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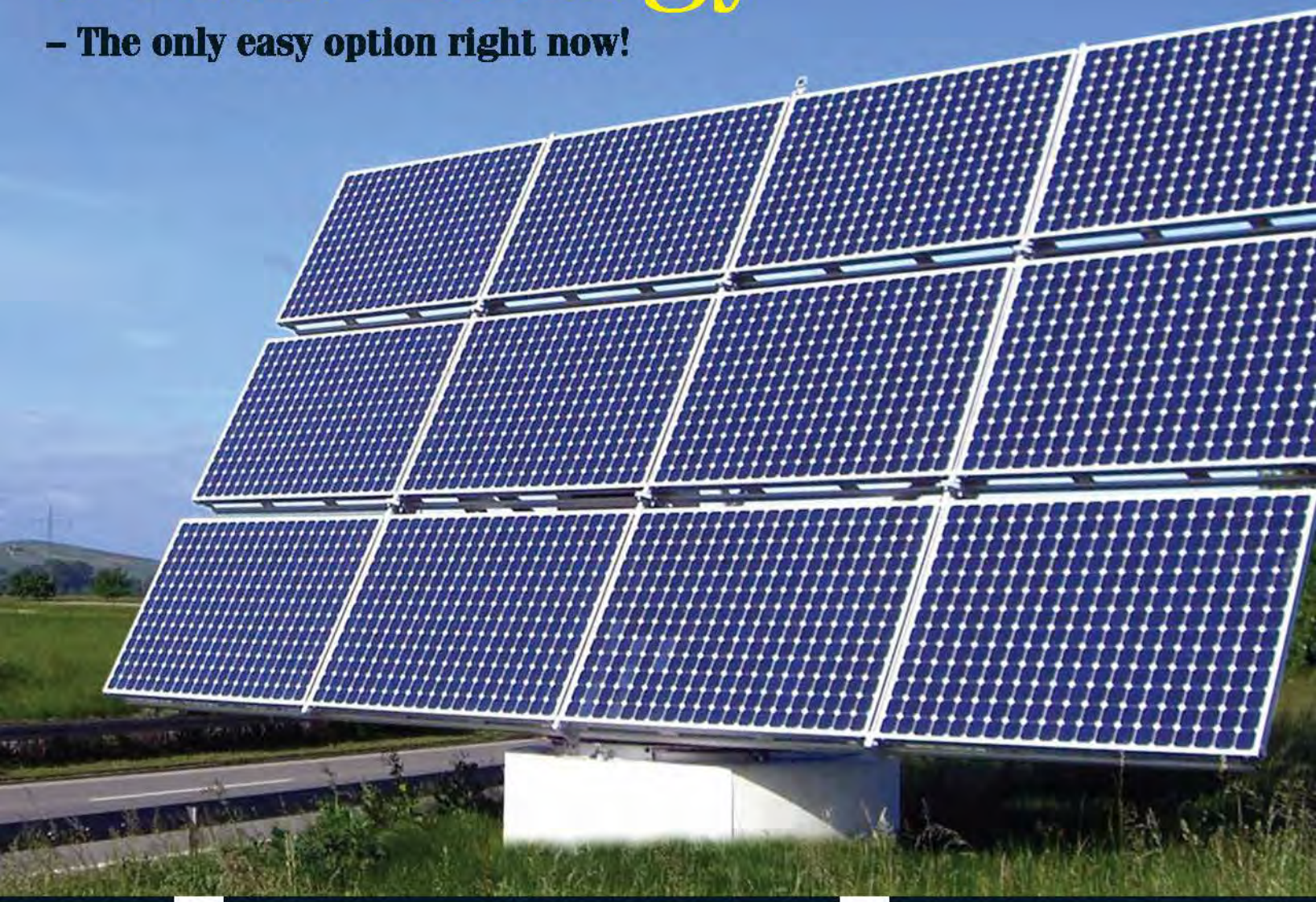

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Articles

Newsline

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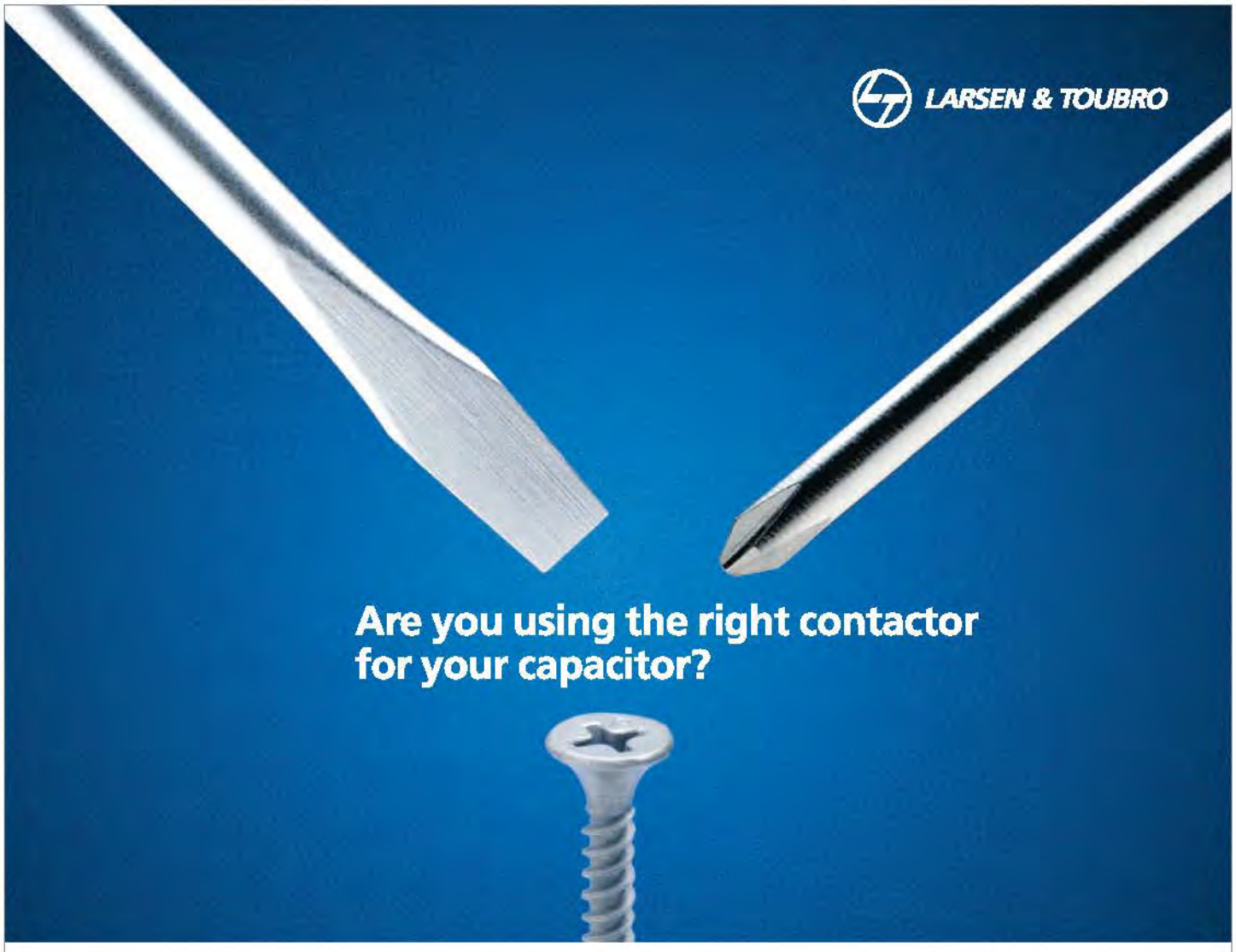

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India's total installed power capacity stood at 237 GW by February end

Energy management and environmental security are the current challenges. India's total installed power capacity stood at 237 GW by February end wherein thermal constitutes 68%, Hydro 17%, nuclear 02% and 12% is renewable energy. In this era of global energy issue, problem can be attributed to insufficient fossil fuel supplies and GHG emissions resulting from increasing fossil fuel consumption. In the gamut from renewable energy generation to options, 'A study of uncertainty in solar power variability' reviews state-of-the-art IIT Jodhpur Rooftop installed 101 kW PV systems.

Another study 'Power System Issues in Solar PV Interface using Automated Power Quality Analysis', highlights that in the deregulated and competitive environment, both electric utilities and customers are becoming increasingly concerned about quality of electric power. And, the major reason is availability of sophisticated technology. One such technology, which integrates two or more electricity generating methods, plays a vital role in supplying uninterrupted electricity to remote locations that are not connected with power grid, is well deliberated in an article 'Hybrid Systems for Renewable Electricity Generating Stations'.

Further, an article 'DC Microgrids: A Technical Perspective' discusses advantages of microgrid. DC microgrid is now changing the paradigm from a centralised generation and distribution system of power delivery to a system that is more flexible and accommodative of load.

