology is actually a two stage power conversion scheme. Here the first stage is creating a high frequency link and the second stage inverting that high frequency into grid compatible form. The use of soft switching for low power applications like MI makes it possible to have low losses. Such types of MI do not have a DC link but they are still classified as a two stage MI. Liang et al. (2011) presented their MI with DC output for renewable energy delivery and management system and presented a novel converter based on resonant switching and power rating of 240 W. They managed to get efficiency up to 96.5%. Their resonant switching is based on ZVS. Kerekes et al. (2011) presented an inverter topology that can be used in a MI. The topology is based on a transformer-less system that provides a separate bypass circuit for ground leakage. They proposed to use uni-polar switching scheme as it produces lower losses in the inverter as compared to the bipolar scheme. The overall efficiency of their inverter is 94.88%.

MPPT for MI

In any micro-inverter it is always desired to have an MPPT applied either through a DC–DC converter or through an inverter. MPPT uses the current and voltage level optimization for obtaining the maximum power. The voltage and current characteristics of a PV panel are generally given by the manufacturer and this helps in defining the operating mechanism of MPPT. It should be noted that a wrong choice of frequency and amplitude of step size can greatly affect the reliability of the system. Thus following MPPT algorithms get importance in this regard (Esram and Chapman, 2007; Jain and Agarwal, 2007a; Kjaer, 2005).

- Hill climbing (perturb and observe)
- Incremental conductance method
- Constant voltage method
- Fuzzy logic control
- State based MPPT
- Beta (β) method

- Sweeping algorithm
- System oscillation method
- Ripple correlation method.

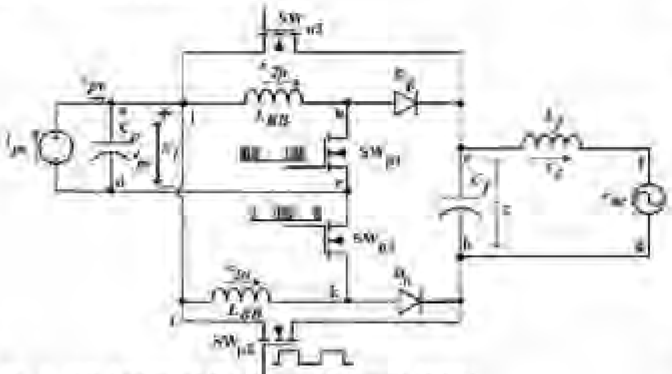

Fig. 6: Jain Design of MI (Jain and Agarwal, 2007b)

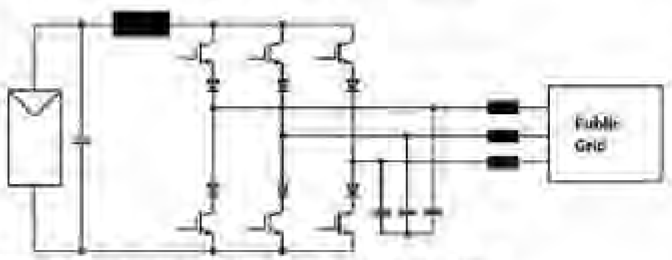

Fig. 7: Sahan Design of MI (Sahan et al., 2007, 2008)

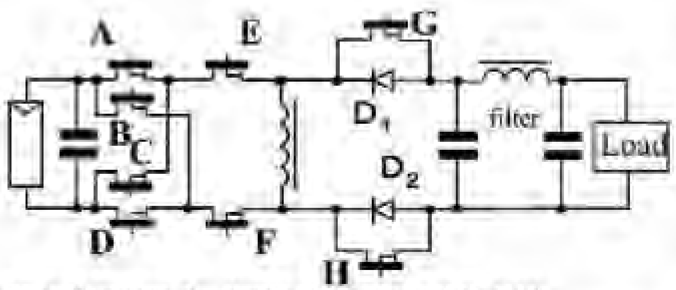

Fig. 8: MI presented by Kusakawa (Kusakawa et al., 1198)

Among the above mentioned techniques three are considered accurate and are widely used. These are Hill climbing, Incremental conductance and Beta method. Hill climbing and incremental conductance and constant voltage method can be implemented using analog or digital circuits. Variations among the implementation of these methods are found in the literature (Esram and Chapman, 2007; Hohm and Ropp, 2003; Salas et al., 2006; Zegaoui et al., 2011). Trujillo et al. (2010, 2011a) used hill climbing technique for analysis of islanding techniques for MI. Kjaer (2005) used a modified sweeping algorithm in which it is pre-assumed that the module is operating on a given point and by monitoring the output voltage the tracking is done every U change in that voltage. Koizumi and Kurokawa (2005) presented the MPPT design based on the characteristic curves of an AC module supplied by the manufacturer. They use the right side of the characteristic curve and by making a linear function they divided the region into two domains. One contains the MPP and other does not. Their algorithm first identifies that domain which does not have the MPPT. Once identified the domain without MPP the MPPT can be rapidly achieved by concentrating only on the region which has MPPT. When the operating point is near to the MPP do main then the algorithm is switched to the incremental conductance method. But by using this algorithm the time required for getting MPPT is reduced to almost half as compared with traditional incremental conductance method (Koizumi and Kurokawa, 2005). In another paper, Koizumi and Kurokawa (2006) used a square root function to divide the I–V domain. The result recorded for a 100 W MI was better than the incremental conductance. Perturb and observe method is used in MI design presented by (Andersen and Alvsten, 1995; Chen et al., 2007; Jain and Agarwal, 2007b; Rodriguez and Amaratunga, 2008; Shimizu et al., 2006) for implementing MPPT. The design presented by Kasa et al. (2005) is actually an improvement in hill climbing as they provided sensor-less tracking of MPPT. Fig. 17 shows an analog MPPT circuit. Some researchers have successfully combined the MPPT and the current wave shaping and claimed to have very good results with reduced component count (Ho and Chung, 2005). The proposed work has a very low THD but, the max efficiency achieved is around 90%. The Ho and Chung (2005) work is based on frequency modulation MPPT the details of which are given in Tse et al. (2002). If the MI is to be connected with the utility then the control must be based on current control to utilize the PV module at its maximum operating point.

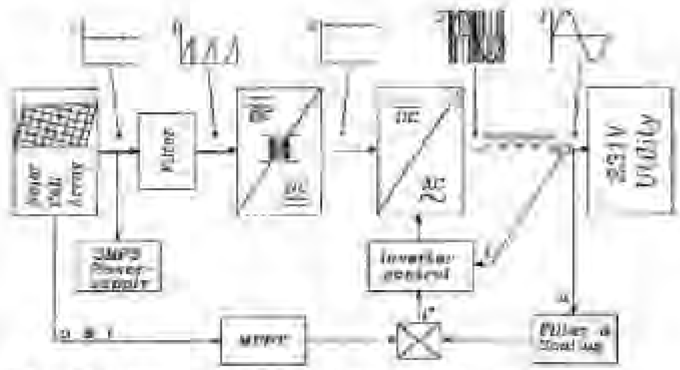

Fig. 9: ZVS based MI by Andersen (Andersen and Alvsten, 1995)

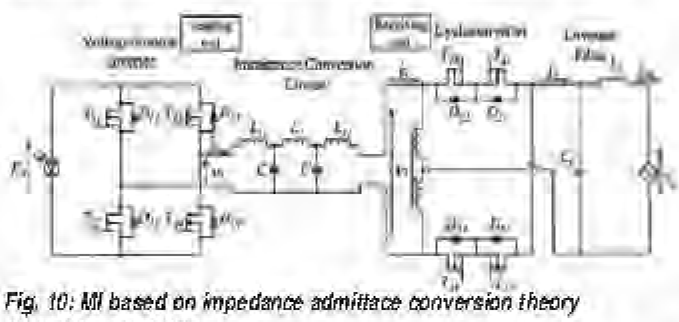

Fig. 10: MI based on impedance admittace conversion theory (Yatsuki et al., 2001)

The comparison of efficiency among various available MPPT techniques is presented by (Petrone et al., 2008). The outcome of their work shows that hill climbing offers an efficiency of 96.5% and incremental conductance 98.2%. Constant voltage technique has a low efficiency of about 88%. In varying environmental conditions the best is to use artificial intelligence based techniques like fuzzy neuro for MPPT (Petrone et al., 2008).

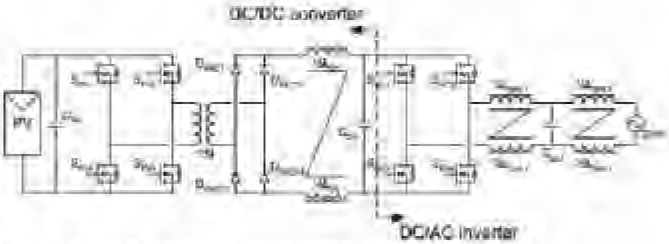

Fig. 11: Kjaer's Design (Kjaer's, 2005)

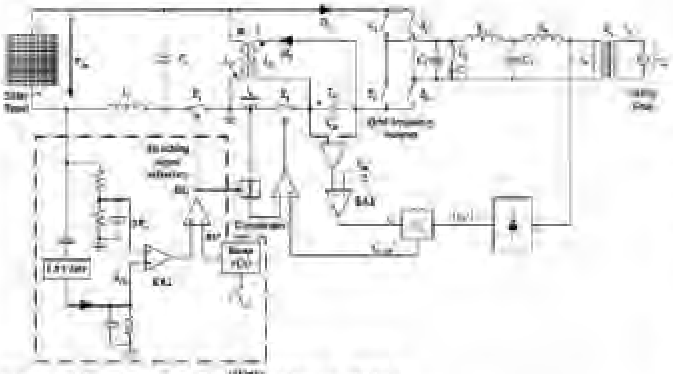

Fig. 12: Ho's Design (Ho and Chung, 2005)

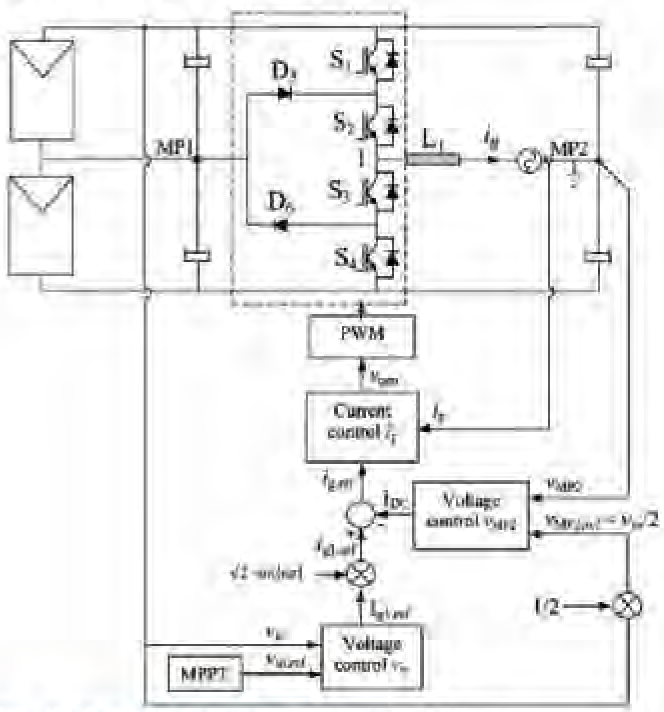

Fig. 13: Multilevel design of MI (González et al., 2008)

Commercial and patented work

While it is an upcoming field for research work, micro-inverters have a lot of room for looking at many aspects. Based on the selection of topology one can then design the parameters of associated passive components for a MI system. Although there are several ways of achieving the power conversion process the best is to have minimum stages of conversion for ease in module integration. We also need to control the component count for a compact design. These aspects need an optimization process for selecting the design topology (Jain and Agarwal, 2007b). The following topologies of power electronics converters are tested in this regard as discussed above (Andersen and Alvsten, 1995; Chen et al., 2007; Fang and Ma, 2010; González et al., 2008; Kjaer, 2005; Li and Wolfs, 2006, 2008; Myrzik and Calais, 2003; Trujillo et al., 2011a; Walker and Pierce, 2006).

Two stage inverter with flyback topology

- Z source inverter
- Zero voltage switching PWM inverter
- Bi-directional flyback inverter
- Two stage inverter with a DC–DC converter used for MPPT
- Flying inductor inverter
- Interleaved MOSFET half bridges
- Neutral point diode clamped inverter
- Transformer-less multilevel inverter
- Coupled inductors double boost inverter
- Inverters based on push–pull technique

Among these above mentioned techniques apart from the basic component count the switch drivers, isolation circuits and biasing circuits must be taken into consideration for optimal sizing of a particular MI.

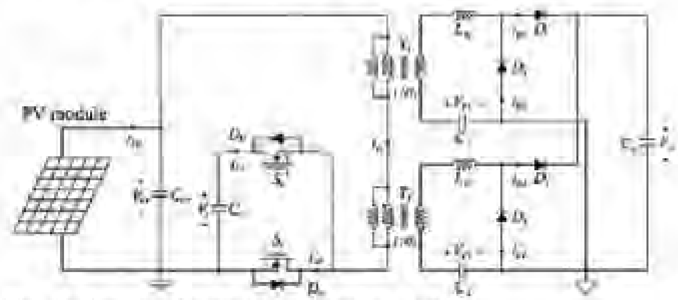

Fig. 14: Two transformer design (Choi et al., 2009)

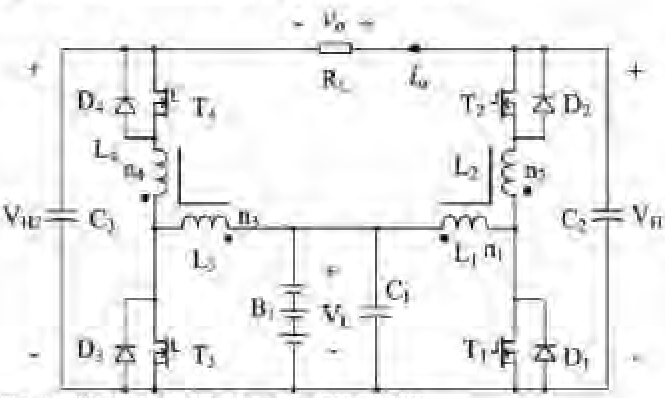

Fig. 15: Yu Fang design (Fang and Ma, 2010)

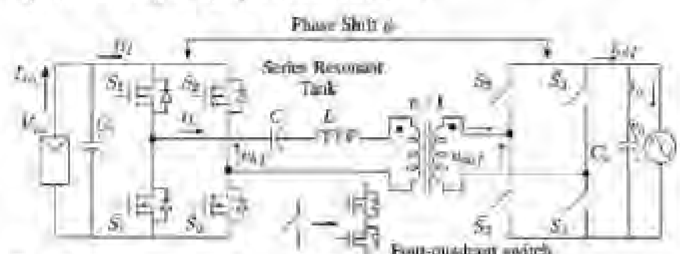

Fig. 16: Krishnaswami design (Krishnaswami, 2011)

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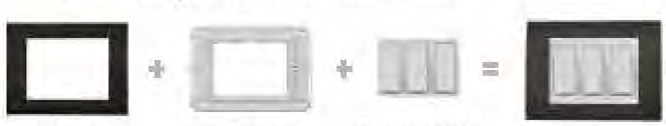

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Apart from the commercially available MI, several patents have been registered in the past few years. The MI based on two stage energy conversion is patented by (Bower et al., 2003) where the first stage is a DC power processing and the second is an inverter. In the year 2008 an MI patent was registered in the US describing the details of roof top installation with at least one MI with one PV module (McClintock, 2008). The power module adjustment can be accomplished using the work of (Dubhashi et al., 2002). The interfacing of PV module with the MI is addressed in a patent by Fornage and Meeker (2008). They called it a universal interface that works equally well for a MI. US patent pub. no. US2010/0194202AI is about the adjustment of multiple solar modules connected with an inverter. Various types of methods and systems including the series connection and shunt connection of modules are also presented in this patent (Sun, 2009). A MI based on two stage energy conversion using hill climbing MPPT has been patented in 2008 (Dickerson and West, 2008). A MPP tracker designed by Kim et al. (2010) is also suitable for MI. Browder (2009) patented his invention aiming for the fully integrated MI. In his patent he has discussed his method of overcoming the difficulties in the connection of MI with the load. The arrangement of support modules for MI based systems using mechanical pivots has been patented by (Jones and Roy, 2008). A safety device against the branch current overload during plug and play operation of PV systems is patented by Wahl (2011). Grid utility interfacing was addressed by Uselton & Brizendine (2011) and was patented in the year 2010.

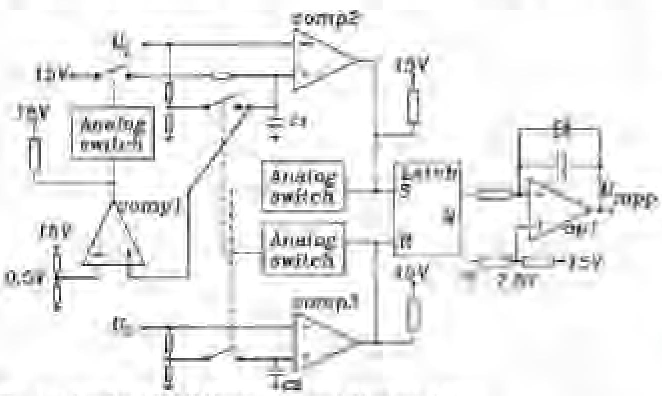

Fig. 17: Analog MPPT (Andersen and Alvsten, 1995)

The energy conversion in MI is based either on single stage or multistage process. The surveyed papers revealed that very little work has been done on single stage MI. Most of the work has been on two stage power conversion process including voltage enhancement either by using a transformer or a DC–DC converter for stepping up the voltage and the inverter stage. Very little work has been done with three stage power conversion. The topologies that use transformers are bulky and require a larger space. In case of DC–DC converter connected with the PV module IGBTs offer good performance as power electronic switch since losses associated with their switching are a function of only the current and not the square of the current (Kusakawa et al., 1998). It is pertinent to mention that Franke et al. (2010b) have shown that among the transformer-less designs NPC inverter linked with a boost converter gives superior performance than the VSI and Z source inverter. Transformers however provide ease in designing and provide galvanic isolation if the output stage is a standard three phase bridge VSI or NPC inverter. Although efficiencies as high as 97% have been attained even with two transformer topology as seen in the design by Choi et al. (2009) but that needs soft switching of power switches. Transformer-less topologies generally have higher efficiencies. Kerekes et al. (2011) have shown that a transformer-less system enhances the efficiency by 1–2%. They need less space and cost. However, leakage currents flow in the path of ground. The transformer-less system employ DC–DC converters for boosting up the DC link voltages that is otherwise not possible. It is also interesting that 3phase full bridge VSI with split capacitor on the DC link side does not needs galvanic isolation. Therefore these can be considered for a transformer-less design as they provide very low leakage current. However, we need a comparatively larger output filter for them. The recent work has shown their ability to work with islanding properties. Z-source inverter that resembles as a mix of VSI and CSI when used in transformer-less topologies gives relatively high switching losses due to the shoot through states although it enables us to use all the available states. The topologies that are based on CSI need large inductors and therefore the size increases. The use of multilevel topologies as presented by González et al. (2008) provides better power quality. Furthermore the voltage stress of each switch is half. The ripple of the output is low and therefore the filter design yields slimmer components. The efficiency is higher due to lower voltage stress on each switch but they suffer because of a high component count and require additional arrangements for thermal management issues. The use of inductors with planner core can provide some space for component placement beneath them and can be used for saving space. Most of the work in MPPT is based on Perturb and Observe or Hill climbing algorithm. A large number of papers surveyed did not mention the type of MPPT used in their designed MI.

Conclusion

Micro-inverter technology is an upcoming field and has a lot of scope for research. MI with ratings less than 1 kW have been discussed here. These are categorized into single stage and multi stage MI based on their energy conversion stages. The pros and cons of the presented work have also been discussed. It seems that single stage MI provides a good room for research as it reduces the cost as well as size and increases the reliability and life of the system. This research survey thus provides an outline for future development of MI.

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Profile

Renewable Energy Sector in India - A Review

India has been blessed with a huge renewable power potential of 245880 MW. Renewable energy sector in India has emerged as a significant player in the grid connected electricity and by contributing 12.7% to the total power, it is playing an important role in reducing the gap between energy/ peak power demand and supply benefitting millions of rural people.

- M P Singh

Now it is emerging as an essential player for electricity access. Commercial renewable power plants installed in India have both on-grid as well as off-grid applications. Although, all the energy resources would go on contributing their important role in meeting electricity demands, the role of renewable energy would continue to be very important for sustainable development and in achieving energy security and access in future.

Renewable energy is the energy from perennial natural resources that are not depleted when used. They are constantly replenished naturally and will never be exhausted. Solar energy, wind energy, geothermal energy, bio energy, hydro energy, ocean energy, energy from hydrogen & fuel cells etc. are main forms of renewable energy.

Energy obtained directly from the sun is called solar energy. It can be used directly for heating/lighting homes & other buildings, heating water, cooking food, generating electricity and in variety of commercial and industrial uses. Energy generated from falling water of small rivers/ tributaries using small water turbines are known as small hydro electric energy. In India, hydro power plants with total plant capacity up to 25 MW are considered as small hydro projects. Biomass, the organic matter/ plant material, can be used to produce electricity, transportation fuels or chemicals. Use of biomass for such purposes is called bio-energy.

Hydrogen found in many organic compounds & water and combined with other elements can be separated from another element. This hydrogen can be burnt as a fuel or converted into electricity. Geothermal energy is tapped from the Earth's internal heat for a number of uses like electricity generation and heating and cooling of buildings. Ocean energy includes energy from tides coming from gravitational pull of moon & sun upon Earth, energy from ocean waves/ currents driven by both the tides &winds and the energy obtained from a temperature difference between the surface of ocean surface & the ocean depths. All these forms of ocean energy can be used to generate electricity.

At present, the major commercial grid-connected renewable resources are hydroelectric, geothermal, biomass, wind energy and solar. Important characteristics of renewable technologies are:

- All renewable energies offer proven technologies today available in marketplace.
- Geothermal and most biomass plants provide base load energy. Most hydro & some biomass plants can offer base load to peaking energy.
- Run-of-river small hydro is intermittent, but variations in its output are slow and predictable.
- Depending on how well it matches the pattern of energy usage, solar ranges from intermittent to intermediate.
- Wind energy is intermittent. Some portion of it can be accommodated in the grid.

Need for/ Role of Renewable Energy in India

All India annual per capita consumption of electricity is shown below. Although, it is increasing year through year, it is very less as compared to those in the developing countries.

2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
631.4	671.9	717.1	733.5	778.6	818.8	883.63	917.18

Hydrogen found in many organic compounds & water & combined with other elements can be separated from another element. This hydrogen can be burnt as a fuel or converted into electricity

During June 2014, there was a shortfall in demand met against availability of electricity as well as in peak demand and peak met by 3.7%in India. During April to June 2014, there was a shortfall in demand met against availability of electricity by 4% and in peak demand and peak met in India by 3.7%.

Renewable energy is an emerging sector and is playing an important role in reducing the gap between energy/peak power demand and availability. Renewable energy provides substantial benefits for climate, health and economy. Renewable energy plants emit little to no global warming emissions. It provides improved public health, environment quality, jobs, economic benefits and stable energy prices. It is a vast, inexhaustible, more reliable and resilient energy.

Decentralized or standalone way of harnessing renewable energy potential is quite appropriate, scalable and viable solution for providing electricity to un-electrified or electricity deficient areas, villages and hamlets. In terms of pace of implementation, quality and cost, the decentralized/standalone renewable energy could become the most effective and democratic element of Indian Village Electrification Programme. Renewable energy could act as the biggest driver of inclusive growth in remote/rural areas by providing electricity access to most disadvantaged and marginalized communities. In near future, renewable energy would play an expanding role in achieving energy and access.

Technologies of renewable energy development can be used in all establishments all over India. These technologies generally offer viable and cost effective solutions for all, especially for those operating in difficult terrains and inaccessible areas as such techniques would lead to substantial saving in the electricity consumption, reduction in usage of diesel fuel and even some reduction in cooking gas.

Millions of villagers in India are getting benefits or renewable energy by meeting their daily needs of cooking, lighting and other purposes in an environment friendly manner. Villagers have also been benefitted by renewable energy at social and economic front. Some of them include:

- Employment generation at village level
- Improvement in the standard of living
- Creation of opportunity for economic activities at village level
- Reduction in labour among rural women and girls engaged in the collection of fuel wood from long distances.

Investment made in the development of renewable energy today would result in securing our future to meet our energy requirement in a sustainable manner. Although, development of renewable energy is optional today, it would become an essential requirement in coming years. In this way, renewable energy would continue to play a major role in future in Indian power sector.

Potential of Renewable Power in India

India has been blessed with a huge renewable power potential. Total renewable power potential in India has been estimated at about 245880 MW. Wind power and solar powers have the potential of about 100000 MW each. Potential of small hydro is about 20000 MW & for Bio-power is about 25880 MW. Resource-wise potential of renewable power in India is shown in the following Table.

S. No.	Renewable Energy Resource	Estimated Potential (MW)	% of Total Potential
1	Wind Power (at hub height of 80 m)	About 100000	40.67
2	Solar Energy (30-50 MW/ m^2)	100000	40.67
3	Small Hydro Power (up to 25 MW)	20000	8.13
4	Bio-Power		
i)	Agro-Residue	17000	6.92
ii)	Co-generation Bagasse	5,000	2.03
iii)	Waste to Energy		
	Municipal Solid Waste to Energy	2600	1.06
	Industrial Waste to Energy	1280	0.52
	Sub-Total Bio-Power	25,880	10.53
	Total	245,880	100.00

Contribution of Renewable Power to Total Power in India

In terms of power capacity, the contribution of renewable power to total power in India is 12.7% as on 31.03.2014 as indicated in the following table. In terms of electricity generation, all India renewable energy generation is about 65,000 MU per annum. Thus,contribution of renewable energy generation in the country's total electricity generation is about 6.5%.

S. No.	Type of Power	Installed Capacity (MW) as on 31.03.2014	% of Total
1	Thermal	172286	69.06%
2	Hydro	40730	16.33%
3	Nuclear	4780	1.92%
4	Renewable	31692	12.70%
	Total	249488	100.00%

Growth of Renewable Power in India

At the end of 9th Five Year Plan (as on 31.03.2002), capacity of renewable power installed in India was 3453 MW. During 10th and 11th five Year Plans and in first two years of 12th Five Year Plan, the renewable power capacity addition was 6802 MW, 14659 MW and 6884 MW respectively. Thus, the grid interactive total renewable power installed capacity in India as on 31.03.2014 was increased to 31797 MW. Thus, renewable energy sector has witnessed a growth of 197% and 143% in 10th and 11th Five Year Plans. The growth in the first two years of 12th Five Year Plan was 27.6%.

Resource-wise growth of renewable power during 9th, 10th & 11th Plans & first two years of 12th Plan are shown in the table given below:

S. No.	Type of Renewable Power	Renewable Power at the end of 9th Plan (As on 31.03.02)	10th Plan (As on 31.03.2007)	11th Plan (As on 31.03.2012)	1st two years of 12th Plan (As on 31.03.2014)	% of Total (As on 31.03.2014)
1	Wind	1628	7092	17352	21136	66.47%
2	Solar	2	3	941	2647	8.32%
3	Small Hydro	1434	1976	3395	3804	11.96%
4	Bio-Power	389	1184	3225	4210	13.24%
	Total	3453	10255	24913	31797	100.00%
% Increase			197%	143%	27.6%	

India has also developed off-grid applications of renewable energy in a remarkable manner. India has also one of the largest decentralized off-grid renewable energy programmes in the World and has developed grid-off applications of renewable energy in an incredible manner. India has one of the largest decentralized off-grid renewable energy programmes in the world with more than 20 lakhs decentralized solar applications, more than 47.4 lakhs biogas plants and more than 81 lakhs sqm of solar thermal applications in some of the remote locations in India.