All the more, we present a new layout for you 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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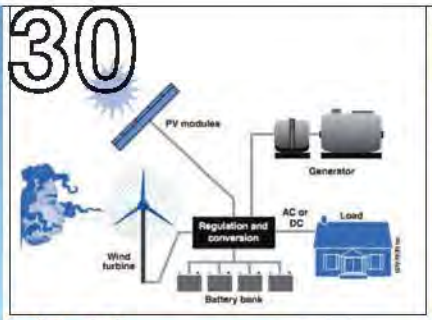

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Dr. Martin Füllenbach
CEO
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Alacrity for Renewable Energy and Energy Efficiency

Energy security and reducing GHG emissions may strengthen a country's economy. This alacrity in change is propelled by a need to conserve clean air, water, energy and land resources and focus onto renewable energy. Country's renewable generation from solar and wind forms major proportion of total generation in the grid in a few states. When we explore status, all India electricity generation during February 2014 was 75,948 BU. And of 237,742 MW, as on 28.2.2014, all India installed capacity for renewable energy sources (RES) is 29,462 MW (12.45%) whereas, thermal and hydro is 163,304 MW & 40,195 MW respectively and nuclear development remains long-stagnant at 4780 MW. However, addition of transmission lines during 2013-14 was 13,620 ckms yet, peak shortage of power supply occurred in J&K and UP in Northern region, Maharashtra in Western, AP, Karnataka and Tamil Nadu in Southern, Bihar in East and Assam in Northern East region of India.

Geographically, country balances variable output of RES located in few states by integrating them into all India grid. The inter-state and inter-regional transmission infrastructure is under development and it is expected that all five electrical regions of India would be synchronously connected in 2014, as mentioned in a report by CEA. Further, according to update from Mercom, a global clean energy communications and consultation firm, China recently announced 14 GW installation goal for 2014 and within it China has set target of 8 GW for distributed generation and another 6 GW for utility-scale projects with specific quotas in individual provinces. PV installations in Germany are forecasted to be around 2.75 GW in 2014, however, Germany's role in the solar market continues to decline as policy support retreats. The US solar market is forecast to install 6.4 GW in 2014.

Another boost for renewable and clean energy comes from need to comply with Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) regulations and continued competition from generators fuelled by natural gas that have recently led several power producers to announce plans to retire coal-fired facilities. Energy efficiency, renewable energy and natural gas are mainly responsible for 10% decline in GHG emissions United States since 2005, taking the country more than halfway to President Obama's goal of achieving a 17% reduction in emissions by 2020.

Global trends in technologies and markets indicate that clean energy sources are positioned to win in the long run. Among it, solar industry demand outlook remains robust and global solar installations are forecast to be around 46 GW in 2014. Further, new transmission corridors would be required for evacuating green energy from states such as Gujarat, J&K (Ladakh), Rajasthan and Tamil Nadu, more so, as Indian solar installations are forecast to be around 1,000 MW in 2014.

> *"Indian solar installations are forecast to be around 1,000 MW in 2014"*

Gopal Krishna Anand

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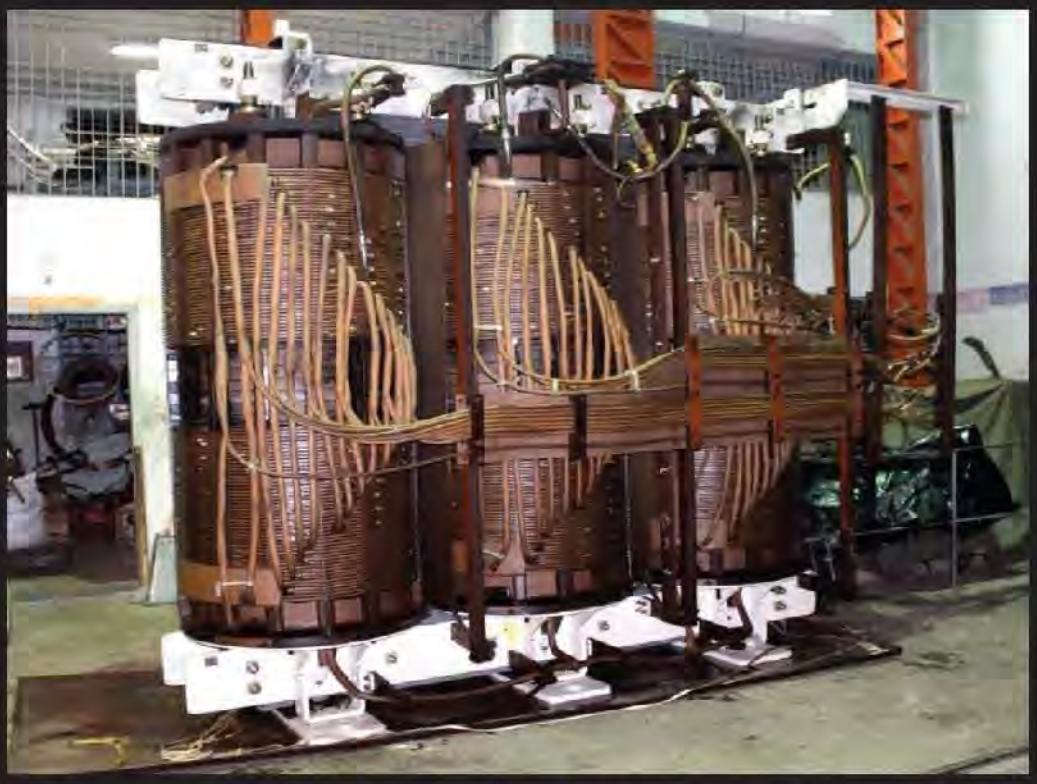

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Tata Power Mundra UMPP lights up lives of villagers with Solar Energy in Gujarat

Tata Power, through its wholly-owned subsidiary, Coastal Gujarat Power Limited (CGPL) announced installation of special Solar Powered street lights in the nearby villages of Nanikhakar, Modhva, Tragadi and Gundiyali in Mandvi Taluka under Project 'Surya Prakash'. Villagers near the plant used to face a problem of mobility at night as they do not have street lights in the village area. Common area lighting was one of the needs identified during company's meetings with community, Sarpanches and village opinion leaders. After consultation, 40 solar street lights in partnership with Tata Power Community Development Trust (TPCDT) were installed in the villages. Solar street lights are designed by Tata Power Solar Systems and

are cost-effective as they require lesser maintenance compared to conventional street lights.

BHEL bags mega contract for 2x800 MW Supercritical Boilers

Bharat Heavy Electricals Limited won an order for supply of 2x800 MW Steam Generators (Boilers) with supercritical parameters for an upcoming power project in Odisha. Valued at nearly Rs 30,000 Million, contract is placed on BHEL by NTPC Ltd for setting up 2x800 MW Steam Generator (SG) package at Darlipali in Odisha. Now, BHEL has taken its tally of supercritical boilers of 660 MW, 700 MW and 800 MW ratings to 32 sets, cementing its leadership position in supercritical technology. The order also reinforces BHEL's position at the forefront of the Indian power equipment manufacturing industry. BHEL's scope of work in the contract envisages design, engineering, manufacture, supply, erection, testing and commissioning of the Steam Generators and associated auxiliaries. The key equipment for the contract will be manufactured at BHEL's Trichy, Ranipet, Bhopal, Hyderabad and Bangalore plants while the company's Power Sector - Southern Region will be responsible for civil works and erection / commissioning of the equipment. BHEL has established state-of-the-art technology for manufacture of thermal sets up to 600 MW rating in the sub-critical range and has the capability to manufacture sets up to 1,000 MW rating. The company is also fully equipped to produce 660 MW/ 700 MW/ 800 MW thermal sets with supercritical parameters, and is shoring up its capability for higher rating Hydro sets and advanced class Gas Turbines to cater to upcoming market requirements. BHEL equipped sets generate around two thirds of the nation's power.

Book on The Political Economy of Energy and Growth

Oxford University Press, the world's largest university press, launched a prestigious book on India's energy security issues "The Political Economy of Energy and Growth" edited by Hon'ble Lieutenant Governor Najeeb Jung. Hon'ble Vice President of India, Hamid Ansari presided as chief guest for the event. The book covers a wide range of global energy debates, such as trends in oil markets, oil diplomacy, political economy of reforms, environmental concerns, interaction between macroeconomic policies and the energy sector, technology challenges, and innovations in oil industry, among others. Assessing the energy sector and its evolution, especially its significance for overall economic growth and development, the book by Jung also analyses India's national energy policy and its long term implications towards achieving energy security. The Hon'ble Vice-President said, "For two very good reasons, such a volume is a dire necessity. Firstly to honour someone who has devoted so much time and energy to this field. Secondly this is a solid compendium by people who have written with the requisite knowledge and experience particularly in the area of hydro carbons. I congratulate Najeeb Jung and the contributors for honouring Dr. Kelker for his lifelong work." Padma Vibhushan awardee Vijay Kelkar lauded Jung for editing such a well-timed volume on Energy and Growth.

EPCOS gets Supplier Excellence award from Bosch Rexroth

Bosch Rexroth in China presented EPCOS Limited in China, a subsidiary of TDK Corporation, with its Supplier Excellence Award 2013 for the first time. Prize honors outstanding performance in terms of product quality, punctual & on-time delivery, and support to R&D. Bosch Rexroth plant in Xi'an China, sources a broad range of EPCOS components. In particular, snap-in and screw-terminal aluminum electrolytic capacitors are used in DC link of frequency converters for all kinds of industrial drives and factory automation systems. Spectrum of products shipped includes EMC filters, film capacitors, varistors and ferrites. Bosch Rexroth is a world leader in the drive, motion and control technologies for automated manufacturing systems.

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Alstom T&D India to secure reliable power supply across North India

Alstom T&D India has secured € 20.1 million (1610 MINR) contract from Powergrid for the extension of air-insulated substations (AIS) at 14 sites across five Indian states, and 765 kV reactors at Bhiwani. The expansion will reduce transmission line overloading and improve grid stability in North India. The turnkey project covers the design, manufacturing, supply, erection, testing and commissioning of 765 kV, 400 kV and 220 kV AIS equipment, 765 kV reactors for Bhiwani and 50 MVAR shunt reactor for one of the substations, all with civil works. The equipment for the project will be manufactured at Alstom T&D India's manufacturing facilities across India. Rathin Basu, MD of Alstom T&D India, said, "Over 50% of India's 765 kV extra-high voltage substations are built with Alstom technology and solutions, demonstrating Alstom T&D India's significant contribution to the transmission backbone of the country. This prestigious and challenging project reaffirms our leadership position in the 765 kV turnkey substation market." Substations to be upgraded include 765/400 kV at Bhiwani and 400/220 kV substations at Hissar, Allahabad, Kanpur, Singrauli, Kota, Koteshwar, Rajpura, Panchkula, Patiala, Dhuri, Makhu, Mukstar and Nakodar in the northern region of the country. The 765/400 kV Bhiwani switchyard is centrally connected and feeds power to states of Punjab, Himachal Pradesh and Uttar Pradesh.

Rays Power Infra sets up 2nd Solar Park in Andhra Pradesh

Rays Power Infra set up its second solar park in the state of Andhra Pradesh, 100 km from Hyderabad city. Solar park is spread over a vast area of 125 acres and will generate approximately 15.5 lakh units per annum per MW of installed capacity. Total capacity envisaged is 25 MW. The solar park will offer clients world-class facilities and pooling substation to develop solar power plants of any capacity from 1 MW onwards. The land and infrastructure is already in place, it will reduce the time and effort required to setup a solar project. Approximately 50% of park's capacity had already been booked prior to the launch. In a bid to revolutionize the solar power sector, Rays Power Infra, the largest private solar park owner in the country also announces completion of its second solar park in the country and first in Andhra Pradesh (just 100 km from Hyderabad Airport).Rays Power Infra has successfully completed the first solar park in Rajasthan. In yet another development that underlines the rapid growth of the company, Ray Power Infra also bagged the EPC Contract for solar project of 5.5 MW from Essel infra (Zee TV group) in Karnataka. The company has so far commissioned a total of 45 MW of solar power plants and is executing another 40 MW in 2014-15. Needless to say, its impeccable track record has helped the company foray into Southern India market.

CG to supply Power Transformers and Switchgear to Ukraine

Avantha Group Company CG, received an order to provide two 40 MVA power transformers and one 110 kV Gas Insulated Switchgear (GIS) of 7 bays, to Ukrainian electricity utility Odessa Oblenergo for its Marazlievskaya substation. The order is valued at €2 million and installation and commissioning of equipment is expected to be completed by 2014 end. CG will undertake supervision of erection and commissioning of the transformers and switchgear. CG designs & manufacture an array of power and distribution transformers and reactors. CG also has the widest range of Medium to Ultra High Voltage switchgear products to meet requirements of power generation and distribution substations in utilities and industries. The equipment supplied will optimise efficiency, reliability and safety at the substation. Avantha Group Company CG's CEO and MD, Laurent Demortier, said, "The latest order is yet another move by CG to expand its footprint in the growing market of Eastern Europe. We look forward to strengthening our relationship with Odessa Oblenergo and establishing ourselves as a partner of choice to supply high-quality, durable power equipment."

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PEL in JV with Japanese Major Meidensha Corporation

Prime Electric Ltd (PEL), a company of the prime Group and a major Power Transformer manufacturer in India, has signed a JV agreement with Meidensha Corporation ("MEIDEN"), a Japanese multinational. Meiden has acquired a 23% stake in Prime Electric Limited ('PEL') as fresh equity. Through this collaboration with Meiden, PEL will expand its power T&D business in India and emerging countries in the global markets. PEL has a fully integrated and most advanced state-of-the-art manufacturing facilities located at Naidupet, Nellore in Andhra Pradesh, to produce large capacity power transformers, with a broad customer base in India and a rapidly expanding market reach to the Middle East, Russia, CIS countries and Africa. PEL is also actively engaged in Electrical Sub-Station EPC Projects which has tremendous potential in India as well as in several other countries where PEL is acitve. This Financial cum technical collaboration will enable PEL and Meiden to create a synergy between PEL's most advanced production facilities and MEIDEN's highly esteemed technologies and quality management, and will provide an opportunity for both companies to develop and expand their market in India and overseas for T&D projects through this JV company and also to offer a wide range of products and services to the continuously growing number of Japanese companies in India as well as to local companies looking for high quality products apart from its major thrust on export markets. In India, as the economy grows and urbanization and Industrialization progresses, which is very much on the cards, it is expected that investment in the power sector will be growing hugely to meet the ever increasing need of electricity in a medium to long term.

India Energy Security Scenarios (IESS) 2047 Website launched

India's import dependence on the energy front can be lowered to 21% in 2047 at its most optimal level from the current level of 31%, provided India takes corrective steps towards pricing that supports energy efficiency and establishes the appropriate regulatory mechanism. This has been projected in the study made under different Scenarios as part of IESS 2047. The tool (IESS) 2047 was launched by the Planning Commission in partnership with the Confederation of Indian Industry in New Delhi. It was developed by Planning Commission in consultation with key stakeholders including the UK Department of Energy and Climate Change, TERI, C-Step and Prayas Energy. It shows various combinations of energy demand and possible energy supply pathways available to the country ranging from the least effort to the heroic effort. The IESS 2047 is an energy scenario building tool which generates the energy demand and supply scenarios for India leading up to the year 2047. The demand and supply scenario for the year 2047 has been projected under four different scenarios: Least Effort; Determined Effort; Aggressive Effort and Heroic Effort Scenario. As per the projections made, the import dependence would be as high as 84% in case of 'Least Effort' Scenario while the same could improve to 21% in case of 'Heroic Effort' Scenario. Renewable energy shall play a crucial role in ensuring a lesser import dependence, hence, all the stakeholders would need to play a proactive role, industry would need to innovate, while the banks would need to reduce interest rates to promote green energy according to Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, who also said that there was a need to put in place the instruments including pricing and regulatory measures that support the shift in energy efficiency that we aim to achieve on the demand side.

Maithon Power Limited certified by IRQS

Indian Register Quality Systems (IRQS) certified Maithon Power Limited for successful implementation of ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2007. Maithon Power Limited (MPL), the 74:26 Joint Venture between Tata Power and Damodar Valley Corporation (DVC) has implemented 2 x 525 MW coal-fired power project power in Jharkhand. MPL is the first successful public-private partnership in green field generation project in the country. Maithon Power Limited (MPL) has successfully completed three internal system audits and two external audits conducted by IRQS, including certification audit which concluded in December 2013. The Integrated Management System (IMS) policy was signed on March 4, 2013. In less than one year, the MPL team successfully integrated Quality Management System, Environment Management System, Occupation Health and Safety Management System and completed the certification audit. Bhaskar Sarkar, CEO - Maithon Power Ltd. said, "It is a remarkable achievement for us to receive the IRQS certification for Quality, Environmental, and Occupational Health & Safety management practices." "We are confident that the ISO systems will help us in institutionalizing all processes and we will continue to strive for continuous enhancement of the project. The zeal and passion of the team members is a source of encouragement in our journey towards continuous improvement." Said Sabyasachi Mukherjee, Station Head, Maithon Power Limited Maithon Power Project is located at Maithon in the state of Jharkhand with a total capacity of 1050 MW. In addition to supplying power to DVC, power from the Maithon Project is being exported to power deficit northern states.

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NTPC's 2640 MW Bundelkhand Super Thermal Power Project

Foundation stone of NTPC's 2640 MW Bundelkhand Super Thermal Power Project was laid by Union Minister of State of Power (I/C) at Barethi, Chattarpur District of Madhya Pradesh. Project comprises of 4 units of 660 MW each with environment friendly super critical technology. Speaking on the occasion, Jyotiraditya Scinda said that the Barethi power project is an important milestone for the state as well as the entire country. Rajendra Shukla, State Energy Minister of Madhya Pradesh, said that government is pro-actively taking up all energy related projects in line with the future power requirements of the state. He said that it is a matter of pride to have a professional company like NTPC contributing to the growth of MP. Fifty percent of the power generated from the project will be supplied to the state of Madhya Pradesh. The estimated cost of the project is approx Rs 18000 crore and is envisaged to be commissioned in the 13th Plan linked to development of coal mine. Total land requirement of the project is 2841 Acres. The coal requirement of the project will be met from Banai coal block and water from proposed Majhgaon Dam and Shyamari Project for which land acquisition is in progress. NTPC presently meets about 24% of the total power requirement of Madhya Pradesh allocated from its various stations and has its largest power station in the country Vindhyachal Super Thermal Power Station of 4,260 MW installed capacity, situated in Singrauli district. With laying of foundation stone in Bundelkhand, NTPC has over 4500 MW of capacity under construction in Madhya Pradesh.