Although, all the energy resources would go on contributing their important role in meeting electricity demands in India, the role of renewable energy would continue to be very important for sustainable development and in achieving energy security and access in future.

Renewable Energy Applications

Renewable energy applications are categories as on-grid and off-grid applications. Every commercial renewable power plant can be and have been installed both on-grid and off-grid.

On-grid Application

An electric grid is an integrated generation, transmission and distribution system serving numerous consumers. A grid may be national, regional or local. Local grid is referred as mini-grid. Hydro, biomass and geothermal power plants are economical for capacity over 1 MW or more for base load operation and connected to a grid. Solar arrays and wind farms can also be connected to a grid. Although larger megawatt installations tend to be on-grid, but

large renewable plants may be built to supply a single customer such as a mine, a manufacturing plant or an agribusiness.

Off-grid Application

Off-grid application of renewable energy serves only one load like a home or small business. For an example, solar photo-voltaic panels can be used for supplying electricity to an individual village home. Centralized windmills can supply electricity to a village to operate water pump or a commercial battery charging facility. Such applications are generally used in remote or rural settings.

For most types of energy applications, on-and off-grid, one or more of the renewable energy technologies is cost-competitive. Now mini grids are being developed for isolated communities. These systems may integrate wind, solar energy and in some cases, diesel generators and/ or storage systems to provide power from a mix of resources to more than one customer, typically a village or cooperative.

Major Benefits of Renewable Energy Resources

- Renewable resources are environmental friendly. They have a very modest impact on their surrounding environment. They provide greenhouse gas reduction benefits.
- Renewable resources promote energy diversification. They reduce dependence on any one particular form of technology or fuel.
- Renewable resources are sustainable. Renewable power plants are operated using inexhaustible natural fuels and thus do not deplete the earth's finite resources. They reduce imports of fossil fuels & hence reduce balance of payment. They can generate significant local economic activity & can act a vehicle for regional development in resource deficit areas of India.
- Renewable energy is well suited to rapidly changing electric industry. Solar and wind power technologies have a short lead-time from installation to operation. Their modular nature provides a flexible option for adding generating capacity in distributed/ decentralized and community-scale applications. Biomass, geothermal and hydro can also be constructed fairly rapidly. Once a renewable project is constructed, it becomes a permanent, environmentally clean and low cost energy system.
- Renewable energy technologies can serve a number of valuable on-grid roles. For grid support, a renewable power plants is constructed somewhere along a transmission line to remedy high resistance in the line. This reduces transmission losses & prevents expensive substation equipment from being degraded by excessive heat. This type of distributed generation tends to yield the largest returns in locations where it averts the need to increase transmission capacity.

Renewable energy is best suited for off-grid applications like to provide power and heat for remote villages, islands, tourist facilities, industrial/ military installations, houses, clinics, schools, stores, water pumping, disinfection, desalination, communication stations, navigational aids and road signals.

Commercial Renewable Energy Technologies

Major commercial grid-connected renewable resources available at present are hydroelectric, geothermal, biomass wind energy and solar. Technologies like hydro power, solar energy, fuels derived from biomass, wind energy and geothermal energy are commercial and are cost effective for on-grid applications. Wave, ocean current, ocean thermal and other technologies are in research or early commercial stage as well as non-electric renewable energy technologies. Solar water heaters and geothermal heat pumps are also based on renewable resources.

Small Hydro Power

In India, hydro power projects up to 25 MW installed capacity are classified as small hydro power (SHP). Small/ mini/micro hydro power potential in India has been estimated at 20,000 MW from 6474 identified sites. Ministry of New and Renewable Energy (MNRE) is implementing Small Hydro Power Programme countrywide to harness power from potential sites, under which MNRE is providing Central Finance Assistance to State Governments and Private Sector to set up small/ mini hydro projects, water mills etc. MNRE is also rendering support towards survey and investigation, preparation of detailed project projects, project monitoring and training through Alternate Hydro Electric Centre. MNRE is also promoting use of new and efficient designs of water mills for mechanical power/electricity generation and setting up of micro hydro projects up to 100 kW for remote village electrification.

Indian Renewable Energy Development Agency (IREDA) started financing private sector SHPs. India has a wide base of manufacturers of equipment for small hydro power projects. State-of-the-art equipment for small hydro power projects is available indigenously. In line with Government of India policy, 24 States announced their policy for inviting private sector to set up SHPs and announced buy back rate for purchase of power from renewable energy projects.

Indian small hydropower development programme received a new dimension and tempo after liberalization of economy and invitation private sector for investment in power. Promoting mini hydro projects is one of the objectives of small hydro Power programme in India as it can provide a solution for the energy problem in rural, remote and hilly areas where extension of grid system is comparatively uneconomical. While these projects are developed by various state agencies responsible for renewable energy, the projects are normally maintained with local community participation. A number of tea garden owners have also set up such micro hydro projects to meet their captive requirement of power.

Hydropower has a central role to play in future grid that will often be more based upon variable output renewable energy generation, especially wind and solar. Hydropower can act to 'balance' supply and demand, store energy and deliver a range of other ancillary benefits. Small and mini hydro projects have the potential to provide energy in remote and hilly areas where extension of grid system is un-economical. As a member of International Renewable Energy Alliance, India is promoting and developing an understanding of how the technologies can be integrated. India is a member of the steering committee of Renewable Energy Policy Network for the 21st Century, a multi-stakeholder organisation

that facilitates the global uptake of renewables.

Solar Power

Solar energy is one of the import energy resources in India. However, at present it accounts for only about 0.85% of the total power generation capacity in India. Jawaharlal Nehru National Solar Mission launched in 2011 is one of the several initiatives that are part of the National Action Plan on climate change of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenges of climate change. This Mission is to be implemented in three phases with the following targets:

- Development of 20,000 MW of grid connected solar power by 2022
- 2000 MW of off-grid solar applications including 20 million solar lights by 2022
- 20 million square meter solar-thermal collector area
- Creation of favourable conditions to develop solar manufacturing capability in India
- Support R&D and capacity building activities to achieve grid parity by 2022.

Wind Power

Wind power is conversion of wind energy into useful form of energy, such as using wind turbines to produce electrical power, windmills for getting mechanical power and wind-pumps for pumping water or drainage or sails to propel ships. In a wind power plant, kinetic energy of wind is converted into mechanical energy for rotation of turbine blades, which again is converted into electricity using a generator sitting inside hub.

Wind farm is a group of wind turbines at same location used for production of electricity. A large wind farm may consist of several hundred wind turbines of same design distributed over an extended area and inter-connected with a medium voltage, power collection system & communication network. Medium-voltage is stepped up to high voltage with a transformer at a sub-station and is fed into high voltage transmission system. Therefore, substations used in wind-power collection systems include substantial capacitor banks for power factor correction.

Large wind farms consist of hundreds of individual wind turbines connected to electric transmission network. On-shore wind is an inexpensive source of electricity. Small on-shore wind farms can feed some energy into grid or provide electricity to isolated off-grid locations. Off-shore wind is steadier and stronger than on land. Off-shore wind power farms are located in large water bodies to utilise the more frequent, steadier and stronger winds available in these locations and have less aesthetic impact on the landscape than land based projects. However, construction/maintenance costs are considerably higher.

Today, wind power is lessening our dependence on fossil fuels and it offers many advantages and thus it has emerged as the fastest growing renewable source of energy. It has become one of the most rapidly expanding industries in India. Out of inter-active grid connected total renewable power capacity of 31797 MW set up in India up to 31.03.2014, wind power has a lion's share of 21136 MW (66.47%).

Biomass Power and Bagasse Co-generation

Biomass encompasses wood and wood waste, agricultural waste and residue, energy crops and landfill gas resources. Resource availability and cost can be highly variable. MNRE has drawn Indian Biomass Power and Bagasse Co-generation Programme. Main objectives of this programme are:

- Efficient utilization of biomass (agro residue in the form of stalks, stems and straw
- Efficient utilization of agro-industrial residues such as shells and husks, de-oiled cakes
- Efficient utilization of woof from dedicated energy plantation for power generation.

Potential for power generation from agricultural and agro-industrial residues in India is estimated at about 17000 MW. Potential of surplus power generation through bagasse cogeneration in sugar mills in India has been estimated at 5000 MW considering progressive higher steam temperature & pressure and efficient project configuration in new coming sugar mills and modernization of existing sugar mills.

Indian sugar industry is producing incidental cogeneration utilizing bagasse as a fuel for meeting the steam and power requirements for sugar processing and sugar mill complex. With the availability of latest advance technologies for boiler and turbine for generation and utilization of steam at high temperature and pressure, sugar industry can produce electricity and steam for their own consumption and the surplus electricity can be sent into the grid for sale using the same quantity of bagasse through optimum cogeneration.

Potential for municipal solid waste to energy and industrial waste to energy in India has been estimated at 2600 MW and 1280 MW respectively. 12 MW waste to energy plant at Ghazipur landfill site in Delhi is expected to become operational in 2015. Its first phase for segregating the waste, which can be converted into refused-derived-fuel to be sold to power plants, has been completed.

Geothermal Power

Geothermal resources require extraction of heat from a depth of earth. Geothermal energy has great potential as a clean, green and naturally occurring renewable source of energy. Geothermal hot water can be used directly for many applications such as heating buildings, raising plants in greenhouses, drying crops, heating water at fish farms and many industrial processes. It can be used for generating electricity as well.

However, power generation through geothermal resources is still in nascent stages in India. Geological Survey of India has identified about 340 geothermal hot springs in India having low surface temperature range from 37^{O}C-90^{O}C which is suitable for direct heat applications. Puga (located at a distance of 180 km from Leh in Ladakh region of Jammu and Kashmir) is considered to be a good potential of geothermal energy hot spring temperatures varying from 30^{O}C to 84^{O}C and discharge up to 300 litres /minute. Chhumathang spring is another geothermal area located about 40 km north of Puga. Chhatisgarh State Government has granted permission for installation of a Geothermal Power Plant at Tattapaniin Balrampur district to NTPC. It will be first Geothermal Power Plant of the country.

Challenges in Renewable Power Development

In Wind Power

- Attractive wind sites are often located in remote locations far from cities where the electricity is needed. Transmission lines must be built to bring the electricity from wind farm to city.
- Wind power must compete with conventional energy generation sources on a cost basis. Although, cost of wind power has decreased dramatically in past 10 years, the technology requires a higher initial investment than fossil-fuel based generators.
- Lack of enforcement of Renewable Power Obligations limit demand energy sources
- Weak transmission infrastructure resulting in only a fraction of generated power reaching grid
- Delays in payment lend financial uncertainty to projects. It dampens interest of investors.

In Hydro Power

- Location of sites for small hydro power projects in remote/ difficult terrain
- Small size of the project
- Delays in acquiring land
- Delay in obtaining clearances & approvals
- Inadequate grid connectivity
- Longer gestation period makes them more sensitive to terms of finance. Lack of long-term finance makes tariff front loaded.

In Solar Power

- Lack of enforcement of Renewable Purchase Obligations, which widen the Renewable Energy Certification demand-supply gap
- Division of solar industry (manufacturers & developers) over anti-dumping duties
- Weak rupee (which may put pressure on project financing in short term)
- Uncertainty with respect to some state government policies.

In Bio-mass Power

- Inconsistent availability of biomass with reasonable cost structure
- Difficulty in managing of feedstock chain due to unorganized nature of market.

In Geothermal Power

- Improper drilling into earth can release hazardous minerals and gases from deep down inside the earth, which can be contained quite easily. It is also feared that the geothermal power plant sites may run out of steam in long run.

Making Renewable Power Cost-effective

On a total cost basis, a renewable energy generating facility is often cost competitive with a conventional fuel facility provided that long-term fuel costs and environmental costs and benefits are considered in cost computations. Any given renewable electric generating technology may be cost effective in one market or application and not in another.

Proximity to resource, existing infrastructure and industry support facilities to customer base directly impacts costs. In case of geothermal, depth of resource is a major cost factor. For hydro, wind and solar technologies, climatic variations viz. rainfall, cloud cover, intense storms affect the cost. For biomass, transportation distances between fuel source and generating facility may significantly affect cost of electricity. Renewable energy projects are front-end-loaded and the capital cost significantly affects their cost of installation. There is a need to drive ways and means to implement new mechanisms to lower their financing costs.

Following are some criteria, which may assist in determining the financial viability of renewable energy generation:

- Expenses associated with each phase of resource development have direct impact on cost-effectiveness of electricity produced. Cost of each development phase is included in the cost of first facility. If there is some assurance of market for power from additional facilities, the reconnaissance and exploration costs may be allocated to additional energy and thus reducing the initial cost. By allocating such costs over multiple projects, cost of electricity can be significantly reduced.
- Cost of renewable energy is in technology effort exerted at the outset of a project and all of renewables share front-end-loaded cost profiles. Consequently, majority of new generation facilities are funded through project financing, whereby principal, interest and profit are paid from proceeds of the project.
- Measures like issuing low interest bonds can be helpful in getting finance renewable energy projects at a lower cost than that with conventional borrowing.
- Organisation and simplification of local institutional processes may prevent adding major costs and time delays as time expended in responding to bid proposals; obtaining requisite permits, licenses and concessions and in negotiating contracts increase the costs of renewable projects.
- Reduction in government-imposed taxes, fees, tariffs and royalty payments will result in reduction in cot of renewable energy, as they all are passed to electricity consumer.

Conclusions

Renewable energies provide means for using sustainable domestic resources, promote increased electrification and minimize the impact on global environment. Renewable energy sector in India has emerged as a significant player in the grid connected electricity. Now it is emerging as an essential player for electricity access. Government of India is expanding and strengthening this sector. Renewable energy has become an important part of India's National Plan on Climate Change with National Solar Mission. Well-developed industrial, financial and business infrastructure has provided excellent investment opportunity in renewable energy. India has become the 5th largest wind power producer in the world.

Profile

M P Singh

BSc Engineering (Electrical) from Aligarh and MBA from IGNOU has over three decades experience in hydroelectric stations working in various capacities & as Director and Chief Engineer (I/C) in Central Electricity Authority and at hydro power projects working as DGM at Koldam HPP of NTPC. Presently he is working as a consultant in WAPCOS. He published/presented over 80 articles in magazines/ Seminars & 6 technical books (Hindi), 5 awarded by Ministry of - Power, Renewable Energy Sources, Science & Technology.

Smart Energy Management

When I was in Saudi Arabia in nineties for a couple of years, we used to say, 'Fill it, shut it and forget it'! On petrol stations, never bothered how much he filled in my Toyota Corolla. Today, we have microprocessor based fuel injection systems in our cars. Fuel efficiency is one of the most important and appealing feature for buyers around the globe.

Aqeel Ahmad

According to IEA 2007 report, our global energy demand will be doubled by 2050, on the other hand, we have challenging target of reducing our CO_2 emission by half during the same period. Let us see the CO_2 foot print in connection with the different possible options of energies.

CO_2 emissions in different type of fuels used in power generation of 1 KWh of electricity using-

- Fossil fuel – 443 to 1050 grams
- Nuclear – 66 grams
- Renewable – 9.5 to 38 grams.

So, we find that Nuclear power plants are 7-38 times better than fossil fuel and Renewable energy plants are two to seven times as efficient as nuclear power plants as far as carbon foot print are concerned.

Global warming is not a myth or a subject to be discussed only in scientific debates and seminars; it is a hard reality, which is hammering our door. This year's bone biting cold (BBC) in USA and floods in Uttarakhand, Kashmir and draughts in Australia are 'waking up' calls for entire humanity.

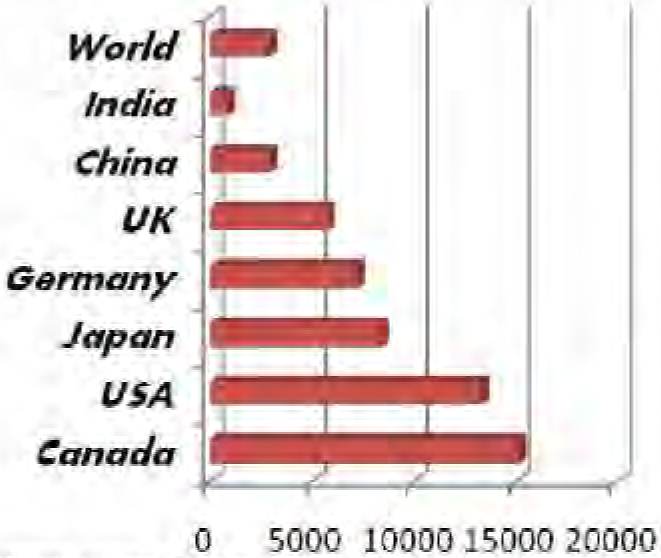
According to the Central Electricity Authority (CEA), Ministry of Power, Government of India's web site the no. of villages electrified in 1947 were only 3061 in India but till 2013, we have electrified more than 60 lacs villages, while our total installed capacity was merely 1.362 GW in1947and today we have achieved more than 223.3GW. We are fifth largest power producing country, after USA, China, Japan and Russia in the world. In spite of that our per capita energy consumption is merely 917.2 units only, probably lowest among the developing countries. Our neighbor China is second largest power producing country in the world but almost 3 to four times than India, as far as power production is concerned.

As per IEA, 2012 report per capita power consumption of the major countries in the year 2010 is as shown in the following Table & Chart.

Country	Per Capita Consumption (KWh)
Canada	15145
USA	13361
Japan	8399
Germany	7217
UK	5741
China	2942
India	884
World	2892

With present installed capacity of 223.33 GW, India is expected to add 88.23GW in the Five year plan ending in March 2017 but still a large population of India remains under dark in peak hours, especially in northern India as the following paper head line says-

> *Hydroelectric power is the cheapest in India but making large dams is time consuming besides the severe mass resistance, we are facing after Uttarakhand tragedy recently*



World's per capita Power Consumption in 2010

"Uttar Pradesh is in the grip of acute power crisis with restricted demand of electricity going up to about 13 GW and availability of power ranging from 10-11 GW." – The Hindu.

The new government at center is grappling with a major power crisis in North India. Many other North Indian states too are facing several hours of load shedding. Even New Delhi, where power supply has been normal in recent years, is facing massive load shedding this summer. Blame game is on ridiculously.

Reasons for the gap in Supply and Demand

Among the fossil fuel, coal and gas are two important components but the coal available in India is not sufficient enough to feed the existing thermal power stations, in addition to that the poor quality due to low calorific value and high ash content. Availability of gas is also not enough to meet the high demands in future.

Hydroelectric power is the cheapest in India but making large dams is time consuming besides the severe mass resistance, we are facing after Uttarakhand tragedy recently.

As far as nuclear power is concerned, Modi Government have signed fresh contracts with Australia, during Australian PM recent visit to India. But it is causing lots of concerns already like dumping of used nuclear fuel, safety concerns after Chernobyl in 1986 in Russia and Japan's nuclear power plant accident few years ago. Chernobyl has caused thousands of deaths and a loss of more than 18 billion rubles. The harmful nuclear radiation is observed up to Alaska in USA and on the Russian coast from Japan's tragedy. India is already having 21 nuclear power stations running in different parts of the country, raising serious safety issues in highly dense Indian population and our past safety track records. For India, the issue of raw material is a serious concerned and it has to remain dependent on Country like USA, Australia and Europe.

Thus we see that the present options of thermal, hydro and nuclear power generation are not able to match the ever widening gap of demand and supply. The only option left is renewable energy like wind, solar, biomass and small hydro plants. India has already utilized the long coastal lines in generating 17 GW of wind energy.

Transmission & Distribution Losses

In our country Transmission & Distribution (T&D) losses are the highest among the developing countries i.e. 23% of the electricity generated. As per studies carried out by independent agencies including TERI, these losses have been estimated to be as high as 50% in some states like UP, Bihar and some other states. Energy losses occur in the process of supplying electricity to consumers due to technical and commercial losses.

4.01%	5.04%	4.53%	6.87%	23.65%	6.86%	9.8%
Korea	Japan	Germany	China	India	USA	World

T&D losses in the world and other countries in 2010

Technical Losses

The technical losses are due to energy dissipated in the conductors and equipment used for transmission, transformation, sub- transmission and distribution of power. These technical losses are inherent in a system and can be reduced to an optimum level. The losses can be further sub grouped depending upon the stage of power transformation & Transmission system as:

Transmission Losses (400kV/220kV/132kV/66kV), as Sub transmission losses (33kV /11kV) and **Distribution losses** (11kV/0.4kv).

Commercial Losses

The commercial losses are caused by pilferage, defective meters, and errors in meter reading and in estimating unmetered supply of energy.

Reasons for high technical losses

- Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution.
- Haphazard growths of sub-transmission and distribution system with the short-term objective of extension of power supply to new areas.
- Large scale rural electrification through long 11kV and LT lines.
- Too many stages of transformations.
- Improper load management.
- Inadequate reactive compensation.
- Poor quality of equipment used in agricultural pumping in rural areas.
- cooler air-conditioners and industrial loads in urban areas.

Reasons for commercial losses

- Theft and pilferage account for a substantial part of the high transmission and distribution losses in India. Theft / pilferage of energy is mainly committed by two categories of consumers i.e. non-consumers & bonafide consumers.
- Antisocial elements avail unauthorized/unrecorded supply by hooking or tapping the bare conductors of L.T. feeder or tampered service wires. Some of the bonafide consumers willfully commit the pilferage by way of damaging and / or creating disturbances to measuring equipment installed at their premises.
- Making unauthorized extensions of loads, especially those having "H.P." tariff.
- Tampering the meter readings by mechanical jerks, placement of powerful.
- magnets or disturbing the disc rotation with foreign matters.
- Stopping the meters by remote control.
- Willful burning of meters.
- Changing the sequence of terminal wiring.
- Bypassing the meter.
- Changing C.T. Ratio and reducing the recording.
- Errors in meter reading and recording.
- Improper testing and calibration of meters.

Problem is so serious that a feature film is made on this issue of power theft named "Katiabaaz" with roaring success and widely acclaimed by the masses. UP Chief Minister suggested the electrical engineers of his state to watch the film to stop theft. Consequently film is declared tax free in some states. Here is the film review on a TV channel.

"Electrifyingly real and refreshing!

Every character on screen brings his coarse self to the forefront. The real language of the jungle, borne out of frustration, is captured with its raw essence. The unscrupulousness of the common man (resorted to by 'what else to do' attitude), the 'perfect-timing' of the scheming politician and the manner in which the electricity board in Kanpur has to grapple with power crunch and its proper distribution is frighteningly disturbing."

Smart Energy management

It is the only option left out for us to adopt to resolve this vital issue of energy crisis by utilizing Smart Energy Management technology.

IT & SCADA

It is supposed to curb the problem partially as we can better manage the power distribution and billing.

Automation of Power Sector

Introduction of automation in power sector is the crying need of the hour to improve the reliability and to reduce the menace of T&D losses. It is the tested policy in western countries to arrest the T&D losses to bare minimum.

Smart Meters

The smart energy meter redeems the traditional Ferrari's wheel, electronic or digital meters. It has bidirectional communication capability for remote control and tariff based operation. The customer has up-to-date price, load and cost information about gas, water, heat and electricity consumption. Smart meter is a basic end-user element of the smart grids.

Use of Quality Products in T& D network:

High quality products in Transmission and distribution network such as distribution transformers, switching devices, cable and metering devices to improve services and reliability of power system.

Renewable Energy

India's power crisis is more serious, specially while it is emerging as strong economic power but now there is silver lining at the end of dark tunnel hopefully i.e. solar energy. There is plenty of Sun (raw material) in India (4-6 KWhr/m^2 radiation) and demand of energy is also endless. So, the only issue is processing cost. Why India is suitable for solar now-

- Huge energy demand – 46.9% demand growth during 2012-17.
- Great potential. Excellent solar radiation in most part of the country i.e. 4-6 KWh/m^2 Thar desert of India (35000 sq. km) is capable to generate 700-2100 GW of solar power, sufficient enough to supply power to rest of the world for years.
- Cheaper erection, commissioning, operation & maintenance cost in the world compared to Germany, Italy, US & other western countries.
- Thanks to massive manufacturing facilities in China.
- Government support as subsidies, REC, RPOs through JNNMM
- Insufficient electrical infrastructure- Solar is suitable for the places, where transmission, distribution lines and other pertinent infrastructure is not up to the mark. In India, transmission & distribution losses are as high as 23%. In some cases, it is more than 45% due to age old lines, poor O&M and aging equipments.
- Many multinational companies are now launching manufacturing plants for Balance of System (BOS) now in India due to multibillion dollar Indian energy market.
- Due to shooting up conventional energy prices and declining solar prices due to massive built up in our neighboring country, India has already achieved Grid Parity.

Public Awareness and accountability

In spite of so many hue and cries for power, we may find abuse of power like day time street lights all over the country, ruthless use of air conditioners by government buildings are hard examples of public's indifferent attitude & our social and moral responsibility. Politicians should stop making false and stupid promises like free electricity to attract the vote bank. Film 'Kaatiabaaz' is a good example to bring public awareness.

Power Factor Management

In our industries 80-85% load is inductive which have an average power factor of 60-70 without correction. Therefore, there is big scope of PF improvement for better voltage regulations and reducing losses.

Smart Grid

To address demand and supply management Smart grid generally refers to technologies using computer based remote control and automation by using two way digital communication. It will link power plants to the end consumer in homes, business and industries to bring energy efficiency and reliability.


Smart Grid

Advantages of smart grid

- Improving power quality and reliability- better monitoring using sensors, better and faster balancing of supply and demand
- Better DSM- by using advanced metering infrastructure
- Expanding deployment of renewable and distributive energy resources – utilizing solar, wind, biomass and small hydro power projects to reduce pollution
- Automating maintenance and operation of grid lines
- Reducing Green house gas emission
- Reducing dependence on fossil fuel
- Increasing customer choice as seen in communication sector already
- Use of energy smart and efficient appliances.

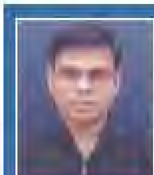
Disadvantage of Smart Energy Management

- Huge amount of money required
- Technology is developing stage.

According to the US Department of Energy, the cost of 1 hour of power interruption is

Cellular network	$41000
Airlines reservation system	$90,000
Semiconductor manufacturer	$2000,000
Credit card operation	$2,580,000
Brokerage operation	$6,480,000

Do we think smart energy management is still costlier!


Profile

Aqeel Ahmad

BSc Engg (Elect), DME, ACPDM, DELF Substation & Solar Energy Expert, acquired diploma in French language. He is having more than 23 years of experience in Steel Authority of India Ltd (SAIL), Gulf Ferro Alloys company in Saudi Arab and a decade long experience of working on UNDP, govt. of Germany sponsored project in Ethiopia, Africa in areas of substations and solar power. He is regularly writing articles and books on electrical engineering and solar for national and international magazines.

Future of Nuclear Power in India

India's primary energy consumption more than doubled between 1990 and 2011 to nearly 25,000 PJ. India's dependence on imported energy resources and the inconsistent reform of the energy sector are challenges to satisfying rising demand.