Eaton launches 93E UPS for variety of Applications

Eaton introduces 93E Uninterruptible Power System, which delivers efficient, safe, sustainable and reliable power. Eaton 93E UPS delivers the most efficient power quality solution in three key areas: space, power and cost. Engineered for maximum efficiency, Eaton 93E UPS delivers up to 98% efficiency while maintaining a small physical footprint. With internal batteries up to 60 kVA, this product provides an all-in-one solution that also reduces complexity of installation and startup and provides maximum runtime. "Eaton understands the challenge of increasing load on mission critical applications and the need for robust power backup with high efficiency and small footprint. 93E delivers high energy efficiency and reliability in a compact size to support applications desiring unswerving power protection." says Syed Sajjadh Ali, MD, Electrical Sector, India, Eaton. 93E's patented Eaton Hot Sync® technology makes it possible to parallel up to four UPSs to increase availability or add capacity. It has a large LCD that graphically displays UPS status and offers easy access to measurements, controls and settings. 93E ensures 30% smaller footprint than similar competitive solutions and its advanced Battery Management enhances battery life, reliability and predictability. Eaton 93E solution facilitates a lower total cost of ownership through a combination of energy-efficiency and high reliability with a compact footprint," said Sushil Virmani, Sales Director, Electrical Sector, India, Eaton.

IET ties up with IEEMA for information exchange

Institution of Engineering and Technology Services India, (IET) one of the world's largest professional societies of engineers and technicians, joined hands with Indian Electrical and Electronics Manufacturers Association (IEEMA), apex association of manufacturers of electrical, industrial electronics and allied equipment in India. The agreement aims to facilitate exchange and dissemination of technical information between the two organizations. This would cover three primary areas --joint events and activities; dissemination of knowledge, and efforts to improve the state of engineering education in India. MoU will make it easier for two organisations to work together to plan technical lectures, talks and to jointly develop programmes, activities and materials aimed at enhancing quality of engineering education in India. This will include forums, conferences, publications, standards, educational materials and awards. Shekhar Sanyal, Director and Country Head, IET India, said, "We believe this agreement will promote co-operation and understanding between our two organisations and will go a long way in furthering technology awareness among the general public and students of engineering. With its tremendous potential to impact the engineering and technology scene in India, the agreement demonstrates the IET's commitment to this aspect of the country's economy". Sunil Misra, Director General, IEEMA said, "IEEMA has been actively engaged in the knowledge enrichment and skill up gradation of its stakeholder community, like the government utilities, MSME manufacturers and the Academia, as part of its stated objective. We firmly believe that collaboration and co-creation is the only way forward and are confident that this MoU with IET will add significant value in IEEMA's pursuit of making Indian electrical and allied industry a knowledge capital of the world".

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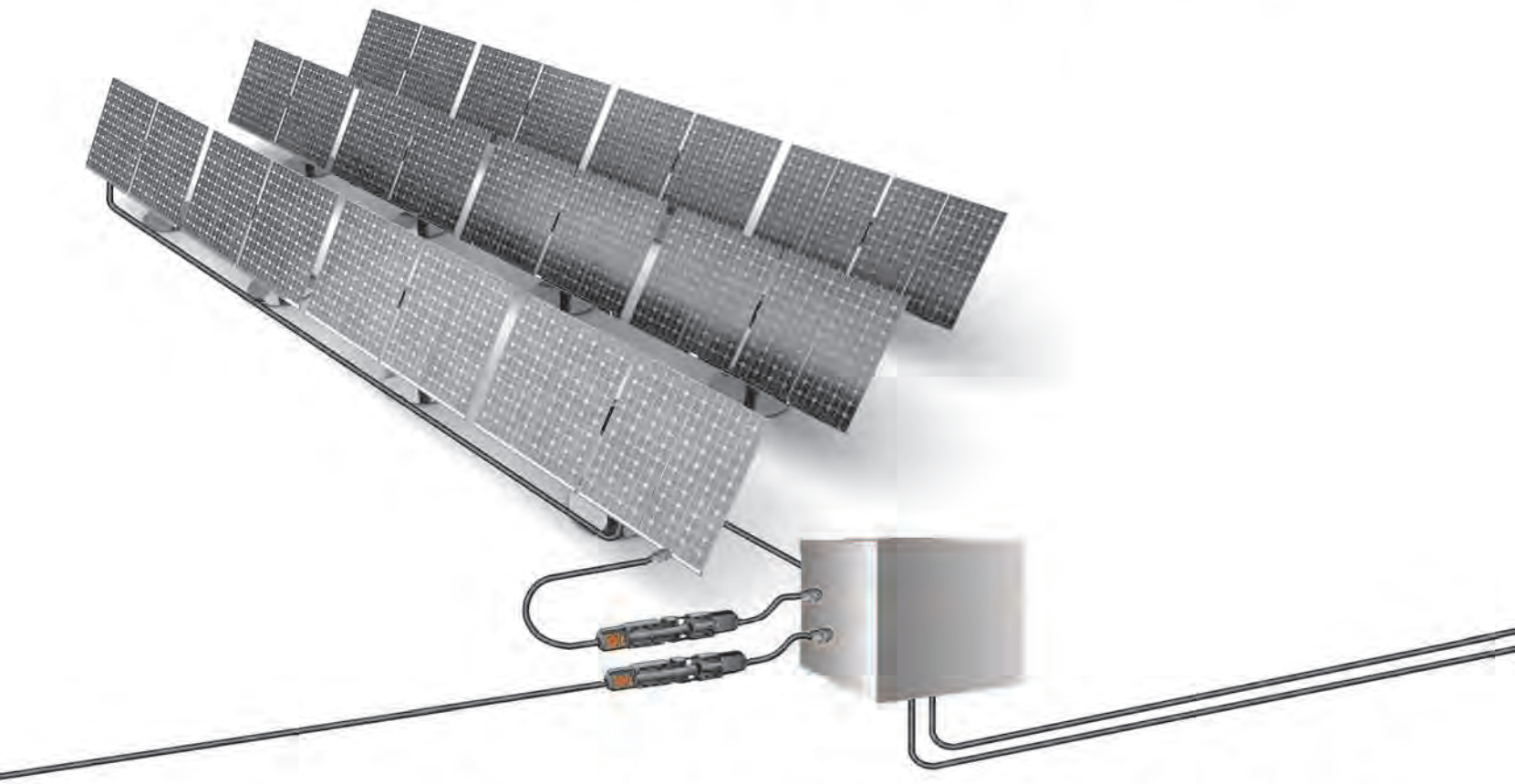

Today renewable energy sources play a crucial role in generating clean, economic and dependable energy. The cables used in solar energy applications must withstand extreme weather conditions and have a lifespan of at least 20 years. This is where Lapp's ÖLFLEX® comes into the picture. The ÖLFLEX® Solar cables are TUV certified with better thermal endurance properties apart from being weather resistant, abrasion resistant and UV resistant. The double layered electron beam cross-linked insulation extends cable's lifespan and also makes it ideal for outdoor applications. ÖLFLEX® covers diverse application areas from major plants to homes.

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LAPP INDIA

Siemens to deliver Direct Drive wind turbine technology in Japan

Siemens Energy secured a total 51 MW wind power order from Japan's largest wind power developer, Eurus Energy Holdings Corporation. Siemens will provide 17 direct drive wind turbines of the type SWT-3.0-101 to Eurus Yurikogen wind power plant, located North West Coast of Japan. The deal also includes a five-year service and maintenance agreement. Siemens SWT-3.0-101 wind turbines ordered for the project each have a capacity of 3 MW and a rotor diameter of 101 meters. Following orders for the Akita Port project in 2013 and recently for a project in South Korea, this latest order from Japan reinforces the increased interest of the Asian market in direct drive wind turbines. Compared to conventional technology, the gearless wind turbine has half the components and substantially fewer rotating parts, setting a new standard for efficiency and low operational costs. Installation and commissioning of the Eurus Yurikogen wind farm will start in January 2016. "By providing competitive Cost of Energy to our customer, we are fulfilling our commitment to further benefit local society with more clean and renewable energy", stated Bernhard Mueller, Head of Onshore Asia Pacific, Siemens Wind Power. "This is going to be our 3rd largest wind farm in Japan. With advanced wind turbine technology, we sincerely hope that the wind farm will contribute to the local community development together with the people in Akita", said Ms. Mitsue Usami, GM, Corporate Communications and Environmental Management Office at Eurus Energy. With a cumulative installation of 126 MW in Japan since 1999, Siemens Wind Power is a trustworthy and reliable business partner for Japan's renewable energy.

GE and Highview Power Storage in technology collaboration agreement

GE Oil & Gas signed a global licensing and technology collaboration agreement with Highview Power Storage, a UK supplier of large-scale liquid air energy storage (LAES) systems. The companies will explore opportunities to integrate Highview's LAES technology in peaker power plants where GE gas turbines and gas engines are currently or will be installed to increase power plant efficiency, grid reliability and the distribution of renewable energy. Highview's LAES technology uses liquid air or nitrogen as the storage medium to provide long-duration energy storage without the geographical restrictions found with other energy storage methods. The technology also can convert low-grade waste heat into power, increasing the overall efficiency of a host power plant. Since 2011, Highview's LAES technology has been operating at a grid-connected 350 kilowatt/2.5 megawatt-hour) pilot plant hosted by SSE (Scottish & Southern Energy) adjacent to SSE's 80-MW Slough Heat and Power Biomass Plant in Greater London. In February 2014, the U.K. Department of Energy & Climate Change awarded Highview and Viridor, a U.K. recycling, renewable energy and waste management company, more than £8 million to build a new 5-MW/15-MWh LAES demonstration plant at a Viridor landfill gas-to-energy plant in the U.K. LAES facility will be powered by a GE Oil & Gas turbo-generator and will demonstrate the technology at commercial scale for the first time when it begins operating in the spring of 2015. "Highview's LAES technology and access to an operational pilot plant makes it an ideal partner for GE Oil & Gas to provide fully integrated energy solutions to our customers," said Luca Maria Rossi, product management general manager for GE Oil & Gas' Turbomachinery Solutions business.

ABB to strengthen power infrastructure in Saudi Arabia

ABB, won an order worth around $110 million from the Saudi Electricity Company (SEC), Saudi Arabia's national power transmission and distribution operator, to construct substations to help boost transmission capacity in the country's western region. New substations will link Taif East Governorate, a part of the Mecca region, to national 380 kV transmission grid. The 110 kV power supply enabled by the substations will serve the settlements of Turbah, Al-Khurmah and Rania, mitigating the use of diesel-generated power in isolated areas. "We are privileged to continue supporting the development of Saudi Arabia's power infrastructure," said Claudio Facchin, head of ABB's Power Systems division. "These substations will strengthen the grid and enhance transmission capacity, bringing much-needed electricity to the region to meet growing domestic and industrial demand." Turnkey order includes design, supply, installation and commissioning of a 380/110 kV bulk supply point substation and expansion of remote-end substations in Bisha and Sised to support the 380 kV grid interconnection. ABB's gas-insulated switchgear & hybrid technologies will ensure reliability and efficiency while minimizing environmental footprint. Other key product supplies include control, protection, auxiliary systems and substation automation equipment compliant with international IEC61850 standard to enable monitoring and control of the substations from a remote control center.

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GAIL signs MoU with Chubu Electric of Japan for joint LNG procurement

During Gastech Conference held in Seoul, South Korea, GAIL signed a Memorandum of Understanding (MoU) with Chubu Electric Power Co Inc., Japan (Chubu) during March. Under MoU, GAIL and Chubu shall mainly explore possibilities for collaboration in the area of joint LNG procurement. It is assessed that with GAIL joining hands with Chubu for jointly pursuing LNG procurement and other allied business opportunities, the collaboration shall augment GAIL's efforts to aggressively source LNG volumes on competitive terms and would be a win-win proposition for both companies. GAIL's latest move is also in sync with the company's recent efforts in establishing and promoting Asia LNG Forum, a sort of Asian LNG buyers' club. MoU is an effort by GAIL towards bridging gap in demand supply of natural gas in Indian market. This is in addition to other initiatives of GAIL towards LNG sourcing, creating LNG regasification infrastructure, reserving liquefaction tolling capacity in overseas projects and augmenting transmission capacity over the next few years. GAIL will continue to make efforts to tie-up affordable LNG in its portfolio to meet the rapidly growing energy demand of the Indian market. Speaking during the inaugural Ministerial session of the Gastech B C Tripathi, CMD, GAIL, highlighted the enormous potential for gas demand in Asia and said that despite being the largest importer of LNG, Asian market is paying premium for LNG. He emphasized need for developing synergies among Asian countries by promoting cross border pipelines to bring gas from central Asia, interlink Asian countries through gas pipelines and also promoting Asian Co-operation Forum to address Asian Gas Grid and Asian LNG forum and Asia Hub/index.

Environmental legislation for furnaces and power plants

Environmental legislation demands stricter efficiency and control of emissions from industrial boilers, furnaces and other power plant processes. In USA, Environmental Protection Agency recently introduced MACT (Boiler Maximum Achievable Control Technology) Rule, requiring operators to carry out tune-up procedures either annually or bi-annually, affecting an estimated 14,316 boilers and process heaters. The precise and swift operation of dampers for accurate control of combustion air and flue gas is essential for achievement of reduced emissions, improved boiler draft control and lower fuel consumption, which can also result in dramatic cost savings. However, many boilers employ old technologies that are not accurate or powerful enough to position dampers with the necessary speed to meet contemporary requirements. Replacing obsolete equipment with fast acting Rotork Type K damper drives has many advantages, contributing to improved burner management and cleaner performance. It offers a swift 'drop-in-place' retrofit solution that precisely fits the application without any field engineering or fabrication. Existing connection rods and linkages can be used without modification; commissioning is quickly and simply completed. Type K damper drives provide a 100% duty cycle, with a continuous modulating service rating of 3,600 starts per hour. An output torque of up to 28,200 Nm (20,800 lbf ft) is available with high speed stroke times as low as 3 seconds full scale. The rugged, open frame construction is designed for virtually maintenance-free operation in harsh, high temperature environments up to 150°C.

Yingli Green Energy to supply 54 MW of Solar modules for Seven Projects in UK

Yingli Green Energy Holding Company Limited, the largest vertically integrated photovoltaic module manufacturer in the world, known as "Yingli Solar", announced that it will supply 54 MW of solar modules to seven projects in United Kingdom that are developed by Grid Essence UK Ltd, a wholly-owned subsidiary of Grid Essence Holdings Ltd. The Company's multicrystalline YGE Series modules will be installed in ground-mounted solar projects located in the south of England and Wales. Construction has already begun, and modules will be delivered between February and March 2014. Scheduled for grid connection by the end of Q1 2014, the seven solar power plants will generate an estimated total of 54,500 MWh of green electricity per year. The fully permitted projects are also eligible to receive Renewable Obligation Certificates (ROCs) issued by the United Kingdom Department for Energy and Climate Change (DECC). ROCs, which can be traded or sold, can be used by U.K. electricity suppliers to meet regulatory requirements to generate electricity from renewable resources. "We are honoured to cooperate with Yingli Green Energy on these projects, which are critical for us to achieve our renewable energy target within the next five years. By leveraging our track record of success in solar project development and combined with Yingli Solar's great brand reputation, we are confident that this cooperation will bring us a sustainable growth," commented Steve Bourbonnais, the Co-Founder & Chief Executive Officer of Grid Essence. "We are pleased to partner with Grid Essence on these projects while at the same time making a positive contribution to the burgeoning solar industry in the U.K. In doing so, we will continue maintaining our leading position in this important market," said Liansheng Miao, Chairman and Chief Executive Officer of Yingli Green Energy.

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India is a growing economy, in spite of its fluid political situation it is emerging strongly as a force to reckon with. India has insatiable appetite for energy for its rising economy. According to the ministry of power, government of India, we have total installed capacity of 214 GW by the end 2013, while our overall growth of power demand is 46.9% in 2012-17 financial years. After 65 years of Independence, still one third of our population remains without power during peak hours. How we will meet those challenges and what are the possible options before us?

Aqeel Ahmad

Out of total 214 GW of electric power 66% thermal, 20% hydro, 02% nuclear and 12% is renewable energy. In the renewable energy 70% is wind, 13% is small hydro (less than 25 MW) projects, 04% solar and 13% biomass.

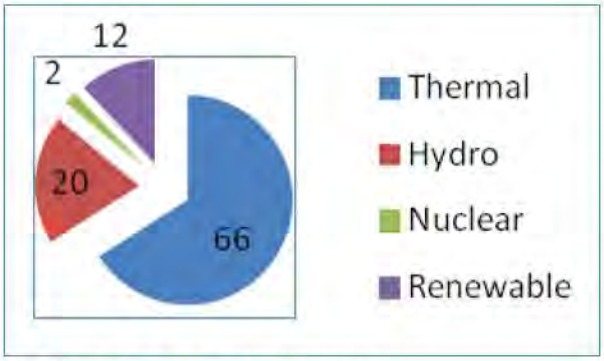

Fig. 1: India's Total Power Generation

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 dames is time consuming besides the severe mass resistance, we are facing after Uttarakhand tragedy recently.

As far as nuclear power is concerned, 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.

Carbon Foot Prints

Global warming is not a myth, it is a hard reality. This year's bone biting cold (BBC) in USA and floods in Europe, China and draughts in Australia are 'waking up' calls for entire humanity.

Let us see 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.

According to Pembina Institute of Ontario, Canada, Ontario can attain 100% renewable energy by 2020 and rest of the world by 2050. Among the Renewable energy, wind energy is leading, India has already commissioned 17 GW on the long coastal line.

Here, there is significant difference in performance in 'on' and 'off' shore wind energy plants. India is still having huge potential to explore on wind. But wind alone can't meet the deficiency in generation and peak demand. Biomass is also having good potential to further explore especially while almost 70% Indian still live in villages.

Now the only option left is solar power, using photo voltaic 'PV'. The advantages of solar for India are plenty of sunny days, already existing electrical infrastructure in form of distribution lines all along the country.

Entire country lies within irradiation of 4-6 KWh/m^2, best areas are Rajasthan, Gujarat, Maharashtra, Tamilnadu and Andhra Pradesh. Thar region (35000 km^2) alone in the Gujarat, is good enough to produce 700 GW to 2100 GW. India is having ambitious plans to explore this

huge natural wealth. By the end of 2013, India has already achieved target of more than 1 GW, by 2017 its target is 3-4 GW and by the end of 2020, it is 20 GW as per the program of Jawaharlal Nehru solar mission of govt.of India.

While China has already achieved more than 7 GW, Japan 4.5 GW, South Africa 1.3 GW, Italy 17 GW and leading country Germany 25 GW. Saudi Arabia one of the largest petroleum producing country also has ambitious plans for the solar power 31 GW by 2020. Saudi is having highest solar irradiation 7KWh/m^2 in the world due to vast desert and longitude and latitudinal position.