Dr P K Vasudeva

Electricity demand in India is increasing rapidly, and the 1052 billion kilowatt hours gross produced in 2011 was more than triple the 1990 output, though still represented only some 750 kWh per capita for the year. With huge transmission losses – 222 TWh (21 per cent) in 2011, this resulted in only about 774 billion kWh consumption. Gross generation comprised 836 TWh from fossil fuels, 33 TWh from nuclear, 131 TWh from hydro and 53 TWh from other renewables. Coal provides 68% of the electricity at present, but reserves are effectively limited* – in 2013, 159 million tonnes was imported, and 533 million tonnes produced domestically. Gas provides 15%, hydro 12%. The per capita electricity consumption figure is expected to double by 2020, with 6.3% annual growth, and reach 5000-6000 kWh by 2050, requiring about 8000 TWh/yr then. There is an acute demand for more and more reliable power supplies. One-third of the population is not connected to any grid.

*Quoted resources are 293 billion tonnes, but much of this is in forested areas of eastern India – Jharkhand, Orissa, Chhattisgarh, and West Bengal. While the first three of these are the main producing states, nevertheless permission to mine is problematical and infrastructure limited.

At mid-2012, 203 GWe was on line with 20.5 GWe having been added in 12 months. In September 2012 it had 211 GWe. The government's 12th five-year plan for 2012-17 is targeting the addition of 94 GWe over the period, costing $247 billion. Three quarters of this would be coal- or lignite-fired, and only 3.4 GWe nuclear; including two imported 1000 MWe units planned at one site and two indigenous 700 MWe units at another. By 2032 total installed capacity of 700 GWe is planned to meet 7-9% GDP growth, and this was to include 63 GWe nuclear. The OECD's International Energy Agency predicts that India will need some $1600 billion investment in power generation, transmission and distribution to 2035.

India has five electricity grids – Northern, Eastern, North Eastern, Southern and Western. All of them are interconnected to some extent, except the Southern grid. All are run by the state-owned Power Grid Corporation of India Ltd (PGCI), which operates more than 95,000 circuit km of transmission lines. In July 2012 the Northern grid failed with 35,669 MWe load in the early morning, and the following day it plus parts of two other grids failed again so that over 600 million people in 22 states were without power for up to a day.

The target since about 2004 has been for nuclear power to provide 20 GWe by 2020, but in 2007 the Prime Minister referred to this as 'modest' and capable of being 'doubled with the opening up of international cooperation.' However, it is evident that even the 20 GWe target would require substantial uranium imports. In June 2009 NPCIL said it aimed for 60 GWe nuclear by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. This 2032 target was reiterated late in 2010 and increased to 63 GWe in 2011. But in December 2011 parliament was told that more realistic targets were 14,600 MWe by 2020-21 and 27,500 MWe by 2032, relative to present 4780 MWe and 10,080 MWe when reactors under construction were on line in 2017.*

*"The XII Plan (2012-17) proposals are being finalized which envisage start of work on eight indigenous 700 MW Pressurised Heavy Water Reactors (PHWRs), two 500 MW Fast Breeder Reactors (FBRs), one 300 MW Advanced Heavy Water Reactor (AHWR) and eight Light Water Reactors of 1000 MW or higher capacity with foreign technical cooperation. These nuclear power reactors are expected to be completed progressively in the XIII and XIV Plans."

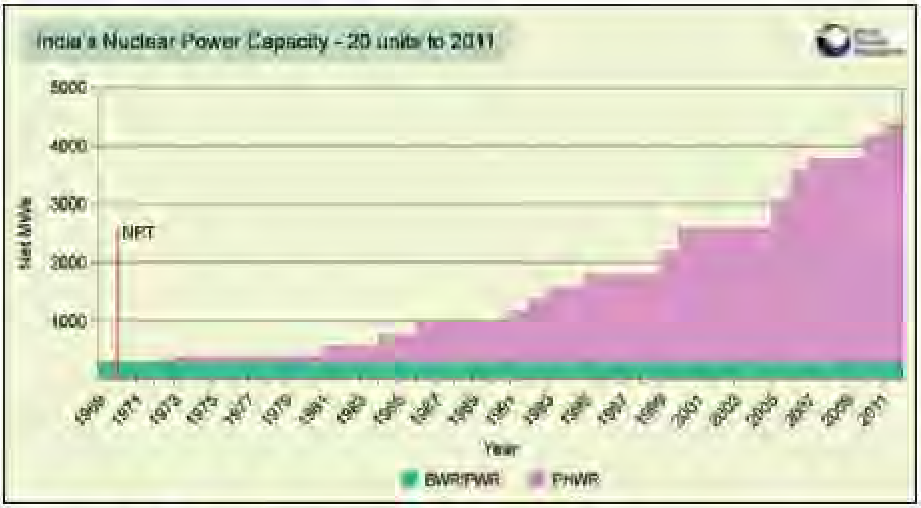
In July 2014 the Prime Minister Narender Modi urged DAE to triple the nuclear capacity to 17 GWe by 2024. He praised "India's self-reliance in the nuclear fuel cycle and the commercial success of the indigenous reactors." He also emphasized the importance of maintaining the commercial viability and competitiveness of nuclear energy compared with other clean energy sources.

Indian nuclear power industry development

Nuclear power for civil use is well established in India. Its civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle, necessary because it is excluded from the 1970 Nuclear Non-Proliferation Treaty (NPT) due to it acquiring nuclear weapons capability after 1970. (Those five countries doing so before 1970 were accorded the status of Nuclear Weapons States under the NPT.)

The Atomic Energy Establishment was set up at Trombay, near Mumbai, in 1957 and renamed as Bhabha Atomic Research Centre (BARC) ten years later. Plans for building the first Pressurised Heavy Water Reactor (PHWR) were finalised in 1964, and this prototype – Rajasthan 1, which had Canada's Douglas Point reactor as a reference unit, was built as a collaborative venture between Atomic Energy of Canada Ltd (AECL) and NPCIL. It started up in 1972 and was duplicated. Subsequent indigenous PHWR development has been based on these units, though several stages of evolution can be identified: PHWRs with dousing and single containment at Rajasthan 1-2, PHWRs with suppression pool and partial double containment at Madras, and later standardized PHWRs from Narora onwards having double containment, suppression pool, and calandria filled with heavy water, housed in a water-filled calandria vault.

The Indian Atomic Energy Commission (AEC) is the main policy body. The Nuclear Power Corporation of India Ltd (NPCIL) is responsible for design, construction, commissioning and operation of thermal nuclear power plants. At the start of 2010 it said it had enough cash on hand for 10,000 MWe of new plant. Its funding model is 70 per cent equity and 30 per cent debt financing. However, it is aiming to involve other public sector and private corporations in future nuclear power expansion, notably National Thermal Power Corporation (NTPC). NTPC is very much larger than NPCIL and sees itself as the main power producer. NTPC is largely government-owned. The 1962 Atomic Energy Act prohibits private control of nuclear power generation, though it allows minority investment. As of late 2010 the government had no intention of changing this to allow greater private equity in nuclear plants.



India's operating nuclear power reactors

Reactor	State	Type	MWe net, each	Commercial operation	Safeguards status*
Tarapur 1&2	Maharashtra	GE BWR	150	1969	Item-specific, Oct 2009
Kaiga 1&2	Karnataka	PHWR	202	1999, 2000	nil
Kaiga 3&4	Karnataka	PHWR	202	2007, 2012	nil
Kakrapar 1&2	Gujarat	PHWR	202	1993, 1995	December 2010 under new agreement
Madras 1&2 (MAPS)	Tamil Nadu	PHWR	202	1984, 1986	nil
Narora 1&2	Uttar Pradesh	PHWR	202	1991, 1992	Due in 2014 under new agreement
Rajasthan 1&2	Rajasthan	Candu PHWR	90, 187	1973, 1981	Item-specific, Oct 2009
Rajasthan 3&4	Rajasthan	PHWR	202	1999, 2000	March 2010 under new agreement
Rajasthan 5&6	Rajasthan	PHWR	202	Feb & April 2010	Oct 2009 under new agreement
Tarapur 3&4	Maharashtra	PHWR	490	2006, 2005	nil
Kudankulam 1	Tamil Nadu	PWR (VVER)	917	(August 2014)	Item-specific, Oct 2009
Total (21)			5302 MWe		

Madras (MAPS) also known as Kalpakkam Rajasthan/RAPS is located at Rawatbhata and sometimes called that Kaiga = KGS, Kakrapar = KAPS, Narora = NAPS

*The safeguarded units to March 2014 are listed in the Annex to India's Additional Protocol with IAEA. Tarapur 1&2 and Rajasthan 1&2 have INFCIRC/66 type, the others INFCIRC/754 type.

Nuclear reactors deployed in India

The two Tarapur150 MWe Boiling Water Reactors (BWRs) built by GE on a turnkey contract before the advent of the Nuclear Non-Proliferation Treaty were originally 200 MWe. They were down-rated due to recurrent problems but have run well since. They have been using imported enriched uranium and are under International Atomic Energy Agency (IAEA) safeguards. However, late in 2004 Russia deferred to the Nuclear Suppliers' Group and declined to supply further uranium for them. They underwent six months refurbishment over 2005-06, and in March 2006 Russia agreed to resume fuel supply. In December 2008 a $700 million contract with Rosatom was announced for continued uranium supply to them.

The Madras (MAPS) reactors were refurbished in 2002-03 and 2004-05 and their capacity restored to 220 MWe gross (from 170). Much of the core of each reactor was replaced, and the life spans extended to 2033/36.

Kakrapar unit 1 was fully refurbished and upgraded in 2009-10, after 16 years operation, as was Narora 2, with cooling channel (calandria tube) replacement.

Following the Fukushima accident in March 2011, four NPCIL taskforces evaluated the situation in India and in an interim report in July made recommendations for safety improvements of the Tarapur BWRs and each PHWR type. The report of a high-level committee appointed by the Atomic Energy Regulatory Board (AERB) was submitted at the end of August 2011, saying that the Tarapur and Madras plants needed some supplementary provisions to cope with major disasters. The two Tarapur BWRs have already been upgraded to ensure continuous cooling of the reactor during prolonged station blackouts and to provide nitrogen injection to containment structures, but further work is recommended. Madras needs enhanced flood defences in case of tsunamis higher than that in 2004. The prototype fast breeder reactor (PFR) under construction next door at Kalpakkam has defences, which are already sufficiently high, following some flooding of the site in 2004.

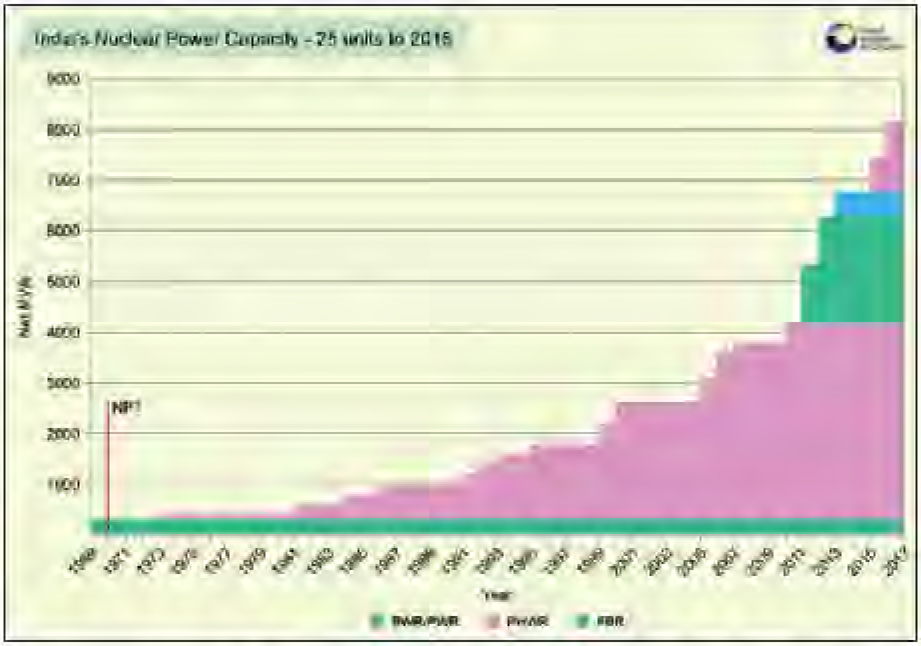
The Tarapur 3&4 reactors of 540 MWe gross (490 MWe net) were developed indigenously from the 220 MWe (gross) model PHWR and were built by NPCIL. The first – Tarapur 4 was connected to the grid in June 2005 and started commercial operation in September. Tarapur 4's criticality came five years after pouring first concrete and seven months ahead of schedule. Its twin–unit 3 was about a year behind it and

was connected to the grid in June 2006 with commercial operation in August, five months ahead of schedule. Tarapur 3 & 4 cost about $1200/kW, and are competitive with imported coal.

Future indigenous PHWR reactors will be 700 MWe gross (640 MWe net). The first four are being built at Kakrapar and Rajasthan. They are due on line by 2017 after 60 months construction from first concrete to criticality. Cost is quoted at about Rs 12,000 crore (120 billion rupees) each, or $1700/kW. Up to 40 per cent of the fuel they use will be slightly enriched uranium (SEU) – about 1.1% U-235, to achieve higher fuel burn-up – about 21,000 MWd/t instead of one third of this. Initially this fuel will be imported as SEU.

Kudankulam 1&2: Russia's Atomstroyexport is supplying the country's first large nuclear power plant, comprising two VVER-1000 (V-412) reactors, under a Russian-financed US$ 3 billion contract. A long-term credit facility covers about half the cost of the plant. The AES-92 units at Kudankulam in Tamil Nadu state have been built by NPCIL and also commissioned and operated by NPCIL under IAEA safeguards. The turbines are made by Leningrad Metal Works. Unlike other Atomstroyexport projects such as in Iran, there has been only about 80 Russian supervisory staff on the job. Construction started in March 2002.

Russia is supplying all the enriched fuel through the life of the plant, though India will reprocess it and keep the plutonium*. The first unit was due to start supplying power in March 2008 and go into commercial operation late in 2008, but this schedule has slipped by five years. In the latter part of 2011 and into 2012 completion and fuel loading was delayed by public protests, but in March 2012 the state government approved the plant's commissioning and said it would deal with any obstruction. Fuel loading was in September, and unit 1 started up in mid-July 2013, with unit 2 expected to do so late in 2014. Unit 1 was connected to the grid in October 2013 and is expected in commercial operation in August 2014 after reaching full power, with unit 2 following in March 2015 after late 2014 start-up. Each is 917 MWe net.



Kaiga 3 started up in February, was connected to the grid in April and went into commercial operation in May 2007. Unit 4 started up in November 2010 and was grid-connected in January 2011, but is about 30 months behind original schedule due to shortage of uranium. The Kaiga units are not under UN safeguards, so cannot use imported uranium. Rajasthan 5 started up in November 2009, using imported Russian fuel, and in December it was connected to the northern grid. RAPP 6 started up in January 2010 and was grid connected at the end of March. Both are now in commercial operation.

Under plans for the India-specific safeguards to be administered by the IAEA in relation to the civil-military separation plan, eight further reactors were to be safeguarded (beyond Tarapur 1&2, Rajasthan 1&2, and Kudankulam 1&2): Rajasthan 3&4 from 2010, Rajasthan 5&6 from 2008, Kakrapar 1&2 by 2012 and Narora 1&2 by 2014.

Nuclear industry developments in India beyond the trade restrictions

Following the Nuclear Suppliers' Group agreement, which was achieved in September 2008, the scope for supply of both reactors

India's nuclear power reactors under construction:

Reactor	Type	MWe gross, net, each	Project control	Construction start	Commercial operation due	Safeguards status
Kudankulam 2	PWR (VVER)	1000, 917	NPCIL	July 2002	3/2014	item-specific, Oct 2009
Kalpakkam PFBR	FBR	500, 470	Bhavini	Oct 2004	(9/2014 start-up) 2015	-
Kakrapar 3	PHWR	700, 630	NPCIL	Nov 2010	June 2015	
Kakrapar 4	PHWR	700, 630	NPCIL	March 2011	Dec 2015	
Rajasthan 7	PHWR	700, 630	NPCIL	July 2011	June 2016	
Rajasthan 8	PHWR	700, 630	NPCIL	Sept 2011	Dec 2016	
Total (6)		**4300 MWe gross**				

Rajasthan/RAPS also known as Rawatbhata

and fuel from suppliers in other countries opened up. Civil nuclear cooperation agreements have been signed with the USA, Russia, France, UK, South Korea and Canada, as well as Argentina, Kazakhstan, Mongolia and Namibia. On the basis of the

Power reactors planned or proposed

Reactor	Type	MWe gross, net, each	Project control	Construction start	Commercial operation due	Safeguards status
Kudankulam 3	Tamil Nadu	AES-92	1050	NPCIL	2014?	2019
Kudankulam 4	Tamil Nadu	AES-92	1050	NPCIL	2015?	2020
Jaitapur 1&2	Ratnagiri, Maharashtra	EPR x 2	1700	NPCIL	2015-16?	2018-19
Gorakhpur 1&2	Haryana (Fatehabad district)	PHWR x 2	700	NPCIL	June 2015	2021, 22
Chutka 1&2	Madhya Pradesh	PHWR x 2	700	NPCIL	6 & 12/2015	2020, 21
Bheempur 1&2	Madhya Pradesh	PHWR x 2	700	NPCIL	2014?	
Mahi Banswara 1&2	Rajasthan	PHWR x 2	700	NPCIL	by 2017	
Kaiga 5&6	Karnataka	PHWR x 2	700	NPCIL	by 2017	
Kovvada 1-2	Srikakulam, Andhra Pradesh	ESBWR x 2	1600	NPCIL	site works, 2016?	2019-20
Mithi Virdi 1-2	Bhavnagar, Gujarat	AP1000 x 2	1250	NPCIL	2016?	2019-20
Kudankulam 5&6	Tamil Nadu	AES 92 x 2	1050	NPCIL	?	2019-21
Kalpakkam 2&3	Tamil Nadu	FBR x 2	500	Bhavini	2014	2019-20
Subtotal planned		22 units	21,300 MWe			
Kudankulam 7&8	Tamil Nadu	PWR – AES 92 or AES-2006	1050-1200	NPCIL		
Gorakhpur 3&4	Haryana (Fatehabad district)	PHWR x 2	700	NPCIL	2019	
Rajouli, Nawada	Bihar	PHWR x 2	700	NPCIL		
?		PWR x 2	1000	NPCIL/NTPC		
Jaitapur 3&4	Ratnagiri, Maharashtra	PWR – EPR	1700	NPCIL	2016	2021-22
?	?	FBR x 2	500	Bhavini		2017
?		AHWR	300	NPCIL	2016-17	2022
Jaitapur 5&6	Ratnagiri, Maharashtra	PWR – EPR	1600	NPCIL		
Markandi (Pati Sonapur)	Orissa	PWR 6000 MWe				
Mithi Virdi 3&4	Bhavnagar, Gujarat	2 x AP1000	1250	NPCIL	2015	2020-21
Kovvada 3&4	Srikakulam, Andhra Pradesh	2 x ESBWR	1600	NPCIL		
Nizampatnam 1-6	Guntur, Andhra Pradesh	6x?	1400	NPCIL		
Haripur 1&2	West Bengal (but likely relocated, maybe to Orissa)	PWR x 4 VVER-1200	1200		2014?	2019-21
Haripur 3&4	West Bengal	PWR x 4 VVER1200	1200		2017	2022-23
Pulivendula	Kadapa, Andhra Pradesh	PWR? PHWR?	1000? 700?	NPCIL 51%, AP Genco 49%		
Chutka 3&4	Madhya Pradesh	PHWR x 2	1400	BHEL-NPCIL-GE?		
Mithi Virdi 5&6	Bhavnagar, Gujarat	AP1000 x 2	1250		2023-24	
Kovvada 5&6	Srikakulam, Andhra Pradesh	ESBWR x 2	1600			
Subtotal proposed		**approx 35**	**40,000 MWe approx**			

For WNA reactor table: first 22 units 'planned', next (estimated) 35 'proposed'.

2010 cooperation agreement with Canada, in April 2013 a bilateral safeguards agreement was signed between the Department of Atomic Energy (DAE) and the Canadian Nuclear Safety Commission, allowing trade in nuclear materials and technology for facilities, which are under IAEA safeguards. A similar agreement is being negotiated with Australia. Both will apply essentially to uranium supply.

Between 2010 and 2020, further construction is expected to take total gross capacity to 21,180 MWe. The nuclear capacity target is part of national energy policy. This planned increment includes those set out in the Table below including the initial 300 MWe Advanced Heavy Water Reactor (AHWR). The benchmark capital cost sanctioned by DAE for imported units is quoted at $1600 per kilowatt.

Early in 2012 NPCIL projections had the following additions to the 10.08 GWe anticipated in 2017 as 'possible': 4.2 GWe PHWR, 7.0 GWe PHWR (based on recycled U), 40 GWe LWR, 2.0 GWe FBR. In June 2012 NPCIL announced four new sites for twin PHWR units: at Gorakhpur/ Kumbariya near Fatehabad district in Haryana, at Banswada in Rajasthan, at Chutka in Mandla district and at Bheempur also in Madhya Pradesh. Initially these would add 2800 MWe, followed by a further 2800. Site work has started at Gorakhpur with Haryana state government support.

Nuclear Energy Parks

In line with past practice such as at the eight-unit Rajasthan nuclear plant, NPCIL intends to set up five further 'Nuclear Energy Parks', each with a capacity for up to eight new-generation reactors of 1,000 MWe, six reactors of 1600 MWe or simply 10,000 MWe at a single location. By 2032, 40-45 GWe would be provided from these five. NPCIL says it is confident of being able to start work by 2012 on at least four new reactors at all four sites designated for imported plants.

New energy parks are to be-

Kudankulam in Tamil Nadu: three more pairs of Russian VVER units, making 9200 MWe. Environmental approval has been given for the first four. A general framework agreement for construction of units 3 & 4 was to be signed in mid-2010, with equipment supply and service contracts soon after, but these were delayed on account of supplier liability questions, with India wanting the units to come under its 2010 vendor liability law. In July 2012 Russia agreed to $3.5 billion in export financing for units 3&4, to cover 85% of their cost. A further credit line of $800 million is available to cover fuel supplies. The credit lines carry interest at 4% pa and would be repayable over 14 years and 4 years respectively, from one year after the start of power generation. The Indian government said it expected to take up the credit offers to the value of $3.06 billion, about 53% of the $5.78 billion estimated total project cost.

Jaitapur (JNPP) in Maharashtra's Ratnagiri district: An EUR 7 billion framework agreement with Areva was signed in December 2010 for the first two EPR reactors, along with 25 years supply of fuel. Environmental approval has been given for these, and site work was to start in 2011 with a view to 2013 construction start. In July 2009 Areva submitted a bid to NPCIL to build the first two EPR units, which will have Alstom turbine-generators, accounting for about 30% of the total EUR 7 billion plant cost. The site will host six units, providing 9600 MWe. Areva now hopes to obtain export credit financing and sign a contract by the end of 2012, which would put the first two units on line in 2020 and 2021. In 2013 negotiations continued and the government said it expected the cost of the first two units to be 1,20,000 crore ($21 billion). France has agreed to a 25-year loan for the project at 4.8 per cent.

In March 2014 Areva and DAE with NPCIL were reported to have agreed on a power price of Rs 6.5/kWh (10.6 US cents, $106/MWh), though Areva had been aiming

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for Rs 9.18. However, in June 2014 it was reported that there was as yet no agreement and that DAE was adamant that the cost could not be more than Rs 6.5/kWh. Areva was holding out for the higher price.

Mithi Virdi in Gujarat's Bhavnagar district will host up to six Westinghouse AP1000 units built in three satages. NPCIL says it has initiated pre-project activities here, with groundbreaking in 2012. A preliminary environmental assessment for the whole project was completed in January 2013. State and local government and coastal zone clearances have been obtained. Westinghouse signed an agreement with NPCIL in June 2012 to launch negotiations for an early works agreement, which was expected in a few months. A preliminary commercial contract between NPCIL and Westinghouse was signed in September 2013 along with an agreement to carry out a two-year preliminary safety analysis for the project. NPCIL said that it "must lay emphasis on strong public acceptance outreach and project planning." The first stage of two units is due on line in 2019-20, the others to 2024.

Kovvada in Andhra Pradesh's northern coastal Srikakulam district will host six GE Hitachi ESBWR units. GE Hitachi said in June 2012 that it expected soon to complete an early works agreement with NPCIL to set terms for obtaining approval from the Government for the project. Site preparation is under way, and a preliminary environmental assessment is being prepared. In February 2014 NPCIL said it hoped to pour first concrete by early 2015 for the first 1594 MWe reactor. Compensation for land acquisition was being organised.

Haripur in West Bengal: to host four or six further Russian VVER-1200 units, making 4800 MWe. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012. However, strong local opposition led the West Bengal government to reject the proposal in August 2011, and change of site to Orissa state has been suggested.

Gorakhpur in the Fatehabad district of Haryana is a project with four indigenous 700 MWe PHWR units and the AEC had approved the state's proposal for the 2800 MWe Gorakhpur Haryana Anu Vidyut Pariyojna nuclear power plant. The inland northern state of Haryana is one of the country's most industrialized and has a demand of 8900 MWe, but currently generates less than 2000 MWe and imports 4000 MWe. The plant may be paid for by the state government or the Haryana Power Generation Corp. NPCIL has initiated pre-project activities here near the villages of Kumharia and Gorakhpur, and the official groundbreaking was in January 2014.

Bargi or Chuttka in inland Madhya Pradesh is also designated for two indigenous 700 MWe PHWR units. NPCIL says it has initiated pre-project activities here, with groundbreaking planned for 2012. A preliminary environmental assessment is being prepared.

At Markandi (Pati Sonapur) in Orissa there are plans for up to 6000 MWe of PWR capacity. Major industrial developments are planned in that area and Orissa was the first Indian state to privatise electricity generation and transmission. State demand is expected to reach 20 billion kWh/yr by 2010.

NTPC Plants

India's largest power company, National Thermal Power Corporation (NTPC) in 2007 proposed building a 2000 MWe nuclear power plant to be in operation by 2017. It would be the utility's first nuclear plant and also the first conventional nuclear plant not built by the government-owned NPCIL. This proposal became a joint venture set up in April 2010 with NPCIL holding 51%, and possibly extending to multiple projects utilising local and imported technology. One of the sites earmarked for a pair of 700 MWe PHWR units in Haryana or Madhya Pradesh may be allocated to the joint venture.

NTPC said it aimed by 2014 to have demonstrated progress in 'setting up nuclear power generation capacity', and that the initial 'planned nuclear portfolio of 2000 MWe by 2017' may be greater. However in 2012 it indicated a downgrading of its nuclear plans. NTPC, now 89.5% government-owned, planned to increase its total installed capacity from 30 GWe in about 2007 to 50 GWe by 2012 (72% of it coal) and 75 GWe by 2017. It is also forming joint ventures in heavy engineering.

Fast neutron reactors

Longer term, the AEC envisages its fast reactor program being 30 to 40 times bigger than the PHWR program, and initially at least, largely in the military sphere until its 'synchronised working' with the reprocessing plant is proven on an 18-24 month cycle. This will be linked with up to 40,000 MWe of light water reactor capacity, the used fuel feeding ten times that fast breeder capacity, thus 'deriving much larger benefit out of the external acquisition in terms of light water reactors and their associated fuel'. This 40 GWe of imported LWR multiplied to 400 GWe via FBR would complement 200-250 GWe based on the indigenous program of PHWR-FBR-AHWR (see Thorium cycle section below). Thus AEC is 'talking about 500 to 600 GWe nuclear over the next 50 years or so' in India, plus export opportunities.