Cost of Rooftop Solar solution

Rooftop Solar Power plants can be broadly categorized into Battery-based and Non-Battery based systems. The benchmark cost set by MNRE for the year 2013-14 for these systems are Rs 90-100 per W for Non-Battery based systems and Rs 170-210 per W for Battery-based systems.

Energy generated from a Solar Power plant?

Energy generated from a Solar Power plant depends on several factors like External, Internal and O&M -

- External factors which are beyond the control of a solar planer can include the following:
  - Number of sunny days
  - Solar Irradiation- based on latitude and longitude
  - Day Temperatures- changes during winter and summer
  - Air Mass- different on sea level and mountainous region
- The output also depends on the following internal factors all of which are within the control of a Solar Developer:
  - Plant Location- ground or roof top
  - Usage of Solar Tracking systems- single or double axis
  - Quality of equipment used- ranging from made in Europe to made in China
  - Workmanship of the EPC contractor- experienced or naive
- And how good are Operation & Maintenance activities like panel dust removing, inverter, AC/DC circuit faults and battery maintenance.

Life Span of a Solar Setup

PV Panel

The useful life of a typical Solar Power plant is considered to be 25 years. This is the duration for which long-term PPAs are signed and financial models are built.

However, Solar Power plants can run beyond 25 years while producing a lower output. Many Solar Panel manufacturers guarantee an output of 90% at the end of 10 years and 80% at the end of 25 years.

Balance of System (BOS)

Balance of system comprises power conditioning equipment like inverter, AC/DC cabling, connection boxes, and switch gear have minimum 5 year guarantee depending upon the manufacturer and all options are available in Indian market ranging from Chinese to Europe. Storage batteries are the weakest and one of the costliest link in the solar set up but it provide reliability too. 'Other options are direct grid connections with net metering options.

How to design your stand alone system

Switching to solar power may require a substantial initial investment. We need to understand the following in order to get a good idea how much your standalone photovoltaic (PV) solar power system will cost.

- **The total watt-hours per day of energy:** Prepare a list of all your appliances and devices and how many hours per day each will be run.
- **Peak instantaneous power output (PIPO):** Determine which appliances you'll be running at the same time; add their power draws, measured in watts
- **Duty cycle:** For example, a weekend room used for two days has a duty cycle of 2/7, or about 28 percent. A system used every day has a duty cycle of 100 percent.
- **Estimate how many hours of good sunlight a day you can expect:** Sunlight is difficult to estimate with much accuracy because it depends on the weather and on the time of year during which you're interested in using your system.
- Here is an example of some of the calculations for an off-grid home in the northern region of India. Here's what you need to keep in mind about this scenario:
  - The duty cycle is 100 percent, and the house is used year-round.
  - Worst-case expected sunlight per day is around four hours during rainy season.
  - A two-day power reserve is required because the backup generator is 20 years old and may or may not start,
  - The system must output 220VAC as the common single phase supply in India.

The following table shows the sample power load for an average home.

Energy Consumption in any average Home

AC Device	Watts	Hours/Day	Watt-Hours/Day
Kitchen lights	120	6	720
Family room light	120	4	460
TV	70	3	210
Electric kettle	200	0.5	100
Clock radio	1	24	24
Table fan	15	6	90
Computer	100	7	700
Other items	400	0.5	200

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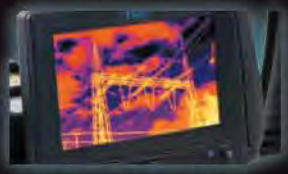

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With this chart, you can do some of the following calculations for your load analysis. To calculate the last column, simply multiply the first two columns.

With this chart, you can do some of the following calculations for your load analysis. To calculate the last column, simply multiply the first two columns.

Calculation	Answer
Total energy needs in one day	2.5 kWh/day
Adjustment for inefficiency (10 percent)	2.8 kWh/day
Maximum instantaneous load	700 W
Duty cycle	100%
Total energy needs in one week	19.4 kWh/week
Power needed from PV panels (@4hrs/day)	700 W

Next, calculate battery size, which is specified in terms of amp-hours (Ah). Most batteries are 12VDC, but other sizes are also available. For this example, assume a 12VDC system.

- Take the total kWh/day, multiply this by 1,000 to get kWh/day, and then divide this value by the battery voltage.
- The generator is old, so triple the result from Step 1 to account for the two reserve days. To cover the two reserve days, the cabin owners need batteries that can hold three days' worth of charge.
- Multiply the minimum battery capacity from Step 2 by a factor of two.

Batteries last much longer when they're not drained of more than about 70 percent of their available energy.

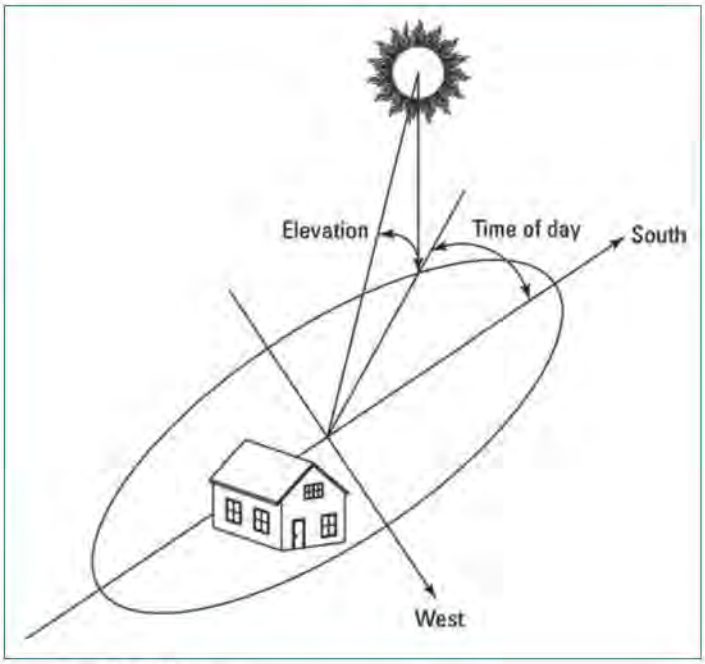
Finally, they're going to need a larger PV module capacity in order to get the three-day reserve. It's okay to go without power a few times, and there's a backup generator, so if they double the size of the PV module capacity, they should be safe. Hence, the owners need 1,400 watts of PV.

Solar radiation Fundamentals: We need to understand the basics for the planning around our roof top.

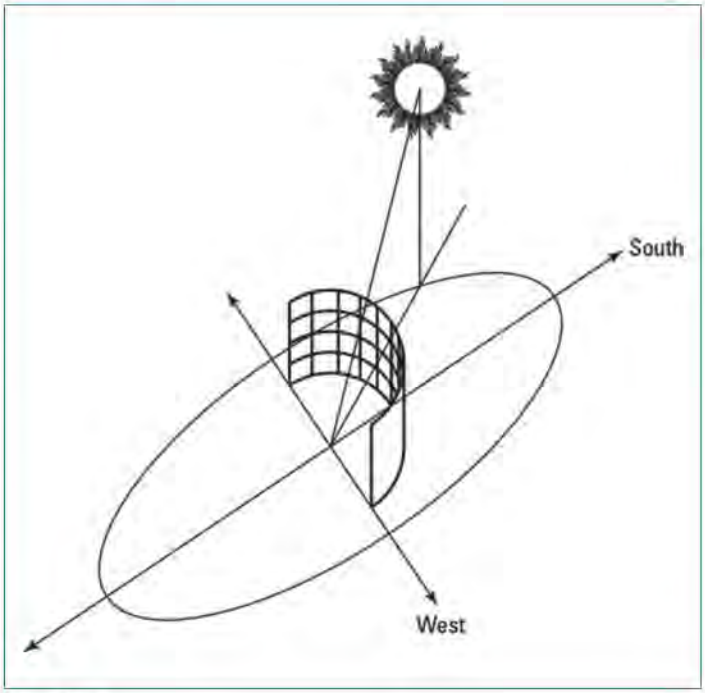
The position of the sun may be plotted with two angles: azimuth and elevation.

- Azimuth is the sun's angular distance from a fixed line; in the northern hemisphere, that fixed line will probably run directly south. Theoretically, at noon, when the sun is directly overhead, the azimuth angle is 0.
- Elevation is the angle created by a line parallel to the ground and a line going from the ground to the sun. If the sun is directly overhead, its elevation measurement is 90 degrees; when it sits on the horizon, the elevation is 0.

Then create a graph of the sun's passage over the course of a day. Imagine a sheet of graph paper wrapped around your house. As the day progresses, you make dots where the suns shines on the graph paper.



Location of the Sun



Sun Chart

The following figure shows your sun chart looks like if you plot the movement of the sun. The arc in the middle represents either spring or fall. All other paths lie somewhere between the two extremes, represented by summer and winter solstice, which are the longest and shortest days of the year (June 21 and December 21, respectively).