In 2002 the regulatory authority issued approval to start construction of a 500 MWe prototype fast breeder reactor (PFBR) at Kalpakkam and this is now under construction by BHAVINI. It is expected to start up in September 2014, fuelled with uranium-plutonium oxide (the reactor-grade Pu being from its existing PHWRs). It will have a blanket with uranium and thorium to breed fissile plutonium and U-233 respectively, taking the thorium program to stage two, and setting the scene for eventual full utilisation of the country's abundant thorium to fuel reactors. Two more such 500 MWe fast reactors have been announced for construction at Kalpakkam, then four more at another site.

Heavy engineering in India

India's largest engineering group, Larsen & Toubro (L&T) announced in July 2008 that it was preparing to venture into international markets for supply of heavy engineering components for nuclear reactors. It formed a 20 billion rupee (US$ 463 million) venture with NPCIL to build a new plant for domestic and export nuclear

forgings at its Hazira, Surat coastal site in Gujarat state. This is now under construction. It will produce 600-tonne ingots in its steel melt shop and have a very large forging press to supply finished forgings for nuclear reactors, pressurizers and steam generators, and also heavy forgings for critical equipment in the hydrocarbon sector and for thermal power plants.

Areva signed an agreement with Bharat Forge in January 2009 to set up a joint venture in casting and forging nuclear components for both export and the domestic market, by 2012. BHEL expects to join this, and in June 2010 the UK's Sheffield Forgemasters became a technical partner with BHEL in a £30 million deal. The partners have shortlisted Dahej in Gujarat, and Krishnapatnam and Visakhapatnam in Andhra Pradesh as possible sites.

In August 2010 GE Hitachi Nuclear Energy (GEH) signed a preliminary agreement with India's Tata Consulting Engineers Ltd, to explore potential project design and workforce development opportunities in support of GEH's future nuclear projects in India – notably the proposals for six ESBWR units – and around the world.

In April 2012 Atomenergomash was negotiating with potential Indian partners on localization of some productions and design of equipment for nuclear power plants being built to the Russian technology both in India and other Asian countries such as Bangladesh and Vietnam. In 2010 a Memorandum of Understanding with Walchandnagar Industries Ltd (India) was signed by Atomenergomash.

Uranium resources and mining in India

India's uranium resources are modest, with 102,600 tonnes U as reasonably assured resources (RAR) and 37,200 tonnes as inferred resources in situ (to $260/kgU) at January 2011. In February 2012, 152,000 tU was claimed by DAE. Accordingly, India expects to import an increasing proportion of its uranium fuel needs. In 2013 it was importing about 40% of uranium requirements.

* 38% vein-type deposits, 12% sandstone (Meghalaya), 12% unconformity (Lambapur-Peddagattu in AP), and 37% other – 'strata-bound' (Cuddapah basin, including Tummalapalle). Exploration is carried out by the Atomic Minerals Directorate for Exploration and Research (AMD). Mining and processing of uranium is carried out by Uranium Corporation of India Ltd (UCIL), also a subsidiary of the Department of Atomic Energy (DAE), in Jharkhand near Calcutta. Common mills are near Jaduguda (2500 t/day) and Turamdih (3000 t/day, expanding to 4500 t/day). Jaduguda ore is reported to grade 0.05-0.06%U. All Jharkhand mines are underground except Banduhurang. Another mill is at Tummalapalle in AP, expanding from 3000 to 4500 t/day.

In 2005 and 2006 plans were announced to invest almost US$ 700 million to open further mines: in Jharkand at Banduhurang, Bagjata and Mohuldih; in Meghalaya at Domiasiat-Mawthabah (with a mill); and in Telengana at Lambapur-Peddagattu (with mill 50km away at Seripally), both in Nalgonda district.

In Jharkand, Banduhurang is India's first open cut mine and was commissioned in 2007. Bagjata is underground and was opened in December 2008, though there had been earlier small operations 1986-91. The Mohuldih underground mine was commissioned in April 2012. The new mill at Turamdih serving these mines was commissioned in 2008. It is 7 km from Mohuldih.

In Telengana, the new northern inland state subdivided from Andhra Pradesh in 2013, the Lambapur-Peddagattu project in Nalgonda district 110 km southeast of Hyderabad has environmental clearance for one open cut and three small underground mines (based on some 6000 tU resources at about 0.1%U) but faces local opposition. The central government had approved Rs 637 crore for the project, with processing to be at Seripally, 54 km away in Nalgonda district. In 2014 UCIL was preparing to approach the state government and renew its federal approvals for the project. A further deposit near Lambapur-Peddagattu is Koppunuru, in Guntur district of AP, now under evaluation, and Chitrial.

In August 2007 the government approved a new US$ 270 million underground mine and mill at Tummalapalle near Pulivendula in Kadapa district of Andhra Pradesh, at the south end of the Basin and 300 km south of Hyderabad. Its resources have been revised upwards by AMD to 53,6500 tU (Dec 2011) and its cost to Rs 19 billion ($430 million), and to the end of 2012 expenditure was Rs 11 billion ($202 million).

In Karnataka, UCIL is planning a small uranium mine in the Bhima basin at Gogiin Gulbarga area from 2014, after undertaking a feasibility study, and getting central

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government approval in mid-2011, state approval in November 2011 and explicit state support in June 2012. A portable mill is planned for Diggi or Saidpur nearby, using conventional alkaline leaching. Total cost is about $135 million. Resources are 4250 tU at 0.1% (seen as relatively high-grade) including 2600 tU reserves, sufficient for 15 years mine life, at 127 tU/yr, from fracture/ fault-controlled uranium mineralisation. UCIL plans also to utilise the uranium deposits in the Bhima belt from Sedam in Gulbarga to Muddebihal in Bijapur.

In Meghalaya, close to the Bangladesh border in the West Khasi Hills, the Domiasiat-Mawthabah mine project (near Nongbah-Jynrin) is in a high rainfall area and has also faced longstanding local opposition partly related to land acquisition issues but also fanned by a campaign of fearmongering. For this reason, and despite clear state government support in principle, UCIL does not yet have approval from the state government for the open cut mine at Kylleng-Pyndengsohiong-Mawthabah – KPM – (formerly known as Domiasiat) though pre-project development has been authorised on 422 ha.

However, federal environmental approval in December 2007 for a proposed uranium mine and processing plant here and for the Nongstin mine has been reported. There is sometimes violent opposition by NGOs to uranium mine development in the West Khasi Hills, including at KPM/ Domiasiat and Wakhyn, which have estimated resources of 9500 tU and 8000 tU respectively. Tyrnai is a smaller deposit in the area. The status and geography of all these is not known, beyond AMD being reported as saying that UCIL is 'unable to mine them because of socio-economic problems'. Mining is not expected before 2017.

Fracture/fault-controlled uranium mineralisation similar to that in Karnataka is reported in the 130 km long Rohil belt in Sikar district in Rajasthan, with 4800 tU identified so far.

AMD reports further uranium resources in Chattisgarh state (3380 tU), Himachal Pradesh (665 tU), Maharashtra (300 tU), and Uttar Pradesh (750 tU).

India's uranium mines and mills – existing and planned

State, district	Mine	Mill	Operating from	tU per year
Jharkhand	Jaduguda	Jaduguda	1967 (mine) 1968 (mill)	200 total from mill
	Bhatin	Jaduguda	1967	
	Narwapahar	Jaduguda	1995	
	Bagjata	Jaduguda	2008	
Jharkhand, East Singhbum dist.	Turamdih	Turamdih	2003 (u/g mine) 2008 (mill)	190 total from mill
	Banduhurang	Turamdih	2007 (open pit)	
	Mohuldih	Turamdih	2012	
Andhra Pradesh, Kadapa/ YSR district	Tummalapalle	Tummalapalle	2012	220 increasing to 330
Andhra Pradesh, Kadapa/ YSR district	Kanampalle	Kanampalle?	2017	
Telengana, Nalgonda dist.	Lambapur-Peddagattu	Seripally / Mallapuram	2016?	130
Karnataka, Gulbarga dist.	Gogi	Diggi/ Saidpur	2014	130
Meghalaya	Kylleng-Pyndeng-Sohiong-Mawthabah (KPM), (Domiasiat), Wakhyn	Mawthabah	2017 (open pit)	340

However, India has reasonably assured resources of 319,000 tonnes of thorium – about 13% of the world total, and these are intended to fuel its nuclear power program longer-term (see herein).

Uranium imports

By December 2008, Russia's Rosatom and Areva from France had contracted to supply uranium for power generation, while Kazakhstan, Brazil and South Africa were preparing to do so. The Russian agreement was to provide fuel for PHWRs as well as the two small Tarapur reactors, the Areva agreement was to supply 300 tU.

In February 2009 the actual Russian contract was signed with TVEL to supply 2000 tonnes of natural uranium fuel pellets for PHWRs over ten years, costing $780 million, and 58 tonnes of low-enriched fuel pellets for the Tarapur reactors. The Areva shipment arrived in June 2009. RAPS 2 became the first PHWR to be fuelled with imported uranium, followed by units 5 & 6 there.

In January 2009 NPCIL signed a memorandum of understanding with Kazatomprom for supply of 2100 tonnes of uranium concentrate over six years and a feasibility study on building Indian PHWR reactors in Kazakhstan. NPCIL said that it represented 'a mutual commitment to begin thorough discussions on long-term strategic relationship.' Under this agreement, 300 tonnes of natural uranium was to come from Kazakhstan in the 2010-11 year. Another 210 t would come from Russia. A further agreement in April 2011 covered 2100 tonnes by 2014. In March 2013 both countries agreed to extend the civil nuclear cooperation agreement past 2014.

In July 2010 the Minister for Science & Technology reported that India had received 868 tU from France, Russia & Kazakhstan in the year to date: 300 tU natural uranium concentrate from Areva, 58 tU as enriched UO2 pellets from Areva, 210 tU as natural uranium oxide pellets from TVEL and 300 tU as natural uranium from Kazatomprom.

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As of August 2010 the DAE said that seven reactors (1400 MWe) were using imported fuel and working at full power, nine reactors (2630 MWe) used domestic uranium.

Australian Assurance of Uranium Supply

Australia's Prime Minister Tony Abbott is set to sign a deal with India that will allow the export of uranium to the country.

There are concerns that some of the uranium will be used to produce nuclear weapons in India. It's not likely, though the possibility remains. Critics have also pointed to poor regulation and the lack of transparency in India's nuclear industry.

But Australia can play a bigger role in improving India's nuclear industry than just exporting uranium. It can also provide expertise in risk governance and communication. It is still unclear how much uranium India will get, but Australia currently ships 500 tonnes a year to China, a country India seeks to catch up with.

Speculation that Australia seeks to make up for its ban on uranium exports to Russia is also unlikely. Less than 100 tonnes of uranium has been shipped to Russia since the 2007 bilateral agreement between the two countries. But concerns over India's nuclear weapons programme are also over-stated. India may not be a signatory to the NPT Non-Proliferation Treaty, but it is a member of a number of other multi-lateral organisations including the World Association of Nuclear Operators and International Atomic Energy Agency.

Uranium fuel cycle

India's main nuclear fuel cycle complex is at Hyderabad in Telengana, established in 1971. It plans to set up three more to serve the planned expansion of nuclear power and bring relevant activities under international safeguards. The first of the three will be at Kota in Rajasthan, supplying fuel for the 700 MWe PHWRs at Rawatbhata and Kakrapar by 2016. Capacity will be 500 t/yr plus 65 t of zirconium cladding. The second new complex will supply fuel to ten 700 MWe PHWRs planned in Haryana, Karnataka and Madhya Pradesh, but its site is not announced. The third will be at Chitradurga in the south of Karnataka state on a site with other science-based establishments, starting with a BARC enrichment plant, to supply fuel for light water reactors (see herein).

DAE's Rare Materials Plant (RMP) at Ratnahalli near Mysore operates a very small centrifuge enrichment plant – insufficient even for the Tarapur reactors –, primarily for military purposes including submarine fuel, but also supplying research reactors. It started up about 1992 as a unit of BARC, and is apparently being expanded to some 25,000 SWU/yr. A conversion plant is also being built there at RMP.

DAE in 2011 announced that it would build an industrial-scale centrifuge complex, the Special Material Enrichment Facility (SMEF), in Chitradurga district, Karnataka, also as part of BARC and having both civil and naval purposes. Construction had not started in mid 2014. India's enrichment plants are not under international safeguards. Some centrifuge R&D is undertaken by BARC at Trombay.

Fuel fabrication at up to 900 t/yr is by DAE's Nuclear Fuel Complex in Hyderabad. DAE is setting up a second Nuclear Fuel Complex (NFC) – a PHWR fuel plant at Kota in Rajasthan, next to the Rawatbhata power plant – to serve the larger new reactors and those in northern India. It will have 500 t/yr capacity, from 2017, and government approval of Rs 2400 crore (24 billion rupees, $393 million) for this was in March 2014. Each 700 MWe reactor is said to need 125 t/yr of fuel. A third fuel fabrication plant is planned, with 1250 t/yr capacity, in Telengana, Rajasthan or Madhya Pradesh. The company is proposing joint ventures with US, French and Russian companies to produce fuel for those reactors.

Reprocessing: Used fuel from the civil PHWRs is reprocessed by Bhabha Atomic Research Centre (BARC) at Trombay, Tarapur and Kalpakkam to extract reactor-grade plutonium for use in the fast breeder reactors. A new Kalpakkam plant of some 100 t/yr commissioned in 1998 in connection with Indira Gandhi Centre for Atomic Research (IGCAR) supplemented small plants at each site, and this is being extended to reprocess FBTR carbide fuel. Apart from this all reprocessing uses the Purex process. A new 100 t/yr plant at Tarapur was opened in January 2011, and further capacity is being built at Kalpakkam.

The Power Reactor Thoria Reprocessing Facility (PRTRF) was under construction at BARC in October 2013, and is designed to cope with high gamma levels from U-232. The recovered U-233 will be used in the AHWR Critical Facility.

Thorium fuel cycle development in India

The long-term goal of India's nuclear program has been to develop an advanced heavy-water thorium cycle. The first stage of this employs the PHWRs fuelled by natural uranium, and light water reactors, which produce plutonium incidentally to their prime purpose of electricity generation.

Stage 2 uses fast neutron reactors burning the plutonium with the blanket around the core having uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as U-233.

Then in stage 3, Advanced Heavy Water Reactors (AHWRs) will burn thorium-plutonium fuels in such a manner that breeds U-233 which can eventually be used as a self-sustaining fissile driver for a fleet of breeding AHWRs. An alternative stage 3 is molten salt breeder reactors (MSBR), which are firming up as an option for eventual large-scale deployment. See R&D section under IGCAR. So far about one tonne of thorium oxide fuel has been irradiated experimentally in PHWR reactors and has reprocessed and some of this has been reprocessed, according to BARC. A reprocessing centre for thorium fuels is being set up at Kalpakkam in connection with Indira Gandhi Centre for Atomic Research (IGCAR).

In October 2013 BARC said that premature deployment of thorium would lead to sub-optimal use of indigenous energy resources, and that it would be necessary to build up a significant amount of fissile material before launching the thorium cycle in a big way for the third stage (though the demonstration AHWR should be operating by 2022). Incorporation of thorium in the blankets

of metal-fuelled fast breeder reactors would be after significant FBR capacity was operating. Hence thorium-based reactor deployment is expected to be "beyond 2070". Surplus U-233 from FBR blankets could be used in HTRs including molten salt breeder reactors. See R&D section under IGCAR.

Radioactive Waste Management in India

In October 2013 BARC stressed the role of accelerator-driven subcritical molten salt reactor systems (ADS) burning minor actinides arising from partitioning of PHWR and LWR Purex output. These working in tandem would address waste issues more effectively and safely than using critical fast reactors to burn minor actinides. Pyroprocessing would treat these wastes.

Radioactive wastes from the nuclear reactors and reprocessing plants are treated and stored at each site. Waste immobilisation plants (WIP) are in operation at Tarapur and Trombay and another vitrification plant was commissioned by BARC in 2013 at Kalpakkam for wastes from reprocessing Madras (MAPS) used fuel. The WIPs use borosilicate glass, as in Europe.

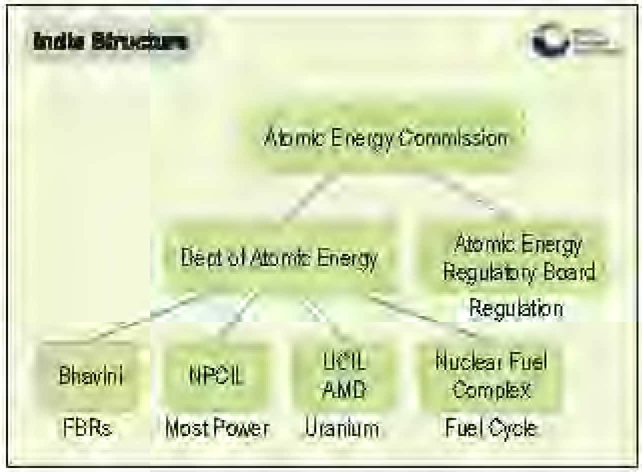
Research on final disposal of high-level and long-lived wastes in a geological repository is in progress at BARC.

Regulation and safety

The Atomic Energy Commission (AEC) was established in 1948 under the Atomic Energy Act as a policy body. Then in 1954 the Department of Atomic Energy (DAE) was set up to encompass research, technology development and commercial reactor operation. The current Atomic Energy Act is 1962, and it permits only government-owned enterprises to be involved in nuclear power.

The DAE includes NPCIL, Uranium Corporation of India Ltd (UCIL, mining and processing), Atomic Minerals Directorate for Exploration and Research (AMD, exploration), Electronics Corporation of India Ltd (reactor control and instrumentation) and BHAVINI* (for setting up fast reactors). The DAE also controls the Heavy Water Board for production of heavy water and the Nuclear Fuel Complex for fuel and component manufacture.

* Bhartiya Nabhikiya Vidyut Nigam Ltd.



The Atomic Energy Regulatory Board (AERB) was formed in 1983 and comes under the AEC but is independent of DAE. It is responsible for the regulation and licensing of all nuclear facilities, and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants. However, it is not an independent statutory authority, and its 1995 report on a safety assessment of DAE's plants and facilities was reportedly shelved by the AEC. In April 2011 the government announced that it would legislate to set up a new independent and autonomous Nuclear Regulatory Authority of India that will subsume the AERB, and that previous safety assessments of Indian plants would be made public.

In August 2012 a parliamentary report from the Comptroller and Auditor General (CAG) on the AERB pointed out serious organisational flaws and numerous failings relative to international norms. The most fundamental issue highlighted by the report was the unsatisfactory legal status and authority of the AERB. Despite India's international commitments, awareness of best practice and internal expert recommendations, the report said, "the legal status of AERB continued to be that of an authority subordinate to the central government, with powers delegated to it by the latter." The Nuclear Safety Regulatory Authority Bill was drawn up in response to events at Fukushima and aims to establish several new regulatory bodies.

A new senior Council of Nuclear Safety (CNS) chaired by the prime minister will oversee and review policies on radiation safety, nuclear safety and other connected matters. It will include various government ministers, with the cabinet secretary and head of the Indian Atomic Energy Commission, plus government-nominated "eminent experts".

The second major body to be established is the Nuclear Safety Regulatory Authority (NSRA) and will be responsible for ensuring radiation safety and nuclear safety in all civilian sector activities. The NSRA will take over the functions of the existing AERB. The government expected to introduce the bill in a 2013 session of parliament, but it was still pending in mid-2014. The AEC is preparing to invite the International Atomic Energy Agency's (IAEA) Integrated Regulatory Review Service (IRRS) to examine the new regulatory system, which will get statutory status after the passage of the Nuclear Safety Regulatory Authority (NSRA) Bill by Parliament. In 2012 an IAEA Operational Safety Review Team (OSART) reviewed the Rajasthan nuclear power plant, notably units 3&4, and reported favourably.

In April 2012 India's AERB joined the OECD Nuclear Energy Agency's Multinational Design Evaluation Program (MDEP) as its eleventh member, and first new member since the program's inception. The NEA said that it would be actively involved in the Codes and Standards Working Group, the Digital Instrumentation and Control Working Group, the Vendor Inspection Co-operation Working Group and, "eventually, one of the specific reactor design working groups." MDEP was launched in 2006 by the US NRC and France's ASN with the aim of coordinating national nuclear regulatory reviews of new power reactor designs.

NPCIL is an active participant in the programmes of the World Association of Nuclear Operators (WANO).

Nuclear liability

The Civil Liability for Nuclear Damage Act related to third party liability was passed by both houses of parliament in August 2010. This is framed and was debated in the context of strong national awareness of the Bhopal disaster in 1984, probably the world's worst industrial accident. (A Union Carbide (51% US-owned) chemical plant in the central Madhya Pradesh state released a deadly mix of methyl isocyanate and other gases due to operator error and poor plant design, killing some 15,000 people and badly affecting some 100,000 others. The company paid out some US$ 1 billion in compensation – widely considered inadequate.)

The 2010 Act places responsibility for any nuclear accident with the operator, as is standard internationally, and limits total liability to 300 million SDR (about US$ 450 million) 'or such higher amount that the Central Government may specify by notification'. Operator liability is capped at Rs 1500 crore (15 billion rupees, about US$ 285 million) or such higher amount that the Central Government may notify, beyond which the Central Government is liable.

In October 2013 it was reported that DAE had set up two committees to find a middle path, with a more "scientific and rational" approach to the issue. "The committees will assess the probabilistic safety analysis to identify a model that will assess probabilities of particular equipment or a set of system to fail in a manner that can lead to an accident. Based on the study there would be a rational basis for working out an actuarial approval to decide on the quantum of liability," according to DAE. The main committee comprises representatives from BARC, IGCAR and NPCIL (2). At the end of October 2013 the Planning Commission said that under the 2010 law the domestic plant operator could limit the amount as well as duration of the liability that accrues to foreign suppliers, so that the liability is limited and therefore insurable. However this interpretation is viewed with some skepticism.

In March 2014 the government reached some sort of agreement with Russia to provide liability insurance through the government-owned General Insurance Corporation of India (GIC), though the actual arrangements for a nuclear liability insurance product had yet to be worked out. GIC apparently discussed reinsurance with international companies, but without any agreement, due partly to the unlimited provisions of the 2010 Act, so was unable to proceed. In April 2014 DAE approached the Ministry of Finance to urge the setting up of a nuclear insurance pool as a high priority, since insurance risks for third party liability alone amount to Rs 1500 crore. NIAEP-ASE, contracted to supply Kudankulam units 3&4, has insisted on the government providing reinsurance.

Indo-Japan Nuclear Deal

The importance of an Indo-Japanese nuclear deal stems from these considerations. The hurdles to this deal emanate from Japan's insistence that no reprocessing of spent fuel would be done in India, and that in the event of a nuclear test by India, the components supplied would be immediately returned to Japan. On the other hand, India considers it should get the same regime applicable to nuclear weapons states (NWS) under the Nuclear Non-Proliferation Treaty, which it has not signed but has unilaterally undertaken to respect. The conditions imposed on India are more stringent than those on countries China, the US and other NWS under the NPT. Japan was one of the countries that reacted strongly to India's nuclear tests in 1974 and 1998. It was pressured by the Bush administration to agree to the waiver given to India by the nuclear suppliers group (NSG). It has refrained from developing nuclear weapons though it certainly has the technical and financial capacity to do so.

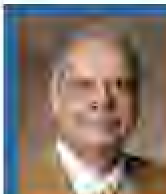
Unfair stipulation

The condition that spent fuel be returned for reprocessing is unacceptable to India as it goes beyond what was agreed with the US and other countries. It would also be difficult and unsafe to transport highly radioactive spent fuel across thousands of kilometres to the fuel supplying country. The other condition that components should be returned in the event of a nuclear test is also impossible to implement for the reason that it involves shutting down a reactor, and dismantling and shipping back massive reactor vessel components which would be highly radioactive. What would be the consequences of Japan continuing to insist on these conditions? It would result in India facing delays in implementing the PWR programme using imported reactors and fuel. India would then be compelled to step up its PHWR and FBR programmes, and also its enrichment and reprocessing capability to compensate for the shortfall in nuclear power generation. These are programmes where India is fully self-sufficient, and is not obliged to declare them as civilian and subject to IAEA inspections.

The question that Japanese negotiators must face is this: Do they wish India to enlarge its indigenous unsafeguarded PHWR and FBR programmes (and possibly its strategic programmes), or do they wish India to enlarge its IAEA-safeguarded PWR programmes that are dependent on fuel imports? Should they give China more favourable treatment than India in matters of civil nuclear cooperation?

If the answer is no to both questions, then they need to show more flexibility in reaching a reasonable agreement with India, along the lines of civil nuclear agreements India has signed with the US, France, the UK, South Korea, Canada and other countries. India has other options that it will and must follow in case the PWR programme is delayed due to the lack of a civil agreement with Japan.

Profile



Dr P K Vasudeva

Professor Vasudeva was Colonel, turned Economist, is PhD in 'World Trade Organization'. He had been Founder Director: Atmanand Jain Institute of Management and Technology (KU), Past President: Chandigarh Management Association; Principal-Director: College of Communication and Management, Bharatiya Vidya Bhavan, and Senior Professor: ICFAI Business School, Chandigarh. He regularly writes for Business and Financial papers - Indian and Foreign Journals and Columnist, American Chronicle.

Solar Energy

- A Rising Future in Power Sector

Energy is the lifetime economy in this world. It can be preferred as energy currency, as it holds a very significant part in determining the economic growth of a country. The spurt in inventions in 19th century of Industrial Revolution was unprecedented in many ways, with the inventions involving the use of natural resources like coal and oil for generation of electricity.

Jyotsana Verma, Anuradha Tomar, and Lakshita Duseja

But in the quest to sustain galloping economic activity, the dependence on coal and oil has soared at a phenomenal rate over the years. Resulting in damaging the environment by evolving carbon dioxide and other harmful gases. Due to this, hunt of finding an alternative source of energy is taken in account which not only provide energy security in the face of acute shortage but also cater sustainability and environment resources. Renewable energy is the energy derived from the natural resources which are abundant in nature like wind, solar, biomass etc. They are inexhaustible and clean providing pollution free generation.

India started on the mission of renewable energy in the early 70's as in 1980 it was the first country to set up a ministry of non conventional energy resources. Today it is the world's largest renewable program that sweeps across remote villages, buzzing metros & huge industries. With the success in power sector from early 70's to 21 stcentury, the renewable energy capacity of India as estimated in 2014 has evaluted as 31,833.01 MW from the total over all capacity of India is 2,37,742.94 MW. From which more than half of the 2,632 MW solar PV capacity as of 31st March 2014 is attributed to the Solar policies.

Solar energy: Photovoltaic Generation, Controlling & distribution

With growing demand of clean energy, the Solar energy sector is growing fast. Solar

> *Solar PV panel is a semiconductor device that converts radiation energy to electrical energy through the photoelectric effect. When light strikes the PV material, it "rips off" electrons from the atoms they were bound to, leaving positive ions behind*

energy is generated through Photovoltaic cells arranged in panels. The solar PV panel is a semiconductor device that converts radiation energy to electrical energy through the photoelectric effect. When light strikes the PV material, it "rips off" electrons from the atoms they were bound to, leaving positive ions behind

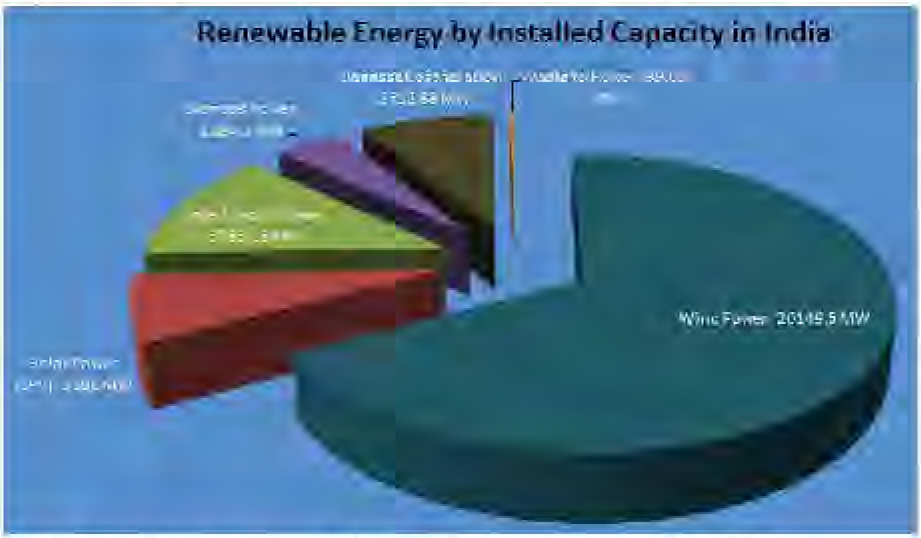


Fig. 1: Sources of renewable energy in India as of December 2013, MNRE India

and allowing some electrons to flow, producing both an electrical current and a voltage drop & therefore electrical power. New Technologies have introduced in the field of PV cells.

The coating a layer of ploy crystalline by DYE sensitized solar cells so that PV cells can absorb more radiation of sunlight to prompt electricity.

Photovoltaic (PV) devices fail to capture about 20% of the incident energy, with sub-band-gap photons being not effectively harvested. Upconversion (UC) of such sub-band-gap photons can minimize these losses. Photon upconversion (UC) is a process in which the sequential absorption of two or more photons leads to the emission of light at shorter wavelength than the excitation wavelength and this upconversion is done by using bifacial n type solar cell.

A typical PV-cell is about 5 cm in diameter, 1mm thick, and has a potential difference of about 0.5 volt between its terminals. The maximum current is determined by the rate at which photons release conduction electrons. Usually 40 or 50 PV-cells are connected in series to make a module with a total voltage of 20-25 volts. To increase the output current it is common to connect several such modules in parallel. The output produced from the PV cells is direct current (DC) which can be used in small applications e.g. domestic solar systems. To convert this DC current into AC current, inverter is required in the circuitry e.g. to feed into the grid. But its efficiency depend upon many conditions like temperature, angle of PV panels to the radiations from sun and shading. These condition not only affect the efficiency but also reduces the output power.

So first starting with the correct orientation or angle of inclination to take full advantage of the Sun's energy. Solar panels should also be inclined at an angle as close to the area's latitude as possible to absorb the maximum amount of energy year-round. A different orientation and/or inclination could be used if you want to maximize energy production for the morning or afternoon, and/or the summer or winter.

The most efficient angle is 28^{O} for Delhi. This is the graph which tells the efficiency at two different tilt angle of solar panel in the month of October. We can see that in this graph that efficiency at 28^{O} at left hand side is greater than 18^{O} at right hand side. Reading have been taken in Solar Lab in TERI.

Now another important factor that can reduce the efficiency is 'Shading' or 'Partial shading' caused by trees or buildings. In a PV module if one of the cell is getting shaded, power production can be significantly reduced.

Due to shading, PV cells act like a load because of its small resistance which is one of the major drawback of PV cells. Instead of supplying, now it is consuming energy from source. To eliminate this phenomenon bypass diodes are used to provide a path to the passing current and prevent a cell to act as a load. But the situation get worst when PV cells works under partially shaded condition because in this case half shaded portion is acting like load and unshaded is acting like source. Due to which

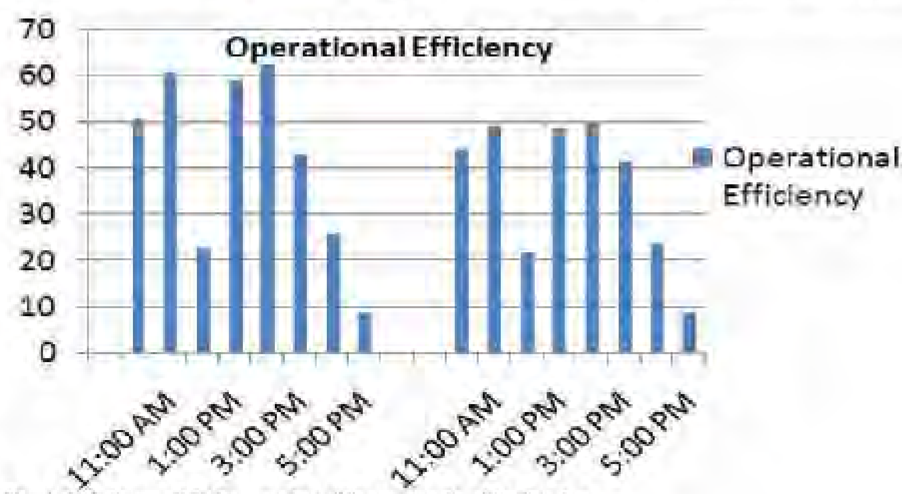


Fig. 2: Efficiency of Solar panel at different angle of inclination

voltage will vary with different PV cells effecting its efficiency.

For every module, there is a point on its PV curve that is higher than any other point, at a specific voltage. This is called the "Maximum Power Point" and this point is an important because the solar inverter is designed to seek out this point at its best in order to deliver the maximum power to the grid . If several solar modules are connected in series where equal current is passing then output voltage will be the sum of individual cell's voltage, but if one of the solar modules gets shaded by some reason then output current and voltage of that particular module will not be as per rating. Due to which current will flow less than the rated current that also affects other panels connected in series. So to flow equal current in series connection, we have to connect an optimizing device which would help to generate same current as other module are generating such that in series, the current will remain same.

There are two methods of MPPT (Maximum Power Point Tracker)

CMPPT: Centralized MPPT, In Perturb and Observe method, the controller adjusts the voltage by a small amount from the array and measures power which helps in maintaining the MPPT of that shaded module.

DMPPT: In DMPPT enhanced PV module number of DC-DC converter is connected across each PV module. In order to extract maximum amount of power from a PV module under partial shading conditions, use of sub-module integrated converters (subMIC) is very necessary, principle of a subMIC is "Voltage or Power equalization". In VEP, voltage across each substring is made equal, or power delivered by each substring is made equal. This is possible by the injection or extraction of current in PV module by the operation of subMIC (sub-module integrated converter).

Talking about the distribution, Smart grid are introduced to make system more efficient & easily controllable. It is a two way communication system from source to sink which passes through renewable sources, transmission and distribution. It has real time monitoring and power system control which helps in reducing the losses (which are non technical losses in India and due to that India losses money), demand response, DSM, power quality management etc. and it brings sustainability and best quality. As we know we can only get solar energy during day and this condition can't be control. But the Smart grid controls this condition by providing energy at night as well.

Micro grid is also an important term which isolates itself and its properties are same as smart grid except that it has ability to operate independently and centralized from source. It can be useful for critical loads in emergency when energy can't be transferred from smart grid. Like hospitals have their own Micro grid of renewable sources and it resynchronized itself when the utility grid returns to normal functioning. Smart grid and micro grid have ability to reduce peak loads and to provide better system management for on-site decentralized generation. It has advanced so much that in future it will be able to sell their generation back to the utilities from whom they buy the power .This will help utilities to reduce the need for massive investments in building new high-voltage transmission lines to carry renewable power from far-off plants to towns and cities. In 12th plan of MNRE they have decide to introduce the power grid of about 43GW from wind and solar source of energy.

Now let's take a glance to the boom of Solar sector in India

The average solar energy incident on India varies between 4kwh to 7kwh/m^2. In solar energy sector, some large projects have been proposed, and a 35,000 km area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 GW. Welspun energy is largest solar energy power plant in Madhya Pradesh which is generating 150 MW which cost 8.05 Rs per unit and Welspun company have also signed new project to built solar plant in Punjab of 130MW capacity. In terms of multi generated projects, Gujarat has been a leader in solar energy by producing 220 MW (approx 2/3 of 900 MW Photovoltaic in the country). Maharashtra is also planning to build 150 MW solar.

In large part of India electricity is still a distant dream but change is underway. Government of India is planning to plant a world largest solar energy plant in Rajasthan which will generate 4000 MW (6000 million units) energy the project is also called as 'Ultra-Mega Green Solar Power Project' is being to built in Sambhar lake. They have planned to finish its first phase which is to produce 1000 MW in the end of 2016 and that will cost to consumer Rs 5.50 for each unit which is not very costly. This energy is being used in 55 villages in Sundarban in which they need electricity because of unavailability of electricity there. Happy sunshine is nature's gift to the city & so people had bought it right into their homes. In Bangalore (Karnataka)they have plan to prompt 200 MW which can be deploy in street lights and it is having around 50% of solar water heaters of countries market which is saving around 300 MW of energy every day.

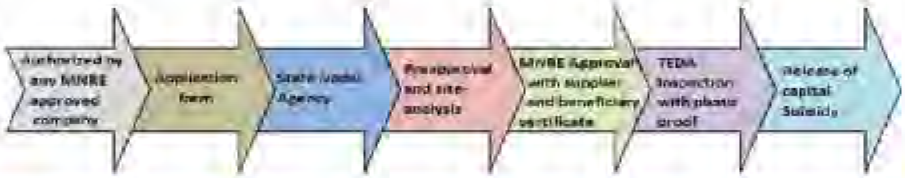
Incentives and Policies taken by government to help the Solar Revolution

Incentives are to encourage the renewable sources in India. The Central Government has given various incentives on setting up the renewable energy power project which includes exemption from customs and excise duties on specific goods required for setting up the renewable energy projects.

Generation Based Incentives (GBI): in this incentive they have made scheme to promote projects under independent power producers to attract foreign investors. 80% accelerated depreciation income tax benefits on renewable energy products including solar.Tax and Fiscal incentives: Almost all revenue and capital expenditures will be allowed as a tax . some of the state governments have provided the incentives in the form of a VAT at a reduced rate (5%) whereas the other states levy a VAT of 15%. Given the vast variety of tax and fiscal incentives available, one needs to quantify the tax cost and explore the structuring options before investing in the solar sector.

JNNSM: Various tax exemptions, capital subsidies and incentives are available for several components and sub-components of solar energy value chain. JNNSM promotes the assembly of solar modules after import of cells which is free from import taxes.

MNRE: It has issued a proposal to the Ministry of Finance for the introduction of tax incentives for homeowners who install solar panels on their rooftops. It also announces 30%



Schemes	Mission
Jawaharlal Nehru National Solar Mission (JNNSM)	Promoting off grid at favorable conditions, Assembly of solar modules free of import axes and also promoting solar home lightning
Policies supporting Grid-interactive Renewable Power National Rural Electrification Policy 2006	To provide electricity in Reliable rates, minimum lifeline consumption of 1 unit and For villages off grid solutions are considering
Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY)	Permitting stand alone systems rural electrification ,bulk power purchase, management of local distribution .It could be financed 90% capital subsidy.
Policies supporting Off-grid renewable power Remote Village Electrification Programme	In this scheme MNRE decided to provide electricity in villages and till now 6446 /8722 villages sanctioned have been completed and 1705 villages under progress. And out of 2533 hamlets sanctioned, 1587 have been completed.
Special Area Demonstration Project Programme	To promote use of renewable energy at prominent places like park, zoos, museum etc.
Renewable Energy Supply for Rural Areas	This scheme was framed with the objective of developing and demonstrating commercially viable models for de-centralized energy supply in rural areas from renewable sources.
Renewable Energy for Urban, Industrial and Commercial Applications	Renewable Energy for Urban, Industrial and Commercial Applications
IREDA (GBI)	(IREDA) has selected 78 projects with a total capacity of about 98 MW for which the Ministry will provide GBI of Rs. 12.41 per kWh to the State utilities when they directly purchase solar power from the project developers.

capital subsidy for all solar power plants.

Following with the incentives, there are some of the government policies that are made by MNRE to facilitate it to the public in coming year. Below is the table that depicts the upcoming schemes and their mission which help Solar power to establish more further to provide electricity even to the remote villages.

"Managing energy costs can yield positive results irrespective of the financial health of the organization or the state economy!!"

Energy management refers to the process of monitoring, controlling & conserving energy within the boundaries of an entity of an organization. Energy demand management is also known as demand side management and it has made to manage the energy demand in India by encouraging consumers to use energy at off peak hours. Because using energy at peak hours could be expected to reduce the need of investors or power plants for meeting peal demands. Several solutions have made to minimize problems and to manage energy demand in our country i.e

Fig. 3: Source: Analyst Report – Deutche Bank, KPMG in India Analysis 2013

Smart metering: microprocessor are used to provide two way communication that helps consumers & suppliers to manage the electricity usage in efficient manner . With the help of the information provided by such smart meters the power companies will have the capability to set up real time pricing systems for electricity.

Virtual power plants: it allows discrete energy resources to access the energy market i.e. to feed the grid constantly.

Consumption and supply management: In this management system, consumer can save cost by changing energy products like example is Kerala in which they have replaced conventional bulbs by CFL and by doing this they have actually saved 350MW energy. And also deferring the non essential loads when there are peak shortage. Battery charging and power back up are available with the mobile towers. Solar water heating systems have helped in demand side management of electricity in various cities & towns during peak hours. Thus smart grid plays very important role in demand management by controlling voltage according to load.

Where in Supply side management in case of power, Renewable energy and Open access procurement of power are increasingly become favorable options for the companies. The Solar power installed capacity has been substantial growth in India in the last three years with over

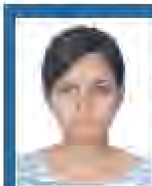
2000 MW installed until October 2013 - over 70% of these are concentrated in Gujarat and Rajasthan. Although comparing with other sources of power present, the variable cost of power from diesel based generation is upward of INR 14 per unit, where as solar power currently is less than INR 7.5 per unit. While Open access procurement not only enhance supply but also reliability with the reduced cost.

The short term power exchange market is gaining popularity amongst the industrial segments which have energy costs typically in the range of 7-15% as a proportion of overall costs.

Conclusion

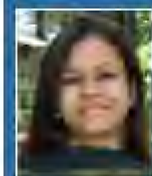
India is on verge to Solar Revolution in coming time. We have discussed in this article about the new technologies in solar module to improve its efficiency i.e. coating layer of DYE sensitized solar cell and Upconversion and the shading problem of solar module with its possible preventions which can help a solar module to generate maximum power in case of partial shading by putting optimize distributor MPPT. All this new technologies and policies made by MNRE are used to promote renewable energy in India and still there are many research going on this energy to make a healthy environment. Today when the India is at a threshold of new era of progress, this is a good reason to believe that India will stride ahead with a green heart having environmental friendly and clean energy.

Profile



Jyotsana Verma

pursuing her BTech from Northern India Engineering College affiliated to Guru Gobind Singh Indraprastha University (GGSIPU). Her area of interest is renewable energy, wireless power transmission.



Dr Anuradha Tomar

BE in Electronics Instrumentation & Control Engineering with "Honours" from Institute of Engineering & Technology, Alwar (Raj) is MTech in Power System from National Institute of Technology, Hamirpur (H.P.) with honours and PhD in 2014. Currently, she is working as Assistant Professor in Northern India Engineering College, New Delhi. She is a Member of IEEE, ISTE, IEI, IETE.

Lakshita Duseja

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Hydro Power
Development in India

Although hydropower has been used since ancient times to grind floor and to perform other tasks, the world's first hydro electrical power generation started in England in 1881. Now worldwide, hydropower plants produce about 24% of world's electricity. World's total hydropower capacity is 675,000 MW, the energy equivalent of 3.6 billion barrels of oil.

Mayadhar Swain

More than 150 countries around the world generate hydropower. Hydropower has many advantages over other conventional sources of power and so it is the main attractive source for developers. It is cheap and no fuel is required. It uses water as its fuel by running it through turbines and discharging it to a water body downstream. In this process, the water remains unpolluted and the hydro power generation process is therefore by definition non-consumptive. It is a renewable, economical, man-polluting and environmentally benign source of power. But it has also some other difficulties and limitations for development.

Hydropower Potential of India

The total hydro potential in the country as assessed by CEA during 1978-87, excluding small hydro plant (SHP) and pumped storage schemes (PSS) comes to 146401 MW. It is 148701 MW if we include SHP. India ranks fifth in the world in terms of available hydro potential. Basin-wise hydro potential in the country is given in Table 1.

Basin	Hydropower Potential (MW)
Indus	33832
Ganges	20711
Rivers of Central India	4152
Rivers of South India flowing westwards	9430
Rivers of South India flowing eastwards	14511
Brahmaputra	66065
Total	148701

Table 1: Basin-wise Hydropower Potential in India
Source: Central Electricity Authority

Development and Growth of Hydro Power in India

The first hydro power plant in India was established near Darjeeling in West Bengal in 1897. The power station, named Sidrapong has 130 KW capacity and uses the water potential of Teesta River. It is still in operation.

The first major hydro power station was set up at Shiva Samudram on river Cauvery with initial capacity of 7.92 MW in the years 1902. It was increased in stages and the final installed capacity became 47 MW by 1938. The power house was established to supply electricity to Kolar Gold mine, 25 KM from the power plant.

In Northern India, Mohora hydro power plant with 4 MW capacity was installed on the river Jhelum in 1905 in Jammu and Kashmir. After that, Tata power have great contribution in hydropower. They established 3 major hydropower plants in the Western Ghats in Maharashtra

In Northern India, Mohora hydro power plant with 4 MW capacity was installed on the river Jhelum in 1905 in Jammu and Kashmir. After that, Tata power have great contribution in hydropower. They established 3 major hydropower plants in the Western Ghats in Maharashtra. These are Khopoli (5x8 MW) in 1915, Bhivpuri (4x12 MW) during 1922-25 and Bhira (5x18 MW) in 1927.

From 1932 till independence, some medium size power plants were established. Some of the noted hydro plants commissioned during this period are:

- Jagindernagar (48 MW) in 1932 in Punjab state (now in Himachal Pradesh)
- Pykara (14 MW) in 1932 in Madras state (now Tamilnadu)
- Mettur (40 MW) in 1937 in Madras State (now Tamilnadhu)
- Papanasam (14 MW) in 1944 in Travancore-Cochin state (now in Kerala)
- Pallivassal in United Province (now in Uttrakhanda).

Total installed hydro capacity at the time of independence was 508 MW. After independence some large multipurpose projects were under taken. These are Bhakra (604 MW) in Punjab, Rihand (300 MW) in Uttar Pradesh, Gandhi Sagar (115 MW) in Madhya Pradesh, Koyana (540 MW) in Maharashtra, Sharavati (891 MW) in Karnataka, Periyar (140 MW) in Tamilnadu and Hirakud (308 MW) in Odisha. A host of other smaller capacity projects were also undertaken and by 1960, the hydropower capacity of the country touched 1920 MW.

More than 100 years after installation of first hydropower plant in India, now we have 186 hydro power stations with station capacity above 25 MW (having 646 generating units) with a total installed capacity of about 39893 MW including PSSs and projects with an installed capacity of 13242 MW are under execution as 31 December 2013.

Initially, the hydropower equipment were being imported. But now we have our own manufacturing units in BHEL. The size of the units has also grown keeping in pace with the development of technology. The largest unit size now in operation is 250 MW (Tehri Power Plant). In near future 300 MW and 342 MW units will be added. The Siang Lower project envisages 5 units of 342 MW and 1 unit of 40 MW unit. These two are being developed in private sector.

Hydro power capacity of the country is increasing rapidly from independence till now. After independence private sector was not allowed in hydro power sector. But after 1992 they were allowed and their contribution is also praise worthy.

Growth of hydro power in different decades is shown in Table 2.

Sl. No.	Period	Capacity added in the period	Total capacity at end of period	Average yearly growth
1.	1947-1960	1188	1614	91
2.	1961-1970	4948	6502	495
3.	1971-1980	5426	11988	543
4.	1981-1990	6078	18066	608
5.	1991-2000	6039	24105	604
6.	2001-2010	10549	34654	1055
Capacity as on July, 2014			40,798 (including PSS)	

Table 2: Growth of Hydro Capacity (in MW)
Source: Ministry of Power

Share of Hydro Power

Hydro Power Plant has the advantage of quick start. It takes hardly 10 to 15 minutes for a hydro plant to be connected to grid, where as a thermal power unit takes about 6 hours from cold start till connection to the grid. In case of grid failure, it is the hydro power units that are first connected to the grid. Due to this reason, hydro power plants are generally used as peak power plants and thermal units are used as base power plants. For flexibility and stability point of view of the grid, the share of hydro power should ideally be 40%.

In our country, share of hydro power is gradually decreasing, reaching 17% till the end of 2013. It is because the easily accessible locations for hydropower plants are already developed and also there is lot of oppositions form public now for hydro power plants due to rehabilitation and resettlement problem. Further, one thermal power plant can be commissioned within 4 years of start, where as it takes 8 to 10 years for a hydro power plant. The share of hydro power in India in different years is shown in Table 3.

As on	Total capacity (MW)	Hydro capacity (MW)	Hydro share (%)
31.12.47	1362	508	37.30
31.12.50	1713	560	32.69
31.03.56 (End of 1st Plan)	2886	1061	36.76
31.03.61 (End of 2nd Plan)	4653	1917	41.19
31.03.66 (End of 3rd Plan)	9027	4124	45.68
31.03.69 (End of three Annual Plans)	12957	5907	45.58
31.03.74 (End of 4th Plan)	16664	6966	41.80
31.03.79 (End of 5th Plan)	26680	10833	40.60
31.03.80 (End of annual Plan)	28448	11384	40.01
31.03.85 (End of 6th Plan)	42585	14460	33.96
31.03.90 (End of 7th Plan)	63636	18307	28.77
31.03.92 (End of two annual Plans)	69065	19194	27.79
31.03.97 (End of 8th Plan)	85795	21658	25.24
31.03.02 (End of 9th Plan)	105046	26269	25.00
31.03.07 (End of 10th Plan)	132329	34654	26.18
31.03.12 (End of 11th Plan)	199877	38990	19.50

Table 3: Growth and Share of Hydro Power (Source: Ministry of Power)

Some Facts on Hydro Power Development

Some interesting facts about development hydro power in India are given in Table 4.

First Hydro Power Station	1897, Sidrapong (130 KW) in Darjeeling
First Major Hydro Station	1902, Sivasamudram (4500 KW) in Mysore
First Private Hydro station	1915, Tata-Khopoli (32 MW) in Maharashtra
Largest Tunnel Diameter	15 m Srisailam (770 MW) in Andhra Pradesh
Longest Tunnel	27 KM, Nathpa Jhakri (1500 MW) in H.P.
Highest Dam	206 m Tehri (1000 MW), Uttarakhand
Highest Head	1,026 m, Pykara (59.2MW), Tamil Nadu
Hydro Capacity in 1947	508 MW
Largest unit size	250 MW (Koyna – IV, Naptha Jhakri & Tehri)
Maximum station capacity	1500 MW (Naptha Jhakri Himachal Pradesh)
Present Hydro Capacity	40798 MW (As on 31 July 2014)

Table 4: Hydro Power Development, Some Facts

Small Hydro Power

In India, a power station having capacity of 25 MW or less is termed as small hydro power. As per Ministry of New and Renewable Energy (MNRE), the potential of SHP in the country has been estimated as 19749 MW. For this, 6474 sites have been identified. These potentials are in natural streams, canal falls and dam toes. The majority of sites, around 50 percent are concentrated in states like Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Arunachal Pradesh. The states of Maharashtra, Chhatisgarh, Karnataka and Kerala also have sizeable potential. As on 31 July 2014, installed capacity of SHPs is 3826 MW. Further SHPs of capacity of 895 MW are under construction. Potential and installed capacity of SHPs in India are given in Table 5. MNRE has aimed to achieve 7000 MW of total installed capacity of SHPs by the end of 12th Plan.

State	Estimated Potential (MW)	Installed Capacity (MW)
Karnataka	4141	1032
Himachal Pradesh	2398	639
Maharashtra	794	327
Andhra Pradesh	978	221
Uttarakhand	1708	175
Kerala	704	158
Punjab	441	156
Jammu & Kashmir	1431	148
Tamilnadu	660	123
Arunachal Pradesh	1341	104
West Bengal	396	98
Madhya Pradesh	820	86
Bihar	223	71
Haryana	110	70
Odisha	295	65
Chhatisgarh	1107	52
Others	2202	248
All India	19749	3803

Table 5: Potential and Installed capacity of SHP in India (as on 31.03.2014) Source: MNRE

Pumped Storage Scheme

The PSS is mainly used for load balancing and making the electricity grid operational system economical, efficient and reliable. It is the only economic and flexible means of storing large amount of excess energy. It can be installed where sufficient surplus off peak-load power is available. Because it draws power from grid to pump water from lower reservoir to upper reservoir during off – peak period and generates power during peak demand period. Although it is a net consumer of electricity, for a reliable grid particularly during peak load period it is required. It is seen that in our country there is about 10 to 35% of shortage during peak-load period in different states of the country.

At present nine PSSs are in operation in India (See Table 6). Besides this, Tehri-II project (1000 MW) and Koyna Left Bank (80 MW) are under construction. Two more projects namely Sharavathy (900 MW) and Kali (600 MW) in Karnataka have been cleared for construction. There are a number of favorable sites in India for PSS. CEA has identified 56 such sites with a total installation possibility of 94,000 MW.

Sl. No.	Station	State	Installed Capacity (in MW)
1	Kadamparai	Tamil Nadu	400
2	Bhira	Maharashtra	150
3	Ghatghar	Maharashtra	250
4	Sardar Sarovar	Gujarat	1,200
5	Kadana	Gujarat	240
6	Srisailam. L.B.	Andhra Pradesh	900
7	Purulia	West Bengal	900
8	Panchet Hill	Jharkhand	40
9	Nagarjuna Sagar	Andhra Pradesh	705.60
	Total		**4,785.60**

Table 6: Pumped Storage Power Stations in India

Conclusion

India have now developed (operation and under construction) 33.27% of its total hydro potential and share of hydropower in its total capacity is only 17%. This is not a good sign in terms of country's energy needs and also grid stability. Government of India has brought out a new hydro policy in 2008 to give impetus to growth of hydropower. The main thrusts of the policy are inducing private investment in the sector, harnessing the balance hydro potential, improving resettlement & rehabilitation and facilitating financial viability. A capacity addition of 90,000 MW from all sources has been assessed during 12th Plan, which includes 30,000 MW of hydro power.

Profile

Mayadhar Swain

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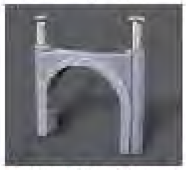
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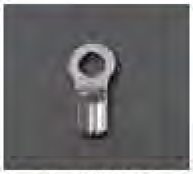
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Development of Wind Power Project

Wind energy has become a prominent source in the present global energy picture. Wind is free, clean, eco-friendly form of energy and inexhaustible energy source. In our country various windy regions have been identified, having potential for generating electricity. One of the prime conditions for utilizing wind energy is knowledge of site/location and meteorological data.