Effect of Weather on Solar Radiation (Summer to Winter)

The following figure shows your sun chart looks like if you plot

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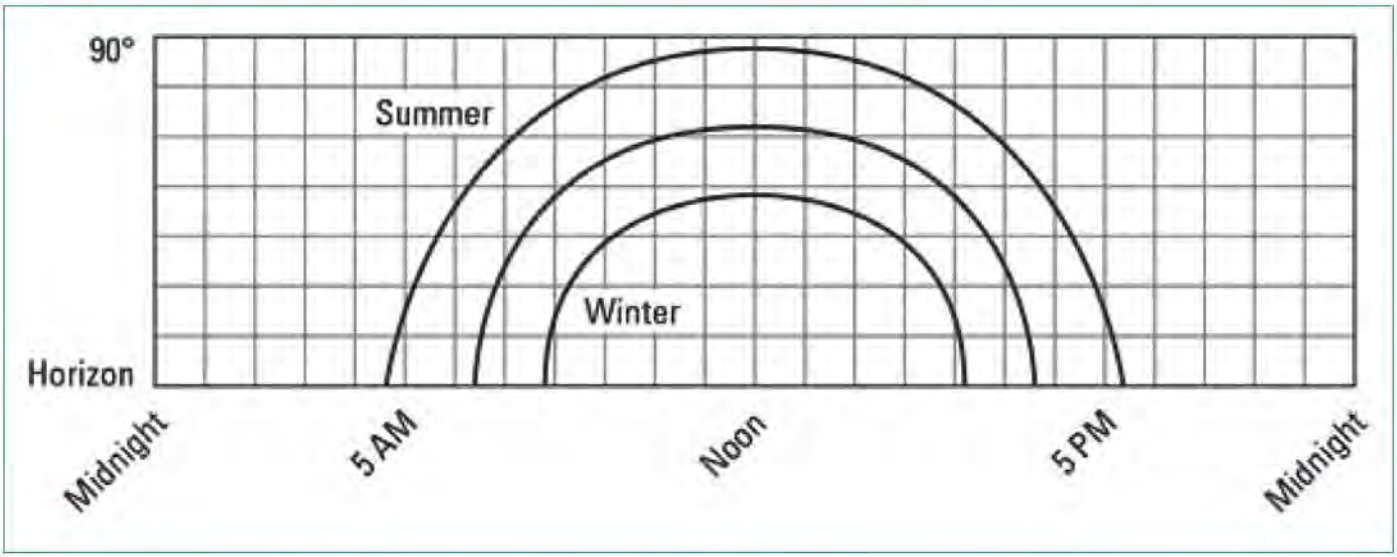

the movement of the sun. The arc in the middle represents either spring or fall. All other paths lie somewhere between the two extremes, represented by summer and winter solstice, which are the longest and shortest days of the year (June 21 and December 21, respectively).

Skyline Effect

When the sun goes behind a mountain or a tall building, you don't get any direct sunlight at all. If the sun goes behind a tree, you may get some direct sunlight, but mostly you get shading. Impediments on the horizon also change the time of dawn and dusk. If a big mountain lies directly west of your house, dusk falls a lot earlier. It is very important during the survey of your building to find actual amount of solar radiation around your home on your roof top.

On Grid or Off Grid

If the cost is not important and we want 24 hours power availability, we need to go off grid system for our home. While the cheaper solution is On Grid i.e. without battery backups, you are connected to grid through net metering, when there is surplus power you give to grid and local power distribution company will settle it in your electricity bill while in case of low solar power production for example during July -August in India, you can get power from the grid.

Electricity tariff is different in different part of the country. For the domestic sector it is divided in different slabs for example 1-50 units x1 and for 51-100 x2 and so on but average power rate is fluctuating between Rs 4.50 to Rs 6.50 per unit and it is highest probably in Mumbai while power generation for one unit (KWh) of power by diesel generator is Rs 17 while using, wind power it is Rs 5.25 – 6.00 per unit and by solar Rs 6.50-7.50 for utility scale plant. India has achieved grid parity i.e. when solar power cost will match average electrical tariff. Therefore, it is right time to go for solar!

Profile

Aqeel Ahmad

has graduation with electrical engineering & diploma in Mechanical engineering from Aligarh M. University. He has acquired diplomas in French language during his stay in Africa. He is having more than 23 years of working 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 the areas of design, commissioning, O&M up to 230 KV substations and solar power. He is regularly writing articles and books on electrical engineering and solar for different national and international magazines and publishers.

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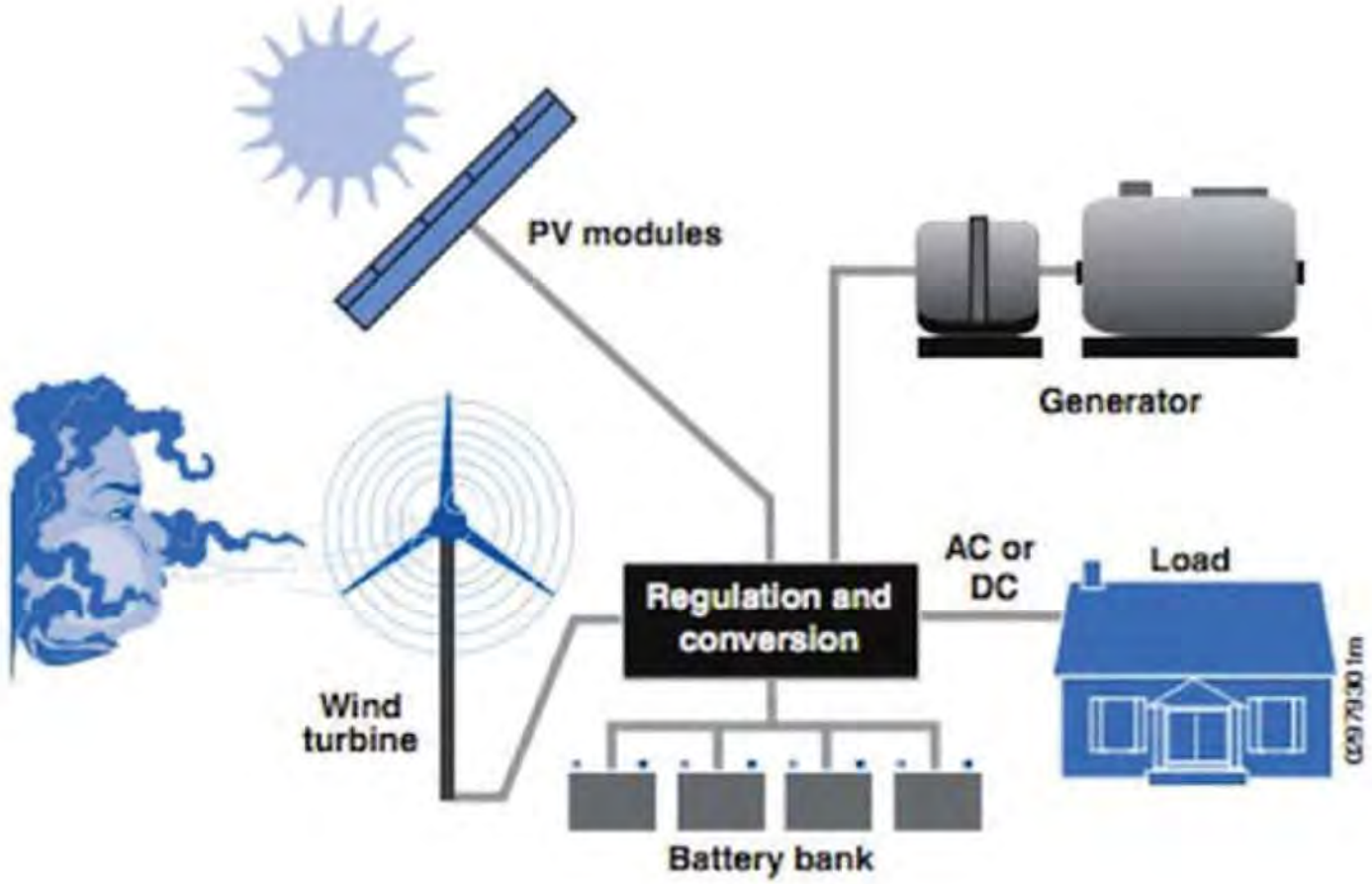
Hybrid Systems *for*
Renewable Electricity Generating Stations



Hybrid power systems integrating two or more electricity generating methods play a vital role in supplying uninterrupted electricity to remote locations, which remain not connected with power grid or it is not possible to connect them with power grid due to high cost of long transmission lines and distribution. They cooperate with different primary electricity generating stations and generate electricity or electricity and heat both using modern power electronic systems. Being modular in nature, they can be expanded in size and minimize or completely avoid necessity of electricity back up.

M P Singh

Most of the rural communities are not connected to public electricity grid and extension of grid involves installation of high or medium-voltage lines, substations and a low-voltage distribution network. Due to low potential electricity demand and long distances from existing grid, costs of electrifying small communities/rural areas through grid extension are high and therefore may not be economically viable. Another option for meeting electricity requirements of rural areas is generation from diesel electricity generating sets. However, the rising cost of diesel has made diesel electricity unaffordable to rural population. Also this source has undesirable impacts on environment. Similarly, other fossil fuel based generating stations may not be feasible due to high cost, lack of load and transportation problems etc.