Dr H Naganagouda

This article presents a methodology for the "Selection of Wind farm site and Wind Turbine /Electric Generator (WTG/ WEG)" based on the Technical and Economical analysis. The average power output of a WEG is very important parameter for an economical viability of the project. Selection of Wind Turbine Generator determines the total energy production & total income and also it demands good knowledge of wind related characteristics such as site selection and energy output. The annual Energy generation using power curve of the WTG, annual capacity factor (ACF), annual capacity utilization factor (CUF) and power density has been calculated for technical analysis. The Economical analysis such as "Cost of generation, Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR), Levellised Cost of Generation and Life Cycle Cost i.e. Pay Back Period has been calculated for Economical viability assessment of the project.

In view of the technical considerations and economical analysis, the results are analyzed and recommended to implement the wind power project at a specific windy site with an optimum WEG.

The prime objective of electric energy generation is to satisfy customer needs economically with emphasis on safety, reliability and quality. Most of the conventional energy generation technologies employ exhaustible sources like coal, oil and nuclear fuel. Recent events have posed a setback to the sector of conventional power generation, the reasons for which include higher fuel prices, societal pressures to conserve resources, environmental awareness, increase in production cost, and concern for safety related to certain technology (like the Nuclear). Hence in present day energy scenario, for meeting the ever-increasing energy demand, efforts have come into focus with a view to develop new generation technologies. The major goals of these approaches are to have reduced environmental damages, conservation of energy, exhaustible sources and increased safety. In this context during the past few years' renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques. The worldwide interest in harnessing and utilizing of renewable energy sources is primarily attributed to;

- The increasing environmental concerns over issues such as quality, global warming and acid rain.
- The realization of enormous needs of electrification of remote rural areas in developing countries where renewable and Non-Conventional energy sources are adequately available.
- Other factor in favour of Renewable Energy source of energy is least impact on environment, ecology and ideally suited for de-centralized variety of applications.

Renewable source of energy has least impact on environment, ecology and is ideally suited for decentralized variety of applications. Wind is free, clean, Eco-friendly form of energy and inexhaustible energy source. In our country various windy regions have been identified, having potential for generating electricity.

There are many different types of WEG'S commercially available in the market for power generation. Therefore, it is necessary to select a best suited WEG'S for a particular site, regardless of turbine size.

In case of conventional source of energy, we have controllable input, so the amount of power developed can be easily estimated. But for wind power the position is different, neither the performance of the wind did indicate by its efficiency as a power unit, nor its annual output of energy can easily be measured or predicted in advance for two reasons, viz. (i) Wind speed and the power input to the machine and (ii) The annual output of energy is influenced greatly by the precise location (micro siting) of the wind Electric generator installation in a given area, for which, the general value of the annual mean wind speed may be known. The general objective in designing a WECS is to adequately match the wind energy conversion system (WECS) capabilities to the load requirements with a minimum cost of the system to the consumer. The production of electricity by a WEG at a specific site depends on many factors. These factors include the mean wind speed of the site and more importantly, the characteristics of the WEG itself, especially the hub height, cut in (UC), rated (UR) and furling (UF) wind speed of the machine. In addition to above, it demands good knowledge of wind related characteristics such as,

- Location /or selection of site,
- Air density and wind speed velocity,
- Influence of height of installation above ground,
- choice of wind turbine generator,

- Grid connected or stand alone for remote areas. i.e. Utilization of power
- Wind power density and annual energy generation.

Why Wind Energy?

The wind power projects have many distinct advantages over the conventional power generating plants:

- Wind power project is of modular type
- The gestation period of wind power project is less than 6-8 months
- The investor is assured of realizing returns on investment in a short duration
- The operation & maintenance costs are very low
- There is no recurring input fuel cost as wind is freely available
- The cost of generation per unit is cheap and almost negligible after the pay back period
- The man power required is very few and therefore, there is no question of any labour problem
- The power generated can be easily wheeled for captive power requirement or can be sold to State Electricity Board's (SEB) / third parties. Therefore there is no marketing problem
- Wind electric generators (WEG's) are environment friendly and free from pollution
- Power can be banked with SEB for a period of 6 months to 1 year.

Wind Data

Renewable source of energy has least impact on environment, ecology and is ideally suited for decentralized variety of applications. Wind is free, clean, Eco-friendly form of energy and inexhaustible energy source. In our country various windy regions have been identified, having potential for generating electricity. One of the prime conditions for utilizing wind energy is knowledge of site/ location and meteorological data.

In case of conventional source of energy, we have controllable input, so the amount of power developed can be easily estimated even for solar plants, considering a little amount variation in narrow limits invariably the output obtained from a single solar piece can be calculated. But for wind power the position is different, neither the performance of the wind indicated by its efficiency as a power unit, nor its annual output of energy can easily be measured or predicted in advance for two reasons, viz.

- Wind speed and therefore the power input of the machine and
- The annual output of energy is influenced greatly by the precise location (micro - siting) of the wind turbine generator installation in a given area for which, the general value of the annual mean wind speed may be known.

In addition to above, it demands good knowledge of wind related characteristics such as,

- Location for selection of site,
- Air density and wind speed velocity,
- Influence of height of installation above ground,
- Choice of wind turbine generator,
- Grid connected or stand alone for remote areas. i.e. Utilization of power
- Wind power density and annual energy generation.

Wind Solar Hybrid System

Present day energy scenario, for meeting the ever-increasing energy demand, efforts have come into focus with a view to develop new generation technologies. The major goals of these approaches are to have reduced environmental damages, conservation of energy, exhaustible sources and increased safety. In this context during the past few years renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques.

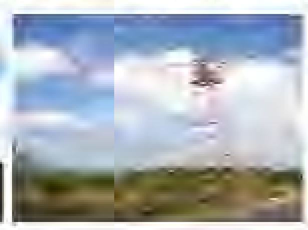
Majority of the population in our country is located in the village and a large number of the villages are still not served by National Grid due to cost involved for laying of the Transmission line, in relation to their power consumption, is prohibition in some cases because of the distance involved, quantity of life, availability of cold storage for Medicine, TV coverage and other aspects are adversely affected in such cases.

Conventional sources of energy have a long generation period, draw heavily on exhaustible deposits and adversely affect ecological balance. New and Renewable sources of energy are not only economically viable but do not suffer from any of the above disadvantages.

Standalone wind with Solar Photovoltaic is known as the best hybrid combination of all renewable energy systems and suitable for most of the applications taking care of seasonal changes. They also compliment each other during lean periods, example additional energy production by wind during monsoon months compensate less output generated by solar. Similarly, post winter months when wind is dull, SPV takes over.

The hybrid system provides more consistent year-round renewable energy production. These systems are modular and can be expanded easily. A hybrid renewable energy system utilizes two or more energy production methods, usually solar and wind power. Hybrid wind & solar systems provide more consistent year-round performance and reduce the need for back-up generation.

The major advantage of solar / wind hybrid system is that when solar and wind power production are used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced as there is less reliance on one method of power production. Often, when there is no sun, there is plenty of wind. The packaged systems are ideally suited to remote homes, schools, clinics and other off-grid applications. They can also be retrofitted to existing diesel -generator systems to save on high fuel costs, minimize noise and provide up to 24-hour power. The standard hybrid systems available to meet power needs. We can also tailor a system to suit should you have a smaller or larger power requirement.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System Design and Objectives

The general objective in designing a WECS is to adequately match the WECS capabilities to the load requirements of the consumer, at a minimum cost of the system to the consumer. In order to accomplish this, the designer will need to know the following types of questions about the system.

- Power requirements,
- Wind availability,
- Type and size of WECS required,
- Cost of energy produced,
- WECS viability,
- System characteristics,
- System requirement,
- Evaluation criteria,
- Design optimization,
- Economic viability and
- Prospects of cost reduction.

Project Study

Stage – 1 Project Study and Analysis

- Wind Energy Site Study
- Micrositing of Wind Electric Generators (WEG)
- Planning and Layout of Wind Farms
- Evaluation of WEG Performance
- Evaluation of Techno – Economic Analysis

Stage – 2 Selection of Wind Farm Type

- The Size of the Wind Farm
- Type of Output
- Type of Wind Electric Generator (WEG)
- Utilisation of Electric Output
- Wind Energy Conversion System (Wecs)
- Methods of Generating Synchronous Power

Stage – 3 Conclusion

- Choose / Install the Optimum WEG
- Forecast Accurate Power Output
- Choose the Best Wind Farm Location / Site
- Overcome the Project Uncertainities

Evaluation criteria

In most WECS applications, the objective will be to design the system to minimize the life-cycle cost of the system and the price of the energy produced by the system. Criteria that should be used in determining the viability of a WECS include.

- The energy pay back time, (i.e., the time required for the WECS to generate sufficient energy from the wind to equal the amount of energy expended in manufacturing the WECS as well as operating and maintaining it during this energy payback period.)
- The energy gain of the system (i.e., the amount of energy generated by the WECS during its life time, divided by the amount of Energy required to manufacture, operate, and maintain it during its life time) and
- Various possible environmental, aesthetic, legal, financial, institutional, or other types of constraints that might have an impact on the public acceptability of the WECS or its acceptability to public utilities, industries, farm owners, home owners or other possible users.

Wind Energy Conversion System

1.	Connection -	Grid Connected / Stand Alone Mode
2.	Regulation	1. Pitch Regulation 2. Stall Regulation
3.	Speed	1. Fixed 2. Variable
4.	Excitation	1. Grid Excitation 2. Self Excitation
5.	Generator	1. Induction (Asynchronous) 2. Synchronous 3. Dual Winding / Dual Generator
6.	Problems	1. Voltage Fluctuatation 2. Generation of Harmonics / Sub-Harmonics Associated with some Pulasting Torque 3. Varying Nature of Wind Speed
7.	Parameters Independent Dependent	1. Wind Speed 2. Voltage 3. Frequency 1. Current 2. Active Power 3. Reactive Power 4. Power Factor 5. Efficiency
8.	Utility Grid	Wecs Connected to a Utility Grid Requires 1. Study of Various Available Options 2. Prediction of System Performance Under • Normal Condition • Unbalanced Condition • Single Phasing • Various Abnormal Conditions.
9.	Analysis	1. Technical 2. Economical

Design optimization

The principal factors that affect the economic viability of wind powered system are the

- Availability of wind power at a given site,
- The investment,
- The operation and maintenance (O&M) costs of the wind power system,
- The expected lifetimes of the systems,
- The interest rate on investment capital and
- The price of competing forms of energy.

Economic viability

For economic viability of the wind power project, the important deciding parameters are follows.

- Pay back period should be less than loan repayment period,
- Net present value (NPV) > 1,
- Internal rate of return (IRR) > 1,
- Benefit cost ratio (BCR) > 1.,
- Cost of generation for 1st year,
- Cost of generation for 10 years average,
- Cost of generation for 20 years average,
- Levellised cost of generation and
- Levellised cost of selling price.


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Year 1989-90 Months	Monthly Hours Hours	Air Density KG/CU.M	Wind Speed M/S At Height		Power Law Index	WEIBULL Factor K	WEIBULL Factor C	Energy Content KWH/SQ.M	Power Density W/SQ.M
			20 M	30 M					
JAN	744	1.082	4.20	4.61	0.229	2	5.16	55.46	74.54
FEB	672	1.066	4.42	4.84	0.226	2.8	5.43	57.20	85.12
MAR	744	1.054	4.65	5.08	0.216	2.8	5.69	72.05	96.84
APR	720	1.045	4.78	5.21	0.213	2.5	5.84	74.92	104.06
MAY	744	1.045	6.12	6.63	0.198	3	7.43	159.36	214.20
JUN	720	1.055	7.35	7.99	0.205	3.7	8.94	271.70	377.36
JUL	744	1.057	8.14	8.83	0.199	3.9	9.89	380.23	511.07
AUG	744	1.058	7.49	8.12	0.198	4.3	9.09	295.84	397.64
SEP	720	1.058	5.77	6.34	0.234	3.4	7.10	136.61	189.73
OCT	744	1.061	4.25	4.73	0.264	2.9	5.30	58.60	78.76
NOV	720	1.068	4.78	5.29	0.251	2	5.93	80.10	111.26
DEC	744	1.075	4.82	5.30	0.235	3.1	5.93	83.59	112.36
		Average	5.56	6.08	0.22			862.63	98.04

Table 1: Wind Speed Data of Site - A Wind Project

Prospects of cost reduction

It is possible to reduce the cost of the wind power project by considering the following aspects.

- Reduce the capital cost of the system,
- Locate the system in a good wind regime to maximize the plant factor,
- Engineering the system to be simple and reliable, so that O & M cost can be reduced,
- Design the system for long life,
- Borrow money at the lowest possible interest rate and
- Taking all advantages of the incentives, subsidy and tax credits made available by the various agencies of the Government.

Technical Analysis

Assessment of Energy Output

The annual output of energy is influenced greatly by the precise location (micro siting) of the WEG'S installation in a given area, for which, the general value of the annual mean wind speed may be known. In addition to above, it demands good knowledge of wind related characteristics such as, Location /or selection of site, Air density and wind speed velocity, Influence of height of installation above ground, Choice of WEG'S, Grid connected or stand-alone for remote areas. i.e., Utilization of power, Wind power density and annual energy generation.

Site Selection

Success or failure of a WEG'S to deliver the power depends critically on mean wind velocity available at the site / location depends on;

- Wind availability i.e., Wind velocity,
- Influence of height of installation above ground,
- Effect of wind gusting,
- Sites with annual mean wind speed of 20 km/hour with a hub height of 30 m and power density of 150 watts /sq.m. is considered to be economically viable,
- Two (2) years wind speed studies are required for assessment of wind power potential,
- Siting in a flat and
- Siting on non-flat terrain i.e., At ridge, its advantages are: a. The ridge acts as a huge tower, b. It increases the available power and c. Avoids undesirable effects of cooling near the ground.

Assessment of Wind Availability - Wind Data

Selection of a windy site for wind power generation requires meteorological data as a base for installation of WEG's for power generation. The uses of meteorological data are

- As a basis for which surveys indicating the areas where the highest wind speeds are to be found.,
- As an indication of the direction of prevailing wind knowledge. This is important in selecting wind power sites,
- As a measure of the constancy or variability of the annual mean wind speeds from year to year,
- As an indication of the annual wind regime for an area from values by monthly mean wind speeds and
- As a measure of derived variations in wind speeds to be expected at different seasons of the year and
- Pre-Requisite - Detailed Wind Data Consisting of:

a. Month wise frequency distribution for power estimation.

b. Wind rose data for the micro siting of WEG'S.

c. Time series data for the analysis of peak-time contribution of energy to the grid.

In this article, 2 years and 4 years wind speed data of 2 sites have been used. Wind speed measurements constitute the fundamental information for assessment of wind energy availability. Wind speed is summarized using statistical methods as shown in table – 1 and table – 2 for a site – A and site – B respectively.

Micro Sitting of Wind Electric Generators (WEG's)

In addition to the above the micro siting of

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			20 M	30 M					
JAN	744	1.074	5.59	5.81	0.10	3.06	6.51	110.20	148.11
FEB	672	1.066	5.72	5.95	0.10	2.38	6.66	105.90	157.59
MAR	744	1.054	5.19	5.26	0.03	1.98	5.89	79.96	107.47
APR	720	1.045	6.67	6.59	-0.03	2.04	7.38	151.22	210.03
MAY	744	1.045	9.99	9.79	-0.05	2.68	10.97	512.58	688.96
JUN	720	1.055	10.7	10.58	-0.03	3.91	11.85	632.77	878.85
JUL	744	1.057	12.2	12.06	-0.03	3.80	13.51	969.40	1302.96
AUG	744	1.058	11.37	11.17	-0.04	7.48	12.51	770.65	1035.82
SEP	720	1.058	7.59	7.44	-0.05	2.54	8.33	220.55	306.31
OCT	744	1.061	5.1	5.15	0.03	2.21	5.77	75.89	102.00
NOV	720	1.068	7.42	7.76	0.11	4.15	8.69	252.60	350.84
DEC	744	1.075	6.14	6.37	0.09	2.76	7.14	145.48	195.54
		Average	7.81	7.83	0.14			2013.60	228.52

Table 2: Wind Speed Data of Site - B Wind Project

land also influences the above-mentioned factors. These factors are:

- A visual inspection of the land gives an idea of the topography of the terrain. Locate the WEG'S at the highest level of the land (i.e., Utilizing natural hub height) in the region of least turbulence.
- Main direction of the wind flow at the proposed location is determined by magnetic compass and wind vane. Map of wind roses gives the frequency distribution of main wind flow.
- Minimum distance criteria of 2D and 5D distance between two turbines in adjacent rows and along the same row respectively.

Estimation of Wind Energy Potential

Wind Speed Extrapolation

Wind speed data are usually recorded in the data loggers at a height of 10 m and 20 m, wind speed increases with height as per power law equation. Since the WEG's is several meters height, the mean wind speed at a particular height will be greater than mean wind speed at 10 or 20 m height. Therefore, to obtain mean wind speed at a WEG's hub height, the mean wind speed has to be projected / upgraded to the hub height.

Methods of Calculation

Estimation of wind energy potential based on the following methods:

- Based on wind data of a specific site using frequency distribution.
- Based on type of Wind energy generator (WEG).
- Based on Weibull factors of the wind data and WEG's characteristics.

Selection of Optimum Wind Energy Generator (WEG)

There are many different types of WEG commercially available in the market for power generation. The size of the WEG range from 1 kW to as large as 3 MW or more. Therefore, it is necessary to select a best-suited WEG for a particular site, regardless of turbine size. To choose the optimum WEG size for the site, 10 different rating / capacity of commercially available WEG were used in this study.

The production of electricity by a WEG at a specific site depends on many factors. These factors include the mean wind speed of the site and more importantly, the characteristics of the WEG itself, especially the hub height, cut in (UC), rated (UR) and furling (UF) wind speed of the machine.

In this section a methodology for the selection of the optimum WEG for a specific site is developed. The selection criteria is based on the comparative statement of annual energy made by the calculated values of the annual Energy generation using power curve of the WEG, annual capacity factor (ACF), annual capacity utilization factor (CUF).

The power density is calculated from the wind data obtained over a period of few years to select an optimum WEG using weibull parameters. These are the factor considered for utilization of a wind energy at a given time and site.

Technical Evaluation

Based on the comparative statement from table- 1, 2, 3 (A) and 3 (B) for annual energy output using power curve of the WEG's and frequency distribution & Weibull parameters of a particular site wind data, it is concluded that

- The annual mean wind speed and power density are higher side for site – B. Hence the site - B is windy site and suitable for development of wind farm compared with site- A.
- The WEG – 10 is optimum one and suitable for installation at site – A and also WEG – 9 is optimum one and suitable for installation at site - B.
- The Energy Generation, ACF, PLF AND UCF from the high capacity/rating of WEG's is on lower side compared to low capacity/ rating WEG's. Hence the high capacity/ rating WEG's are not viable at these sites.

Economical Analysis

This section provides the total cost of installation as also the cost per unit of energy

Sl. No.	WEG Make	Rating KW	As per Power Curve			ACF PLF %	As per [WF] WEIBULL Factor		As per Energy Density W/SQ.M	CUF %	Pavr KW	Average Annual Energy		For 5 MW WF Method Cor. FCT=0.875 MU
			KWH Per 1 WTG	MWH Per MW	For 5 MW Annual Energy-MU		MWH/ MW	KWH/ SQ.M				KWH	MWH/ MW	
1	WEG-1	500	2047428	4095	20.47	51.91	596	12805	1436	6.74	33.68	295016	590	2.61
2	WEG-2	250	1125362	4501	22.51	57.07	735	14340	1608	8.33	20.83	182464	730	3.22
3	WEG-3	600	2504571	4174	20.87	52.92	759	14340	1608	8.60	51.58	451853	753	3.32
4	WEG-4	225	969975	4311	21.55	54.65	1026	1780	202	11.67	26.26	230032	1022	4.49
5	WEG-5	500	2274956	4550	22.75	57.68	1208	11872	1332	13.70	68.49	600012	1200	5.29
6	WEG-6	250	975361	3901	19.51	49.46	837	1726	196	9.52	23.81	208539	834	3.66
7	WEG-7	225	945063	4200	21.00	53.25	938	1726	196	10.67	24.00	210246	934	4.10
8	WEG-8	250	981731	3927	19.63	49.78	870	1625	185	9.89	24.74	216699	867	3.81
9	WEG-9	230	1075440	4676	23.38	59.28	2143	1938	220	24.39	56.10	491419	2137	9.38
10	WEG-10	230	1161985	5052	25.26	64.05	2525	2328	265	28.74	66.10	579023	2517	11.05

Table 3[A]: Comparative Statement of Annual Energy for Site - A

Sl. No.	WEG Make	Rating KW	As per Power Curve			ACF PLF %	As per [WF] WEIBULL Factor		As per Energy Density W/SQ.M	CUF %	Pavr KW	Average Annual Energy		For 5 MW WF Method Cor. FCT=0.875 MU
			KWH Per 1 WTG	MWH Per MW	For 5 MW Annual Energy-MU		MWH/ MW	KWH/ SQ.M				KWH	MWH/ MW	
1	WEG-1	500	1928016	3856	19.28	48.88	1195	3492	397	13.60	67.99	595613	1191	5.23
2	WEG-2	250	1082837	4331	21.66	54.91	1462	3481	395	16.65	41.62	364580	1458	6.40
3	WEG-3	600	2375015	3958	19.79	50.18	1566	3481	395	17.83	106.97	937032	1562	6.85
4	WEG-4	225	955006	4244	21.22	53.81	2239	4020	456	25.48	57.32	502161	2232	9.80
5	WEG-5	500	2179288	4359	21.79	55.26	2491	3500	397	28.36	141.81	1242284	2485	10.91
6	WEG-6	250	959513	3838	19.19	48.66	1954	4027	457	22.24	55.59	486979	1948	8.55
7	WEG-7	225	935700	4159	20.79	52.72	2188	4027	457	24.89	56.01	490666	2181	9.58
8	WEG-8	250	977066	3908	19.54	49.55	2192	4042	459	24.93	62.32	545934	2184	9.59
9	WEG-9	230	1047280	4553	22.77	57.73	3501	3775	429	39.85	91.66	802931	3491	15.32
10	WEG-10	230	1099919	4782	23.91	60.63	2951	2837	322	33.61	77.31	677193	2944	12.92

Table 3[B]: Comparative Statement of Annual Energy for Site - B

delivered to grid. The methodology to calculate cost of energy is similar to the one adopted by Central Electricity Authority (CEA) and includes cost of all capital equipment's, electrical and civil works. For Economic viability of the project, the following factors are considered while locating the Wind Energy Generators (WEG's).

- Sites with annual mean wind speed of 20 km/hour with a hub height of 30 m and power density of 150 watts /sq.m. is considered to be economically viable.
- Nearest load center and nearest distance from grid.
- Availability of basic infrastructure such as Roads and institutional aspects they are a) Cost of the land, b) Safety considerations & c) Meteorological hazards.

Project Details

Installed Capacity = 5 MW

Project Cost Rs. = 2000 Lakhs

Interest Rate = 14%

Construction Period = 6 Months

Depreciation Amount = 0.9 *Project Cost X Depreciation Factor.@ 4.5%

Return and Provision = 3.5%

Loan Repayment = 10 Years

Moratorium Period = 1 Year

Operation and Maintainance = 1% of the Project Cost

Calculations and Statements

- Loan Repayment Schedule and Phasing Expenditure Statement:
- Cost of Generation per KWH:
- Income and Expenditure Statement:
- Cash Flow Statement:
- Net Present Value (NPV):
- Internal Rate of Return (IRR):
- Benefit Cost Ratio (BCR)


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Sl. No.	Particulars	Unit	Make of the Wind Electric Generator									
			1	2	3	4	5	6	7	8	9	10
1	Installed Capacity	MW	5	5	5	5	5	5	5	5	5	5
2	Total Cost of the Project	Rs. Lakhs	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
3	MNES Subsidy for 5 MW	Rs. Lakhs	-	-	-	-	-	-	-	-	-	-
4	Cost of the Project to KPCL	Rs. Lakhs	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5	Interest During Construction on Capital Cost @14%	Rs. Lakhs	77	77	77	77	77	77	77	77	77	77
6	Total Cost of the Project (2+3)	Rs. Lakhs	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077
7	Cost per MW (4/1)	Rs. Lakhs	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40
8	Annual Generation	MU	2.61	3.22	3.32	4.49	5.29	3.66	4.10	3.81	9.38	11.05
9	Aux. Consumption 1% Annual Generation	MU	0.03	0.03	0.03	0.04	0.05	0.04	0.04	0.04	0.09	0.11
10	Net Generation [8-9]	MU	2.58	3.19	3.29	4.45	5.24	3.62	4.06	3.77	9.29	10.94
11	Investiment Cost Per Kwh Generation	Rs./KWh	76.63	62.11	60.24	44.54	37.81	54.64	48.78	52.49	21.32	18.10
12	Depreciation on Total Cost of the Project for 20 Yrs (4*0.9)*0.045	Rs. Lakhs	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12
13	Return (3%) & Provision (0.5%) on Total Cost of Project (4) for 20 Yrs	Rs. Lakhs	72.70	72.70	72.70	72.70	72.70	72.70	72.70	72.70	72.70	72.70
14	Net Present Valve	Rs. Lakhs	-1416	-1272	-1249	-973	-785	-1169	-1065	-1133	176	569
15	Internal Rate of Return	%	-1.15	1.12	1.46	4.96	7.00	2.56	3.87	3.02	15.38	18.30
16	Benefit Cost Ratio		0.22	0.30	0.31	0.47	0.57	0.36	0.42	0.38	1.10	1.31
17	Cost of Generation for 1 Year	Rs./KWh	18.13	14.69	14.25	10.54	8.94	12.93	11.54	12.42	5.04	4.28
18	Levallised Cost of Generation	Rs./KWh	14.60	11.83	11.48	8.49	7.20	10.41	9.29	10.00	4.06	3.45
19	Levellised Selling Tariff (SEB)	Rs./KWh	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
20	Generation Starts from the Year		2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
21	Selling Price for 1st Year	Rs./KWh	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
22	Pay Back Period	Years	>20	>20	>20	>20	>20	>20	>20	>20	16	11
23	20 Years Average Cost of Generation	Rs./KWh	12.46	10.10	9.80	7.24	6.15	8.89	7.93	8.54	3.47	2.94
24	20 Years Average Cost of Selling Price to SEB (from 2000)	Rs./KWh	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99

Table 4[A]: 5 MW Windfarm - Comparative Cost Summary of Site - A

- Levellised Tariff for Cost of Generation (LTCG)
- Levellised Tariff for Cost of Selling Price (LTCG)
- Pay Back Period.

Cost Evaluation

In addition to the above technical aspects, the cost analysis such as " Cost of generation, Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR), Levellised Cost of Generation and Life Cycle Cost i.e. Pay Back Period has been calculated using above equations for Economical viability assessment of the project. The results are tabulated for cost of generation in table – 4 (A) for site – A and table – 4 (B) for site – B.

As per analysis and cost summary in table – 4 (A), for site – A and WEG – 10, it is concluded that cost of generation and pay back period is lower and NPV, IRR and BCR are also on positive side as per condition mentioned above. Therefore from cost analysis for the site - A and WEG – 10 is optimum one and recommended to install at site - A. Similarly, WEG- 9 is optimum one and recommended to install at site – B as per table – 4 (B).

Techno- Economical Analysis Conclusion / Results

Based on techno - economical analysis methodology for assessment of windy site, evaluation of wind energy potential and selection of optimum WEG for a particular site may be decided in general on the following.

- Optimum windmill can be easily be determined by calculating capacity factor.
- For an increase in Turbine rated wind speed, the capacity factor decreases.
- Higher the capacity factor the over all rated wind speed of WEG should be nearer to


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Sl. No.	Particulars	Unit	Make of the Wind Electric Generator									
			1	2	3	4	5	6	7	8	9	10
1	Installed Capacity	MW	5	5	5	5	5	5	5	5	5	5
2	Total Cost of the Project	Rs. Lakhs	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
3	MNES Subsidy for 5 MW	Rs. Lakhs	-	-	-	-	-	-	-	-	-	-
4	Cost of the Project to KPCL	Rs. Lakhs	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
5	Interest During Construction on Capital Cost @14%	Rs. Lakhs	77	77	77	77	77	77	77	77	77	77
6	Total Cost of the Project (2+3)	Rs. Lakhs	2077	2077	2077	2077	2077	2077	2077	2077	2077	2077
7	Cost per MW (4/1)	Rs. Lakhs	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40	415.40
8	Annual Generation	MU	5.23	6.40	6.85	9.80	10.91	8.55	9.58	9.59	15.32	12.92
9	Aux. Consumption 1% Annual Generation	MU	0.05	0.06	0.07	0.10	0.11	0.09	0.10	0.10	0.15	0.13
10	Net Generation (8-9)	MU	5.18	6.34	6.78	9.70	10.80	8.46	9.48	9.49	15.17	12.79
11	Investment Cost Per Kwh Generation	Rs./KWh	38.24	31.25	29.20	20.41	18.33	23.39	20.88	20.86	13.05	15.48
12	Depreciation on Total Cost of the Project for 20 Yrs (4*0.9)*0.045	Rs. Lakhs	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12	84.12
13	Return (3%) & Provision (0.5%) on Total Cost of Project (4) for 20 Yrs	Rs. Lakhs	72695	72.695	72.695	72.695	72.695	72.695	72.695	72.695	72.695	72.695
14	Net Present Valve	Rs. Lakhs	-799	-524	-419	275	536	-19	223	226	1573	1009
15	Internal Rate of Return	%	6.85	9.54	10.49	16.13	18.06	13.85	15.74	15.76	25.21	21.40
16	Benefit Cost Ratio		0.56	0.71	0.77	1.15	1.29	0.99	1.12	1.12	1.86	1.55
17	Cost of Generation for 1 Year	Rs./KWh	9.05	7.39	6.91	4.83	4.34	5.53	4.94	4.93	3.09	3.66
18	Levallised Cost of Generation	Rs./KWh	7.29	5.95	5.56	3.89	3.49	4.46	3.98	3.97	2.49	2.95
19	Levellised Selling Tariff (SEB)	Rs./KWh	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
20	Generation Starts from the Year		2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
21	Selling Price for 1st Year	Rs./KWh	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
22	Pay Back Period	Years	>20	>20	>20	14	11	>20	15	15	6	8
23	20 Years Average Cost of Generation	Rs./KWh	6.22	5.08	4.75	3.32	2.98	3.80	3.40	3.39	2.12	2.52
24	20 Years Average Cost of Selling Price to SEB (from 2000)	Rs./KWh	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99	4.99

Table 4[B]: 5 MW Windfarm - Comparative Cost Summary of Site - B

the mean wind speed, At this condition the size of the wind mill will be optimum.

- Based on MWH / MW.
- Based on the energy density watts / sq.m.
- Cost of generation per kWh.
- NPV should be more than one/positive and nearer to project cost is more viable.
- IRR should be more than one/positive i.e. internal rate of return should be more than borrowed interest.
- Benefit cost ratio (BCR) should be more than one/overall benefit should be more than investment cost.
- Pay back period should be nearer / less than loan repayment period for more economical viability of the wind power project.
- Investment cost per kwh generation.
- Rated power of the WEG (Per) increases for a given turbine, the cost of the necessary generator transformer, switches, circuit breakers and distribution lines all increases.
- However, if the CF – capacity factor decreases it means that these items are being used proportionately less of the time.
- Higher the rating of WEG, Equipment cost will increase more, rapidly than energy output.

Profile

Dr H Naganagouda

B.E., M.E., M.I.S.T.E., F.I.E., C.E.,Ph.D Director, National Training Centre for Solar Technology, Karnataka Power Corporation Limited, (A Government of Karnataka Enterprise), Bangalore. He has around 22 awards/ certificates to his credit.

Schneider Electric unveils two new inverters at REI Expo 2014

Schneider Electric India launched two products – Conext CL and Conext XW+ – at the Renewable Energy India Expo 2014, India Expo Centre, Greater Noida. Conext CL is a new line of three-phase string inverters, while Conext XW+ is the next-generation version of the Conext XW hybrid inverter. Both products come from Schneider Electric Solar Business – a global leader in solutions for solar power conversion chain. Anurag Garg, VP, Solar BU, Schneider Electric India said, "The Conext CL addresses a wide range of customer needs and is the ideal solution for commercial buildings, carports and decentralized power plants, while the Conext XW+ is a single solution for grid-tie backup and off-grid solar for homes, businesses and communities. At Schneider Electric, we are accelerating our investment by transferring global technology to India, increasing our local R&D capabilities and manufacturing locally in our world class facilities. The launch of these new inverters further reinforces our commitment to the Indian market."

Conext CL: The Conext CL offers high flexibility (an integrated wiring box with five configuration options gives customers installation flexibility and lowers costs by eliminating the external DC combiner box cost, and 10-to-90 degree tilt angle allows flexible mounting); easy installation and service (lightweight 45-kg inverter with detachable 16-kg wiring box makes mounting easy and fast); high ROI (98.4% peak efficiency, designed for high uptime providing customers maximum energy harvest from their solar plants); high reliability (electrolyte-free design works in harsh environment too).

Built for decentralized architecture, with full grid support features, a broad range of Schneider Electric's low and medium voltage products and industry leading system capabilities, Conext CL is backed by Schneider Electric's global service infrastructure and expertise in energy management.

Conext XW+: The new Conext XW+ is the next-generation version of the Conext XW Hybrid inverter – a hybrid inverter specifically designed for backup power for homes and businesses, residential retrofit of grid-tie solar with backup, residential self-consumption, off-grid homes and businesses, community electrification and micro-grids.

With the Conext XW+, one can simplify system installation with the Conext XW+ Power Distribution Panel, integrate Conext MPPT solar charger controllers, AC couple with compatible PV inverters, and monitor battery resources with the New Context Battery Monitor. Moreover, with Schneider Electric's new Conext ComBox, one can monitor and configure an entire system seamlessly from a PC or tablet device.

Solar Alternative

Recently there has seen a lot of interest in Solar energy, especially in India. We attempt here to have an objective look at Solar energy.

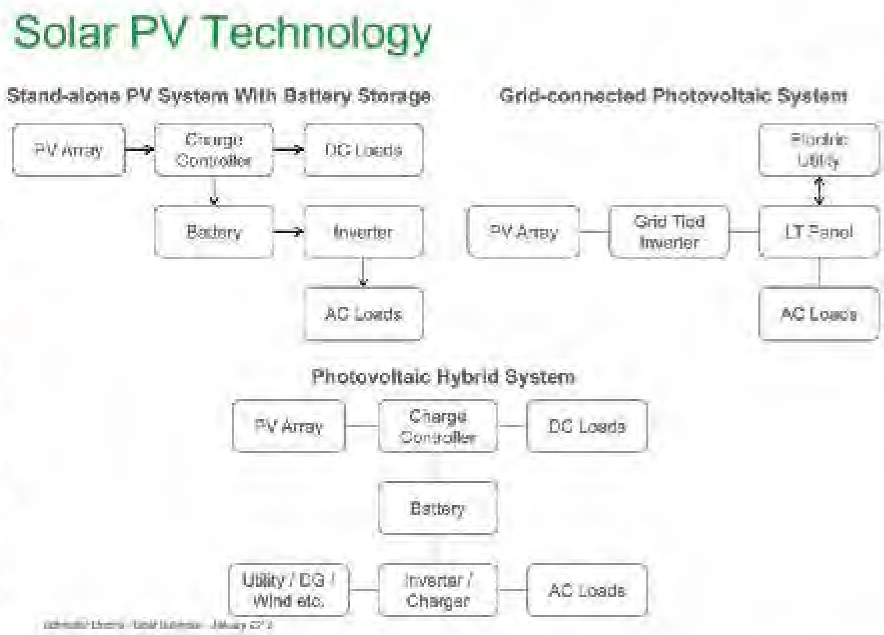
Anurag Garg

Most of us today live in the times of power deficit the country faces. As of February 2013, the data released by the Central Electricity Authority, shows a deficit of a little more than 8% in all India energy requirement. Aggregations, unfortunately, tend to obfuscate the devil in the details. It is in this context that most of us perceive Solar Energy as a panacea. Well like all such panacea, Solar ain't a cure all. Like all medication, prudent application, is what will cure the disease. This article attempts to guide on prudent application of Solar Energy.

Understanding today's Solar Technology

Before we get into understanding the technology employed in converting Solar Energy to electricity, it's imperative we understand the nature of the source i.e. the Sun. Sun is the only truly decentralized source of renewable energy, as its available everywhere. We all know that Sun's only available during the day time. This variability is also seasonal, meaning the amount electricity units generated in winter, will not be the same as in summer, or any other season of the year.

The Block Diagrams below outlines the three types of Solar PV systems in use today:



The stand alone PV system with battery storage is conceptually similar to the early commercial applications mentioned. Here Solar Energy is directly converted to DC by the PV Array, to charge the batteries and to supply to the DC loads. The inverter is used to invert the DC into AC for supplying to the AC loads. This is a pure off-grid application, as there is no grid source used in the system.

> *The grid tied inverter, is a current source and pumps current into the bus, after synchronizing with the AC voltage available on its output*

The second one shown – grid connected PV system, converts Solar Energy to AC current, to be pumped into the power system, whenever a voltage is available. Like before, the PV array converts Solar to DC. The grid tied inverter, is a current source and pumps current into the bus, after synchronizing with the AC voltage available on its output. In the event, there is no voltage reference on its output, the grid tied inverter stops pumping current. This is the fundamental principle behind all the Utility Scale Solar power plants coming up in India and is also being increasingly used in residential, commercial & industrial installations. Europe continues with its leadership in adoption of this technology, primarily to rebalance its energy supply mix.

Like any other domain, the best in Solar too comes at a cost, a cost which even today retards the wide scale adoption of this option.

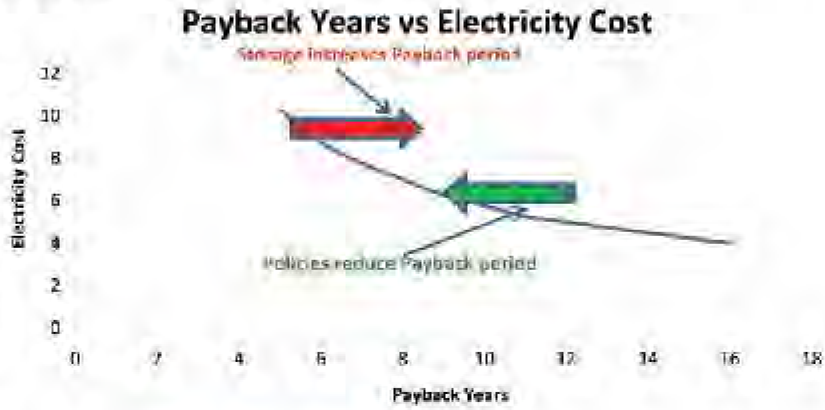
This brings us to the all important topic of economics of Solar Electricity.

Economics of Solar PV Electricity

What attracts everyone to Solar, is the abundance and free nature of the source. The Sun is freely available anywhere and is not expected to disappear as a source in the foreseeable future. That simple fact opens up possibilities, possibilities of reducing dependence on sources below the ground, hence region specific & limited. The limited nature of these fossil fuels, not only affects the demand-supply equation, it also raises the speculative possibilities in the commodities market. All of which results in an ever increasing variability in the cost of electricity from these sources and that too with an upward trend. So what then dampens the adoption of Solar, is the nature of the source itself (after all we need electricity 24 x 7) and more importantly the high initial investment required for setting up a Solar Power Plant.

At benchmark cost levels itself, setting up a mega watt scale Solar PV power plant is about 60% more expensive than setting up an equivalent coal based power plant. At kilo watt levels, more pertinent to most of residential, commercial or industrial users, the capital expenditure involved in setting up a Solar Power Plant is a few times the cost of an equivalent capacity Diesel Generator set. The equation reverses though on operational costs, where in a Solar Power plant significantly scores over its fossil fuel counter-part. That's because of the nature of the source, which in the case of Solar is free.

It is to mitigate this impediment that world over and in India, governments have been subsidizing solar power. Subsidies have taken various forms – feed in tariffs, capital subsidies, generation based incentives, tax benefits through accelerated depreciation etc. The net result of all these policy actions has been to rapidly increase the adoption of Solar power, by either driving down the capital costs or by providing attractive return on investments or both.



State of the Industry

Solar solutions and systems have a pretty long lifetime (typically 25 years). The supplier's ability to provide after-sales support through-out this long life cycle is very crucial. Hence the residential, commercial or industrial users are giving increasing importance to high levels of bankability and reliability of the supplier. Bankability means you can rely on the supplier's financial strength, support, industry experience, and reliable products for any solar project.

Conclusion

With the declining system costs & active promotion through government policy, Solar is fast emerging as a viable and sustainable alternative source of electrical energy. At the consumption end of electricity, it's even more relevant, especially when compared to diesel generation, which is widely used to offset our power deficit. It is in this perspective, that one needs to understand the reasons for exploring the Solar alternative. These could be to reduce the cost of electricity & its variability or it could be improve electricity availability or green initiatives or all of these. The choice of the appropriate technology is a derivative of this. The benefits that can be derived from Solar, highly depend on the time invested in this phase of the project.

Profile

Anurag Garg
Vice President, Solar Business, Schneider Electric India.

Solar
The Future of India

In a short span of 4 years, India has made spectacular moves in expanding its ample solar power potential. It has appended capacity at a commendable pace and is leading amongst the economic cost destinations for grid-connected solar power in the world.

Abhinav Gupta

The Search led by AT Kearney revealed that India's solar market could be worth billions of dollars over the next decade. In January 2010 India's concerted efforts had begun to proceed towards solar power when Jawaharlal Nehru National Solar Mission (JNNSM) was launched. The main aim of JNNSM was to position India as a major world power in solar manufacturing as well as in research and development. It is expected that in the coming years, solar power will hold a dominant position in Indian market; both from financial viability and availability perspectives.

If we look from technological point of view, India is even an excellent place for the wide implementation of solar energy. It gets abundant sunshine for most parts of the year with the summer temperatures 40 to 47^{O} in most parts of the country. The northwest India has even got the Thar Desert which has been recognised as a feasible spot for the development of solar power because of receiving plenty of sunlight. India not only has plenty of opportunity to generate solar power at large scale but also there is enough scope for household solar harvesting. This primarily owes to two reasons – the amount of sunshine homes are receiving yearly and the existence of flat roofs almost throughout the country. Flat roofs are eligible to tap the solar energy much more efficiently, helping homes generate their own power. The per capita energy consumption of India is about 15 times more than the US, which means the Indian home can be easily powered through household solar energy harvesting. In a country like India rooftop solar generation is particularly important as there is scarcity of land in the country and for the development of new projects acquisition of huge lands could be slow and tedious process riddled with bureaucracy. The shining future of Indian energy segment is now knocking at our doorstep and it's the Sun that will continue to power our economic and energy growth into the next millennium.

Solar energy is the perfect solution for such problems. Government in its road map has planned to achieve 20,000 MW installed capacity from nearly zero as of now & both governmental and non-governmental organizations are actively working towards development and growth of solar sector in the country

The country government has also identified solar energy as a priority because nearly 10,000 thousands villages of India is still not electrified & there are no measures taken yet to extend the grid to these villages. Therefore, solar energy is the perfect solution for such problems. Government in its road map has planned to achieve 20,000 MW installed capacity from nearly zero as of now and both governmental and non-governmental organizations are actively working towards development and growth of solar sector in the country. In order to meet this target government has also taken several significant measures. Nearly 3000 villages have been planned to be completely powered through solar energy by end of 2014.

Parameter	Central Government	Gujarat	Karnataka	Tamil Nadu	Andhra Pradesh
Type	Grid connected	Grid connected	Grid connected	Grid connected	Grid connected
Capacity Target	10 MWp	5 MW in Gandhinagar 3	1.3 MWp	350 MWp	-
Off Taker	-	Utility	Utility	Consumer	Consumer
Incentives for Rooftop owner	-	Green Incentive	Lease Rental	-	-
Metering	Gross/Net	Gross	Gross	Net	Net

Evolving net-metering model regulation for rooftop based solar PV projects (Source: Bridge to India)

The $19 billion National Solar Mission plan will lead India to stand at par with other developing and developed nations in the field of solar energy. Numbers of foreign companies are also entering this league and the private sector is also now playing a prime role in the development of solar energy in India. Recently, an US private equity firm Blackstone group has invested $300 million that is Rs 1350 corer in Moser Baer India, which is just a start, a lot more established companies are expected to join ahead in this blooming market of solar energy.

So we anticipate that the future of solar energy in India is definitely at brighter side. Global warming & regular hike in oil price has also added to the need of this. Recently the net metering policy announced by government for various states like Delhi, Karnataka, Gujarat, Kerala, Tamil Nadu, Haryana is about to bring great revolution in this solar era. On September 2, 2014 the Delhi Electricity Regulatory Commission (DERC) announced the "Net Metering for Renewable Energy Regulations". After two most awaiting years Delhi's Net metering policy is finally in place. Now Delhi residents with solar rooftop systems will be able to supply excess solar energy to the grid. This will bring them energy credits, which will be later adjusted against their electricity bills.

Thousands of renewable energy producers in coming years can be seen feeding the grid or supplying electricity to consumers through local mini grids. Generating electricity on own and feeding surplus to the grid will soon become the trend.

The government has committed to invest about $20 billion in the next 10 years for the growth, development & implementation of solar energy in the country. The actions are also taken in order to fulfil the commitment.

- India has made the use of solar energy mandatory in all government run buildings and hospitals.
- 500 corers are allocated for solar power projects which will be started soon in Rajasthan and Ladhak. It is one of the largest solar power projects in the world expected to achieve the capacity of 2000 MW to 4000 MW.
- Indian Government in its biggest tender yet has planned 1500 MW solar power auction.
- BHEL is about to set up a solar power projects at Rajasthan, which is an ultra mega solar power project with a capacity of 4,000 MW. The power generation potential of this plant is estimated to be 6,400 million units of (solar) electricity per year with an estimated plant life of 25 years.
- Installation of 30 Kilo watt solar plant would begin shortly in secretariat and all the new government buildings will be constructed with rooftop solar system while the existing buildings will get this in a phased manner.

Hence the future of solar in India could be clearly anticipated with above mentioned data. Today, coal is still dominating the India's power-mix, which includes around installed capacity of 60% where Solar stands with it at just around 1%. But as per the road map of the government regarding solar power solar is just ready to go mainstream. It is expected that, 2040-50 will finally be the decade when coal based installed capacity would be overtaken by renewable energy installed capacity and then India will be standing equally at par with the other developed nations in solar energy sector.

Profile

Abhinav Gupta

Founder & CEO and Director, SunSwitch India Pvt Ltd is BSc Mechanical Engineering from University of Illinois, USA) is responsible for most of the management decisions at SunSwitch. Before, he was associated with the parent company Ambica Steels Limited. In the past, he assisted in research in The Ertekin Research Group (USA) and was also an integral part of his University's Solar Decathlon team in US.

Interview

Best-in-class solar cell manufacturing equipment

James W Mullin, Corporate Vice President, GM
Solar Products, Energy and Environmental Solutions, Applied Materials, Inc.

With more than 45 years of commitment to facilitating positive change through technological innovation, **Applied Materials, Inc.,** is the global leader in precision materials engineering solutions for the semiconductor, display and solar industries. Applied Materials ranked No. 82 on the EPA's National Top 100 list of the largest green power users, as well as No. 13 on its list of Top 30 Tech & Telecom companies. In an exclusive interview to **Electrical India, James W Mullin** states, PV manufacturers need to adopt new cell architectures and process solutions.

➢ What is your perspective about solar energy scope globally and in India?

Solar panels are a clean, sustainable, and economic method for producing electricity. In many regions of the world with sunny climates, solar energy is already at grid parity, even without subsidies. The global end market continues to be strong with the industry forecasting 45 GW of solar panels to be installed in 2014, with estimates of an increase to 50 GW in 2015. The potential for solar energy in India is significant.

Despite early delays due to permitting, currency fluctuations and the general election, the new Modi government has given a clear indication that solar energy is a key focus with the withdrawal of the anti-dumping case against China. Additionally, the recent net-metering announcement for the Delhi and Punjab regions also points to major solar growth in India.

➢ Could you share your vast experience in solar business as well as technologies which you would use to lower PV system cost with impact on company's revenue?

The use of higher power modules directly lowers photovoltaic (PV) system costs by reducing the area-related, balance-of-system costs, as well as producing more power to further lower the cost per kWh. The key to producing high power modules is to use high efficiency cells to increase module power (Wp) while keeping manufacturing costs low. High efficiency cells require technologies such as Fine Line Double Print, passivated emitter rear contacts (PERC) as well as technologies using n-type wafers, such as passivated emitter rear locally diffused contacts (nPERL). Applied Materials provides best-in-class solar cell manufacturing equipment and process integration knowledge, to deliver these high efficiency cells at low cost and high yield, enabling lower cost per kWh.

➢ What is your concept to optimize the company's investment in the solar segment? What are the further needed developments in the solar industry?

For at least the past 5 years, solar manufacturers have improved module power output by 5 to 10 W per year—a solar industry efficiency clock. To keep pace with this clock, solar manufacturers are developing road maps for high efficiency cells and module powers exceeding 300 W. Applied's strategy is to enable these technology road maps by delivering world-class manufacturing equipment and innovative process solutions, which meet target cell efficiencies at low cost and high yield, and also can be extended for future cell technologies.

➢ What strategy would you suggest to have competitive advantage in producing high-efficiency solar cells?

To continue the solar efficiency clock and improve module power by 10 W year-on-year, PV manufacturers need to adopt new cell architectures and process solutions, such as Fine Line Double Print and PERC, as well as high efficiency cells using n-type wafers, such as nPERL and interdigitated back contact (IBC) cells.

With the highest cell efficiencies achievable, we expect all manufacturers to ultimately converge to n-type wafers. It is likely that existing solar cell manufacturers will pursue a step-by-step approach and introduce technologies sequentially, such as double print, PERC, nPERL and then IBC, while new entrants can directly move to n-type cell architectures.

➢ Could you detail about various solar products and technologies available and their application? Which products are more suited to Indian solar market?

Demand for electricity in India is growing rapidly, and solar energy is one of the best options to address this need. This is because solar modules can be used in multiple applications: connected to the grid in utility applications of hundreds of MW, or in smaller, distributed applications on building rooftops, and even in off-grid applications with energy storage. In all of these applications, using the highest-power module available with the highest cell efficiencies will enable the lowest installed system cost, generate more electricity and provide the lowest cost per kWh.

➢ Where are the manufacturing facilities located to have geographical advantage world-wide for distribution of products?

The majority of solar module manufacturing today is located in Asia, and coincidentally Asia is experiencing the largest growth in solar energy compared to other regions. While strong end markets in a region are important to facilitate a local manufacturing base, a developed industrial infrastructure and local government support are critical.

➢ Applied Materials' solar products leverage the company's expertise in precision materials engineering. What key opportunities and challenges you envisage in India for company's products?

Applied Materials is a global company that is committed to its customers. We have had a strong presence in India since 2003. For Indian PV manufacturers, Applied can support strategic partnerships to help them develop and accelerate their technology road maps for wafer and cell manufacturing in order to provide differentiated, valuable and profitable products to address India's critical energy needs.

➢ What major accomplishment does Applied Materials has achieved?

As one of the leading PV equipment manufacturers, Applied Materials has the largest installed capacity of screen printing tools in the field, which have been used to produce over 7 billion solar cells to date. Our Fine Line Double Print solution with Esatto Technology has been proven to increase cell efficiency and reduce costs at leading PV manufacturers. In addition, we have shipped over 1500 slurry-based wire saws. Applied continues to innovate in precision materials engineering and has recently launched a new ion implanter for emitter formation in advanced cells.

➢ What is your vision in the next two years?

Over the next two years, the solar industry is expecting continued strong growth in global solar installations, likely exceeding 45 GW in 2014 and 50 GW in 2015. While China, Japan and US will probably install the largest volumes, we believe that India will also see significant growth. We also expect that more high power solar modules will continue being used (the efficiency clock), thereby lowering overall PV system costs for both distributed generation and utility applications. This in turn will lower electricity costs, & enable more regions of world to reach grid parity with solar.

Waste-to-Wire: Electricity from Sewage in India

India's newly elected government's agenda on sanitation and sewage treatment is intent towards improving the socio-economic spheres of our times. Financial schemes from the central government to build sewage treatment plants, river cleaning programmes and providing clean sanitation facility for all are indicators of enterprising solutions which have been embarked by the Narendra Modi led government.

Sanitation & renewable energy generation

A holistic approach at the micro level – sanitation & sewer – can contribute towards a healthy and hygienic society along with minimising our electricity woes. At community levels, a centralised collection and waste treatment from toilets answers not only proper sanitation but if treated scientifically, yields renewable energy as well. Adopting bio-methanation the waste can be effectively treated and the biogas thus produced can either be used as a cooking gas or can power a biogas engine for generating electricity. At many public toilets across India the biogas-to-power concept is getting implemented. There are success stories scripted for generating electricity from the waste generated at public toilets. Many countries are adopting the concept too. A government's mandate for energy generation from public toilets shall be notable towards meeting our needs and contributing for sustainability; in the form of waste treatment and renewable energy production.

With the rapid urbanisation and increasing population of Indian cities, it becomes paramount to treat the waste generated. The Indian Government's announcement to develop sewage treatment plant through project funding shall ensure keeping financial challenges at bay. The Government's fast track implementation of developing sewer networks and connecting to a Sewage Treatment Plant (STP) (or wastewater treatment plant (WWTP) at community levels or at a central location shall ensure the implementation of proven ways of sewage collection and disposal. Also, adoption of latest waste treatment technology can be done which serves multi-purpose motives.

One such way to treat sewage by achieving multi-prong benefit is anaerobic digestion. The technology transforms sewage treatment into a revenue generation option. Whilst effectively treating the sewage, anaerobic digestion generates a high grade of gaseous fuel – sewage gas. The methane produced can be utilised for generating electricity – renewable energy – through a biogas engine thereby making the sewage treatment plant meet its electricity requirements. Moreover, surplus power generated can be supplied to the grid.

Massive potential for power from sewage in India

At many sites both in India and internationally, Clarke Energy has executed sewage gas based power generation facilities with long term maintenance contracts intact with the developer using GE's Jenbacher gas engines. However, the sewage gas based power generation plants built are miniscule against the total number of STP's in India. Guidelines from the government favouring captive power generation using sewage can spur electricity-from-sewage.

Consuming sewage gas, a gas engine can be configured as a Combined Heat & Power Plant (CHP). Waste heat emanating can be utilised for heating the bio-digester thereby facilitating bacterial growth for the sludge treatment. In the CHP mode, the overall plant efficiency increases significantly. Benefits from the government through project subsidies, availing renewable energy certificates, eligibility for clean development mechanism, production of a soil improver and sustainability through a sewage gas based power plant encourages us to 'Think & Act' on the concept.

Profile

Alex Marshall

Group Marketing & Compliance Manager, Clarke Energy

Shishir Kumar

Marketing Manager, Clarke Energy

INDIA NUCLEAR ENERGY 2014
Energy Security for the Future...

6th edition of
India Nuclear Energy

UBM India announced the 6th edition of its flagship international exhibition and summit for the Civil Nuclear Energy sector, India Nuclear Energy 2014. The event is slated for the November 6-8, 2014 at Nehru Centre, Worli in Mumbai.

The event will serve as an industry platform for over 75 exhibitors from across the globe, like Canada, Korea, France and UK, in addition to India, to showcase their products and technologies for the civil nuclear industry. The civil nuclear fraternity from India and overseas will share the platform, providing an opportunity for domestic and international companies to explore and tap the huge untapped potential that the nuclear industry presents in India.

Against the backdrop of India having a largely indigenous Nuclear power program in place with Nuclear deals being inked with countries like Australia, the sector promises a huge potential in India. In addition to the same, India today has a very technology friendly government, validated by the Prime Minister's visit to various technology intensive units and BARC. Most recently the successful and historic space flight of the Mars module 'Mangalayaan' together are positive signs of fulfilling power capacities of over 14,600 MW by year 2020.

Commenting on the focus of the 2014 edition of India Nuclear Energy, Joji George, Managing Director, UBM India said, "India, under the leadership of the new government, has a vision of leading nuclear technology, globally by leveraging its expertise in fast reactors and thorium fuel cycle. India Nuclear Energy 2014 will address these very technologies, preparing the launch-pad which would catapult the nation into a power surplus eco-system."

Along with the co-organizer, DAE (Department of Atomic Energy) and supporting partners, NPCIL (Nuclear Power Corporation of India Ltd.) and INS (Indian Nuclear Society), the event will also be marked by a summit based on the theme of 'Nuclear Power: Global and Indian Perspective' which would have Dr R Chidambaram, Principal Scientific Adviser to the Government of India as the Chief Guest. The summit will bring together senior nuclear professionals from DAE, NPCIL, INS and other private companies from the civil nuclear space. The summit would further shed light on the nuclear landscape, charting out India's ambitious path towards fulfilling 25% of India's total power requirements through nuclear technology by 2050.

Additional highlights of India Nuclear Energy 2014 would include seminars based on the collaboration between Canada & India and India & the UK.

Counterfeit Connectors: the Dangers

'Multi-Contact has been involved in the solar industry with their high quality plug connector systems for photovoltaic installations for more than 10 years, and has gained considerable experience on the long-term behavior of millions of plug connectors.'

Photovoltaic (PV) Connectors are critical in regards to safety, and yet they are frequently overlooked, compromising performance and putting home owners at risk. The wrong connector or the mismatching of different brands can cause high resistance connections or allow water ingress, which can result in premature failure of the array and possibly fire. Unfortunately some unscrupulous companies are selling such counterfeit connectors. It is often hard to tell the difference between copies and the genuine product. Despite legitimate connector companies using their own branding on their connectors, some "unknown" manufacturers are hiding behind these brands. The biggest loser in this is the home owner, who has paid thousands of dollars for a solar installation and ended up with an inferior, and potentially dangerous, product on their roof.

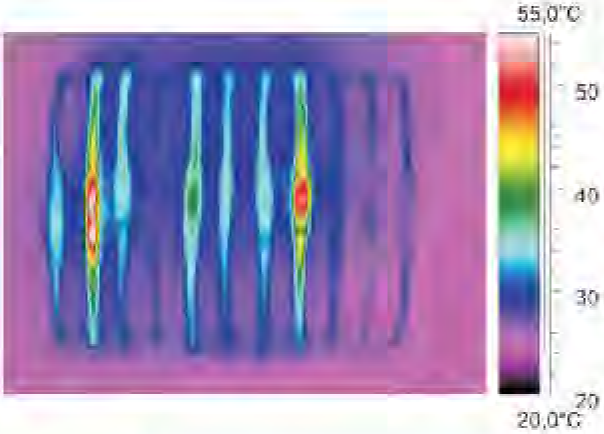
Matching Connectors are Essential

Only connectors which are the same model and from the same manufacturer are allowed to be married at a connection point. UL, a global safety science company, have stated in their Conditions of Acceptability section that these devices have only been assessed for UL Recognition with specific types of mated connectors within their product family. They have not been assessed to operate with any other similar devices from any other manufacturer. This means that compatibility of PV Connectors can only currently be confirmed for products of the same series from the same manufacturer. With mismatched and counterfeit connectors, concerns have been highlighted about safety characteristics such as UV resistance, contact resistance, and material quality, that may be dangerous when installed in a PV system. The most serious problems which result from inadequate compatibility or the use of inferior copies frequently occur only after a considerable period of time. The use of poorly matched connectors can cause contact problems that can lead to a marked rise in

Perspective of	Pros	Cons
Importer of Counterfeits	Usually looking for short term gains and not considering the implications on installer, home owner, or solar industry.	Breaches CEC Code of Conduct4. Risks court action for breaches of Trade Practices Act.
Wholesaler	May save a very small amount of money, and may or may not pass on the savings to the installer.	Risks court action for breach of copyright and misleading behaviour. May have to compensate installer for rework, if system fails.
Installer	May save $2 on an installation that the client has paid many thousands of dollars for.	Risks livelihood and peoples lives if connector fails. May have to spend time reworking job if it doesn't work first time.
Home owner	None	Shorter system life. Possible fire and loss of property or life.

the temperature of the plug connector due to a higher contact resistance. This can subsequently result in arcing and fire, resulting in substantial damage to professional reputations, loss of revenue from the PV system, material damage, and quite possibly personal injury.

Counterfeit PV connectors have proved to be a particular problem for the Power plant investor and Multi-Contact (MC) as a growing number of suspect copies of their MC Solar components have appeared bringing considerable losses in power generation and transmission



Don't Risk It

If this advice is ignored, then the installation will not meet CEC/ORER requirements, and it will not follow manufacturers guidelines. This leaves full responsibility for any failure of the connectors to the installer, unless the installer can prove that they have been mislead by the supplier of the counterfeit product. As an installer or OEM, you guarantee your system for 20 years or more. Don't risk it for the sake of saving a few cents in the overall cost of an installation and always demand genuine and matching PV Connectors.

Trouble for PV systems

Counterfeit PV connectors has proved to be a particular problem for Multi-Contact (MC) as a growing number of suspect copies of their MC Solar components have recently appeared on the market. Multi-Contact is tackling the issue by taking court action against the imitators and also by increasing awareness to protect manufacturers, installers and homeowners from the financial and reputational damage that can result from the use of inferior products. Visually, the copies are virtually indistinguishable from the genuine MC products, but comparative measurements and material tests on the counterfeits have revealed substantial deficiencies in quality, and compromised safety and system performance. Using copies mated with the genuine Multi-Contact connectors can result in a poor fit between insulator parts, resulting in system failure due to compromised sealing against the elements such as rain or dust. Subsequently, the insulating properties are no longer assured and a person touching the connector may be electrocuted. For your safety, Multi-Contact does not recommend using inferior copies, as the mating forces, plating materials and insulation properties cannot be guaranteed. Effects such as fretting corrosion may be caused by incompatible plating materials, contact forces and other influences. In order to avoid such adverse effects, the contacts and insulating parts of the connectors must have compatible properties. Tests of such properties are time-consuming and are not covered by certification tests. Division Manager of Photovoltaics for Multi-Contact, Dr. Joachim Hirnke, has highlighted the importance of not marrying genuine MC technology to counterfeit connectors, even if the manufacturers claim compatibility:

"In connection with developments in the PV sector, a growing number of competitors have brought PV plug connectors claimed to be "compatible for mating with MC" onto the market. Some of these competitors use "TÜV certificates" of mating compatibility with MC connectors as a sales argument. In this regard, the following should be noted: To our knowledge, these in no way constitute a TÜV certification of the mating of non-MC products with MC products. They relate only to a selection of tests from those prescribed by the standard which have been carried out by TÜV at the request of our competitors. The results of such neutral test reports certify only that only various tests selected from the standard showed no deviations from the norm. Test reports of this kind confer no right to bear a

GS symbol or other mark of compliance. In detail, such TÜV documents as are known to us include only the results of a number of short-time tests from the test standards. All long-time tests such as Accelerated Ageing are systematically omitted. Water-tightness tests have been only partially carried out, and we are not aware of any complete IP65 test having been performed. Nor is there any long-term field experience with such combinations of MC and non-MC products.

To sum up, it can be categorically stated that such documents do not constitute "TÜV certification" of the mating of other makers' products with MC products. For safety and liability reasons, MC does not itself recognize the compatibility of products advertised by competitors as MC-compatible."

Courtesy:
Multi-Contact India
Email: india@multi-contact.com

Axcend Automation & Software Solutions Pvt Ltd

This company is a focused Industrial IT solutions provider working closely with Manufacturing and Utility organizations across the globe. They provide solutions that enhance productivity by optimizing the manufacturing operations. Axcend adds value to organizations through innovative solutions in the areas of Industrial Automation, Manufacturing Execution Systems, and Industrial Software product development. They provide customer centric solutions to meet specific business scenarios of the customer by architecting solutions utilizing best of the breed products, practices and frameworks. With a rare breed of talent who possess the industry domain knowledge and technical know-how, Axcend has been benchmarked with SEI CMMi Level 3 certification for the hybrid processes of Industrial Automation & IT.

For further details contact:
www.axcend.com

Rachna Metal Industries Pvt Ltd

RMI was established in the year 1978 backed by extensive experience in the field of metals. They are leaders in their field and are involved in manufacturing an extensive range of high quality semi-finished copper and copper alloy products (Rods, Tubes, Bus Bars, Strips, Plates, Wires, Pipes, Sheet and Circles) for a wide range of engineering industries. They have the capability and flexibility to meet unique product requirements and exact specifications and sizes. It holds strongly to excellent customer service, product quality, commitment, compliance and competitive price structure. They have the sophisticated manufacturing facilities and a team of highly qualified, motivated and experienced staff in production and sales to meet the customers' ever growing quality and service expectation. RMI is the approved vender of Power Grid Corporation of India Limited and BHEL Rudrapur for transmission line mass manufactured items which require copper flats, copper sheets, copper tubes and copper rods. As an independent manufacturing unit, RMI serves the needs of a large variety of sectors across the landmarks of India. Their clients includes corporate, Government and Agricultural sectors. They service the Electrical Industry, the Sugar Industry, Distillery Plants, Ordinance Factories, Religious Institutions and other enterprises who find the need for their high quality products.

For further details contact:
www.rachnametal.com

Zhuhai comking Electric Co Ltd

Comking is a specialized hi-tech power equipment manufacturer, located in Zhuhai City Industrial Park Xiangzhou Hongwan. In recent years, the company's business growth has been leaps and bounds, with eight offices nationwide: Jiangxi, Heilongjiang, Guangxi, Henan, Chengdu, Hunan, Hubei, Shandong, and products throughout the country. Currently the company's products are side-mounted high-voltage vacuum circuit breakers, high voltage closed solid vacuum circuit breakers, high-voltage vacuum switch, the whole closed-wide high-pressure SF6 insulated switchgear, outdoor vacuum circuit, and neutral grounding resistors cabinets, counters, and High-voltage Switch Cabinet portfolio ground, such as loop counters. Company also based, on the actual situation in power supply to provide High-voltage Switch Cabinet's overall program design and neutral grounding of the overall solution. The company introduced a high-quality pre-sale, sale and after-sales service measures, serve customers to create product solutions to provide customer service.

For further details contact:
www.zhcomking.com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Elmeasure offers Power Distribution Unit

Elmeasure known as the trend setter has introduced a new product in electrical system monitoring and control. This product is intended for energy auditors, space critical panels, need for monitoring live data from multiple devices in a single location etc.

A Multichannel load manager that provides 3 channel 3 phase electrical information and is available in two different constructions. A technological wonder that provides the customer with 3 times faster data communication to the SCADA / Energy Management Software, saves critical panel space, reduces cabling and best of all reduces the cost of the panel substantially. Multiple PDU's can be cascaded to measure multiple channels with a maximum of 15 channels in a series with common display unit making up the Power Distribution System (PDS). The system also allows the user to have multiple meters placed in the panel with a single display unit placed at a remote location.

For further details contact:
marketing@elmeasure.com

Field Intensity Meter by Kusam-Meco

Model KM 828 is a new Field Intensity Meter introduced by "KUSAM-MECO", an ISO 9001-2008 certified company. This model has LCD display & over range indication function. This model can inspect particular objects or devices that radiate low frequency electromagnetic waves. It can be used for power cables, computer monitor, TV, audio and visual, electromagnetic oven or analogous electrical installation. It's measuring range is 0.1-400mG, 1-4000mG, 0.01-40uT, 0.1-400uT with accuracy ±(3%rdg+3digits). The Frequency range is 30Hz~400Hz. The Sampling time of this meter is 0.5 second. It has an ergonomic design easy to carry. It has a holster to prevent the instrument for damage due to accidental fall. The Power used is 9V battery. It's Operating temperature is 0-50^{0}C (32-122^{0}F) & Relative humidity is ≤80% RH. It's dimensions is 138(L)x 71(W) x 35(H) mm.

It is supplied with 9V Battery, Carrying case, Instruction Manual.

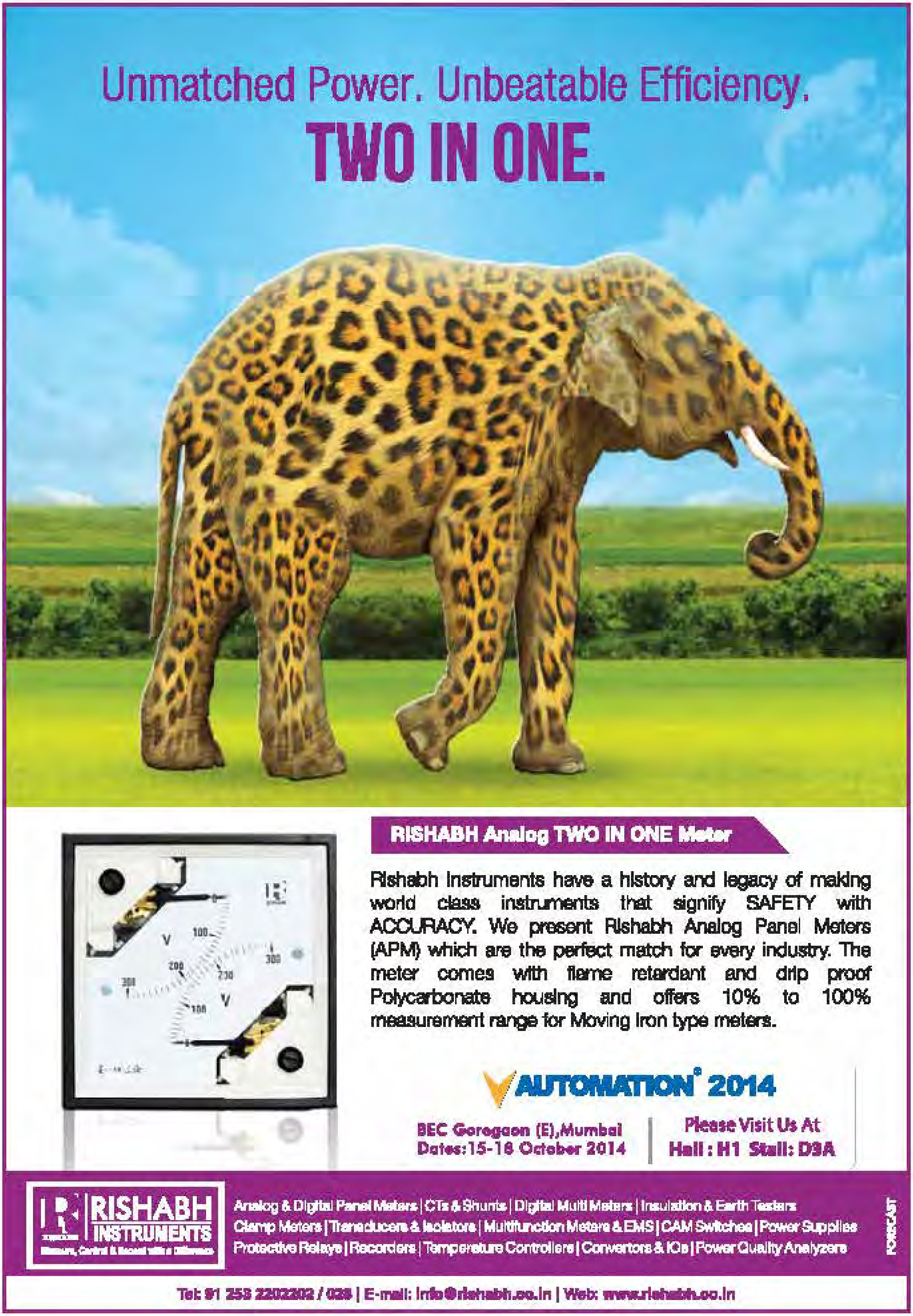
For further details contact:
sales@kusam-meco.co.in

Megger brings Portable Appliance Testing PAT 420 'Business in a Box'

The New PAT420 'Business in a Box' from Megger includes everything an electrical contractor needs to diversify into PAT Testing. It includes comprehensive guides on performing PAT testing, PAT420 Portable Appliance Tester, Powersuite software, protective pouch, Adaptor for testing laptop power supplies, Combined earth bond, continuity, and insulation test lead with probe and crocodile clip, 13 A extension lead adaptor, PASS labels for tested assets, roll of 1000 Lead storage pouch, Laminated quick-start guide for the PAT420 and full user guide for the PAT420 on CD. The PAT testing and marketing guides included are a unique feature of the package. They are designed to assist in setting up, running and growing a PAT testing business. The Guide to PAT testing explains how to perform PAT testing. While remaining simple, it is intended to aid in the detail of how to test and includes identification of the different types of assets that exist and which tests to perform on each type. It also includes the recommended pass/fail criteria from the Code of Practice for In-service Inspection and Testing of Electrical Equipment (published by the IEE) enabling easy identification of a good or faulty asset.

A key feature of this guide is that it has been written in a brief, enabling an easy grasp of PAT testing. It includes some of the legal background and explains that as an experienced electrician, no additional qualification is required. PAT420 has memory storage for 10,000 assets and can download direct to a USB memory stick for reading by PC. It has fully configurable tests with direct access via soft-keys, and a full QWERTY keypad for fast and precise data entry. Automatic testing proceeds sequentially through bond, insulation and operational tests, indicating a pass or fail at each test, with user-selectable PASS/FAIL limits. Should a fail occur, testing is stopped.

For further details contact:
india.sales@megger.com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Omicron's Tando 700 - New system for high-voltage insulation testing and analysis

OMICRON's new TANDO 700 is a precise measuring and analysis system for dissipation/ power factor (Tan Delta) and capacitance of insulation in high-voltage (HV) equipment. Due to its compact and lightweight design, TANDO 700 can be easily transported for use in many different test areas. The system provides reliable measurement accuracy even in heavy interference environments, including power plants, substations and unscreened test labs.

Flexible testing solution

TANDO 700 can be used to measure both grounded and ungrounded test objects, since it can be operated on high-voltage potential. The flexible system is compatible with any type of reference capacitor for testing a variety of high-voltage equipment, including rotating machines (motors and generators), power cables and cable accessories, transformers, bushings, capacitors and circuit breakers.

TANDO 700 measures currents in a dynamic range from 5 µA to 1 A. The input range can be extended up to 28 A by means of optional external shunts provided by OMICRON. The system's powerful internal batteries enable long, uninterrupted measurement sessions. The easy-to-use software offers various functions for real-time data display, trend analysis and reporting.

TANDO 700 is a complete digital test and analysis system used to measure dissipation/power factor & capacitance parameters of high-voltage equipment.

The TANDO 700 system provides a precise and extremely safe measuring solution that makes insulation tests easier and more reliable.

Safe, plug-and-play operation

TANDO 700 automatically recognizes connected hardware for easy plug-and-play setup and operation. Fiber optic connections ensure complete galvanic isolation between the user and the measuring device for superior safety in high-voltage areas.

Early loss detection improves performance

The condition of insulation is essential for secure and reliable operation of high-voltage electrical equipment. Dissipation/ power factor (Tan Delta) and capacitance measurements are standard methods for testing overall insulation condition. Differences in electrical losses are often signs of mechanical displacements, the ingress of moisture, partial discharge, aging or degradation in insulation. By detecting these conditions early, corrective action can be taken to improve the performance and reliability of electrical equipment.

Additional measurement parameters

In addition to dissipation/power factor and capacitance, TANDO 700 also measures parameters such as power, current, voltage, impedance and frequency. All measurement data is displayed in real time.

The modular TANDO 700 system can also be used with OMICRON's MPD 600 system for simultaneous measurement and analysis of partial discharges.

Website:
www.omicron.at

Pyrotech's Energy Saving LED Flat Panel Down Light

Pyrotech offers a complete range of Energy Saving LED Flat Panel Down Light with optimum thermal management & highly efficient constant current driver having short circuit & open circuit protection in die-cast aluminum housing. With these lights you can save upto 60% power.

The salient features are: Upto 60% Power Saving
220V AC

Power Factor > 0.9 (above 6w)
Recessed Mounted
Ideal replacement for traditional PAR/CFL lamp
Suitable for Indoor Light

These are manufactured in-house using latest machinery. The manufacturing facilities available are:
3 SMT Line's for electronic driver assembly
Powder Coating Booth
CNC/LATHE Machines
Integrating Sphere for Lab testing.

For further details contact:
mktg@pyrotechlighting.com

Power to your device through COMBICON by Phoenix Contact

As a leading manufacturer of connectors, they always work to turn the growing requirements of industrial and infrastructure applications into new innovations. Whether it's for convenient conductor connection on site, automated PCB assembly in the THR process or reliable data transmission – they can always provide one with the right connection technology. Phoenix contact introduces a vast product range for power electronics based on innovative connection technologies which are much faster, simpler and easier to use and thus increase the efficiency and productivity of the whole system by saving valuable time, cost and space.

PWO 16

The new PWO 16 feed-through terminal block has an angled push-in connection and can transmit up to 76 A,1000 V. The terminal block features a single-position modular design and can be connected with any number of positions. The terminal block base can be additionally secured with rivets and screws. Space saving installation at a 45 degree angle and maximum tightness of seal even with low-viscosity selling compounds are attractive features for device manufacturing.

Technical Data

Conductor Cross-section 1.5 mm - 16 mm.

Ratings up to 76 A/1000V.

Connection method Push-In technology (Outside the device), Screw connection (Inside the device).

PLW 16

The PLW 16 feed-through terminal block is primarily used to transmit high currents and voltages through housing panels and other operating equipment. Due to fixed installation in the housing panel, it can offer a compact design even for large cross sections, suitable for housing wall thicknesses of 2.8mm to 3.2mm.

Technical Data

Conductor Cross-section up to 16 mm solid can be connected outside the device and up to 6 mm stranded can be connected inside the device.

Ratings up to 41 A/1000 V.

Pitch 10 mm.

Connection method Push-Lock (outside the device), Push-In (Inside the device).

PTSPL 6

PTSPL 6 has been introduced by Phoenix Contact which requires less space on PCB as compare to other power connector of same rating. It is suitable for THR soldering process. This cost effective innovative product solution is available in 2.1 mm pin length and 2.9 mm pin length. It also allows the customer to choose the variants which come in either closed or open condition.

Technical Data

Conductor cross-section 2.5 to 6 mm.

Ratings up to 41 A/1000 V.

Connection method Push-In.

SPTA 16

The new SPTA 16 PCB terminal block offers a 30 angled cable connection funnel for convenient conductor connection. The corresponding insulated jumpers enable the easy and convenient connection of multiple positions.

Technical Data

Conductor cross-sections 0.2 to 6 mm.

Ratings up to 41 A/1000 V.

Connection Method Push-In.

Pitch 7.5 mm.

For further details contact:
adverts@phoenixcontact.co.in

HT Metering Cubicle by Fateh Power Products Pvt Ltd

It is a four compartment MS cabinet used for accommodating. HT metering accessories like CTs, PTs, Trivector meter. It consists of central main compartment for mounting 3nos. CTs and 3 nos. PTs and 6nos Epoxy cast wall through bushing insulators.

Front compartment is for trivector meter and couple of left and right compartments are for incoming and outgoing supply connections. The purpose of HT Metering cubicles is to replace old pole mounted outdoor CT PT arrangement for metering purpose.

Compact and low maintenance equipment. Safe and easy for maintenance. Reduce theft of energy. It is indoor as well as outdoor worthy equipment used for 11KV, 22KV, and 33KV system voltages for energy metering.

For further details contact:
www.fatehpower.com

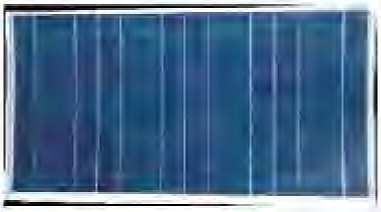
Solar PV Modules by Surana

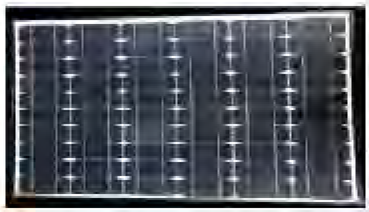
SURANA offers high-quality silicon Photo Photovoltaic Modules: a clean, reliable and economical source of energy. Their Solar PV Modules range from 3 Wp to 230 Wp and feature:

High-quality, Mono- or Polycrystalline cells from their European Suppliers.

SVL Solar PV modules confirm to International Standards IEC 61215 Ed – 2, IEC 61730, IEC 61701.

Strong Durability with aluminum alloy frame, tempered glass and waterproof lamination result in rugged protection against hostile conditions.





Quality: ISO 9001:2008 and ISO 14001: 2004.

Flexibility: Modules Ranging from 3Wp to 300 Wp.

MNRE Channel Partener.

SURANA takes great pride in continuously developing innovative, top-quality products for its costumers. In addition, SURANA provides a 5-year product guarantee on each Solar PV Module detailed below, plus a power warranty of 90% of the first 10 years and 80% for 25 years.

For further details contact:
www.suranaventures.com

The Advanced Multi-Level Inverter by Tmeic

SOLAAR WARE 500/630 redefined the PV utility scale solar inverter solution in reliability, efficiency and productivity. TMEIC sets the standard of Utility scale installation with its own proprietary and the most advanced multi-level inverter system by reducing the switching loss by 56%.

The advanced multi-level inverter uses a new circuit topology to create 3 output voltage level. With this new design, the inverter size has also been significantly reduced, achieving the world's smallest 500KW Inverter.

Featuring Compact Footprint

With this advanced inverter design, the size has also been significantly reduce, achieving the smallest 500/630kW inverter.

Grid connection Features

TMEIC has long history working with Japanese power companies and have developed the grid connection features together. All of TMEIC's utility scale inverters come with latest interconnection technology enhaced by most skilled engineers and scientists.

Power factor control.

Reactive / Active power control.

Fault ride/ through:

Voltage ride through (Low voltage ride through).

Frequency ride through.

TMEIC's proprietary Anti-islanding techniques: Slip mode frequency shift method.

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