Option left to provide electricity to fragmented rural areas or areas distant from grid is through renewable electricity sources like small hydro power, solar power, wind power, biomass power stations etc. They can contribute to realization of important economic, environmental and social objectives by enhancing energy supply security, reducing greenhouse gases/other pollutants and creating local employment to improve general social welfare/ living conditions of rural population. However, standalone renewable electricity generation systems have their own limitations. Small hydro stations have variations in electricity generation on daily, weekly, monthly and seasonal basis. Solar electricity is available during sunny days and not in rainy/cloudy days & during nights. Investment is required on storage batteries to use it in cloudy days and during nights. Wind electricity is available only when wind is blowing at required speed, which is not available at all times and at all places.

Therefore, need arises for combination of two or more renewable electricity generating stations or a renewable electricity generating station with a conventional electricity generating station to have all the time electricity availability in rural areas. A typical hybrid power system can combine two or more electricity sources from renewable electricity technologies like photovoltaic panels, wind, small hydro turbines and from conventional technologies fossil based generation. This paper describes the hybrid power systems, their role in rural development and their different types.

Hybrid Power System

A combination of different but complementary energy generation systems based on renewable energy or mixed (renewable energy hybrid with fossil-fuel based electricity generation) is known as hybrid power system or simply hybrid system. Hybrid systems capture the best features of each energy resource and can provide grid-quality electricity from few kilowatts to hundred kilowatts or megawatts. They can be developed in new integrated designs within small electricity distribution systems and can also be retrofitted in diesel based power systems.

Hybrid power systems cooperate with different primary electricity generating stations and generate electricity or electricity and heat both. Mutual cooperation between them is accomplished by using modern power electronic systems. However, they are able to supply electricity independently to a house or group of houses, farms and from small scale industrial equipment to large local communities. They can be connected with power grid. They can serve as reserve for electric power and when they generate electricity more than their consumption, surplus power produced by them is fed in to the grid.

Hybrid power systems contain a number of power generation devices/ stations such as wind turbines, photovoltaic modules, pumped storage hydro, small/ mini/micro hydro, biomass, battery banks, converters, rectifiers, and local controller and/or fossil fuel generators. They are generally independent of large centralized electric grids and are used in isolated areas; especially where cost for large scale expansion of electrical grids is prohibitive and transportation costs of diesel or other fuels are very high. They can range from small systems designed for one or several households to very large areas for remote island grids/ large communities.

With the use of hybrid power systems, electricity generated from new and renewable sources of energy can be made available almost throughout year continuously and it can solve problems of seasonal variations. Such systems are modular in nature and can be expanded in size easily. They make use of two or more electricity generating methods. They minimize or completely get away from necessity of backup electricity. Hybrid power system of standalone wind power generating turbines with photovoltaic cells is considered the best hybrid system. These two renewable electricity generating systems are complement to each other.

Hybrid power systems required for supplying electricity to houses may not have an automated backup generator. They may require simple design including turbine, photovoltaic array, disconnects, batteries, DC loads and AC power through an inverter. Small loads can be met through photovoltaic power and larger loads through wind power. In many cases, a combination of photovoltaic and wind power may be required.

Role of Hybrid Power Systems

Basic services like lighting, drinking water supply, health care, education, transportation and communication are essential requirement for prosperity of a community and must be available at affordable prices. Rural areas are in great need of such services. Hybrid power systems provide steady community-level electricity service for village electrification and can offer possibility to be upgraded through grid connection in future. Furthermore, due to their high levels of efficiency, reliability and long term performance, these systems can also be used as an effective backup solution to public grid in case of blackouts or weak grids and for professional electricity solutions like telecommunication stations or emergency rooms at hospitals, health

care centres and households/community services like school, public lighting, health centre, community meeting, dining halls, clinic, postal office, TV broadcasting station and tourist facility. Hybrid power systems of local renewable energy sources play vital role in meeting demands of people living in remote areas far from reach of electricity grid and also improves their standard of living.

Main objective of hybrid power systems is to supply electricity continuously to communities located at remote locations and not connected with power grid or it is not possible to connect them with power grid due to high cost of long transmission lines and high cost in distribution. They play an important role in increasing the reliability/availability and flexibility of electricity power supply and optimizing production of electricity.

Renewable electricity based hybrid power systems are suitable and cost-competitive solutions for rural electrification and play an important role to achieve following objectives:

- They provide an access to reliable electricity at any time.
- They avoid long waits for grid extension.
- They reduce dependency from oil price fluctuations.
- They improve quality of electricity service.
- It improves education facilities.
- They increase economic productivity and generate local employment opportunities.
- They reduce climate change and poverty.
- They allow for a better use of local natural resources." OF
- They facilitate security, safety and emergency assistance.
- They result in reduction of marginalization.
- They enhance social life and cohesion by providing access to electricity to all users.
- They help in empowering of women.
- They help in generating added value products.
- They help in having productive use of electricity/generation of income or value linked to direct income generating activities like motive power for agricultural, industrial and commercial uses.
- Access to electricity may automatically generate surplus within domestic economies and promote micro-enterprises/ small scale industries.
- They have following major applications:
- In household lighting, public lighting and community lighting.
- In internet, telephone, TV broadcast and video, cinema & radio-telephone communication.
- In refrigeration of medicines, cold storage and ice making.
- In drinking water supply, irrigation water supply, water purification and de-salination.
- In drying & preservation of food, production of sugar & silk, textile dyeing, weaving and crop processing like coconut fibre.
- In health services (sterilization of medical equipment, medical treatment, electric diagnosis).
- They provide income-enhancing opportunities like keeping shops open, carrying out activities like basket weaving and sewing for a few extra hours.

Classification of Hybrid Systems

Based on coupling voltage (DC, AC and mixed: DC/AC)

Hybrid Power Systems coupled with DC Bus: In this system, all electricity generating components are connected to DC bus from which battery is charged. AC generating components need an AC/DC converter. Battery is controlled and protected from overcharge and deep discharge by charge controller and meets demand of DC loads. AC loads can be supplied optionally by an inverter. Hybrid Power Systems coupled with AC Bus: In this system, all electricity generating components are connected to AC bus. AC generating components may be directly connected to AC bus or may need AC/AC converter to enable stable coupling of components. In both options, a bidirectional master inverter controls the energy supply for AC loads and battery charging. DC loads can be optionally supplied by the battery.

Hybrid Power Systems coupled with AC/DC Bus: In this system, all DC and AC electricity generating components are connected at both sides of a master inverter, which controls the energy supply of AC loads. DC loads can be optionally supplied by battery. On AC bus, AC generating components may be directly connected to AC bus or may need AC/AC converter to enable stable coupling of components.

Based on Types of Electricity Generating Stations Being Connected

Based on types of electricity generating stations being connected, hybrid systems can be classified as: standalone renewable hybrid system of electricity generation system, wind–hydro electricity hybrid power system, wind–hydrogen hybrid power system, wind–diesel hybrid power system, wind–compressed air hybrid power system and wind–solar hybrid power system. Standalone renewable electricity generation system, standalone grid connected renewable electricity generation system and these hybrid power systems have been described in the following sections.

Standalone Renewable Electricity Generation System

In this method, electricity generated from renewable source of energy is stored in battery banks in the form of direct current (DC)

Objective of hybrid power systems is to supply electricity continuously to communities located at remote locations and not connected with power grid or it is not possible to connect them with power grid.

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The **WT500 Power Analyzer** can concurrently measure direct current and alternating current signals with extreme precision, making it the perfect tool for assessing voltage, current and power conversion efficiency in the burgeoning solar and wind power generation systems. Also the WT500 is an **accepted device by Standard Performance Evalution Corporation (SPEC)** used for Power Efficiency Benchmarking.

Features:

- The WT500 provides highly precise measurements of power conversion efficiency in the photovoltaic generation system that has became a focus of world attention as new energy.
- One unit of the WT500 concurrently measures direct current signals from the photovoltaic generation and converted alternating current signals.
- The WT500 measures the electric power conversion efficiency of the power conditioner including the converter and the inverter with a high accuracy.
- High currents up to 40A and high voltage up to 1000V can be measured.
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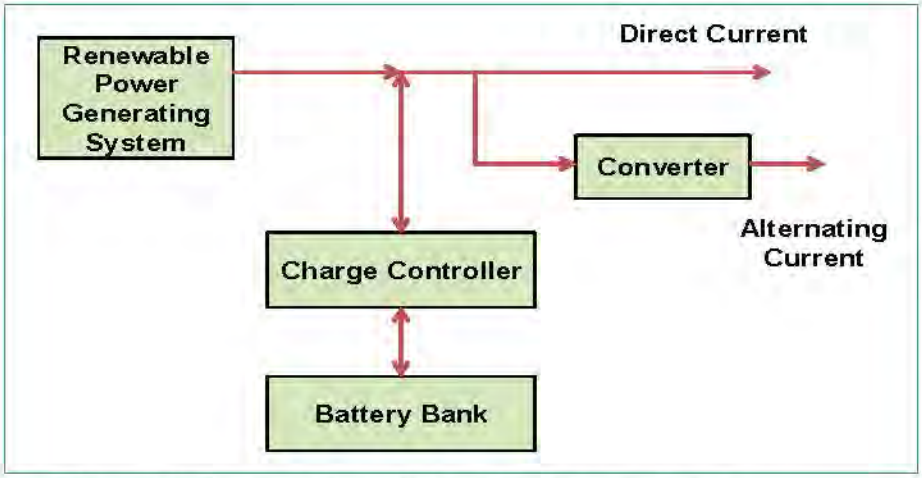


Fig. 1: Concept of Standalone Renewable Electricity Generation System

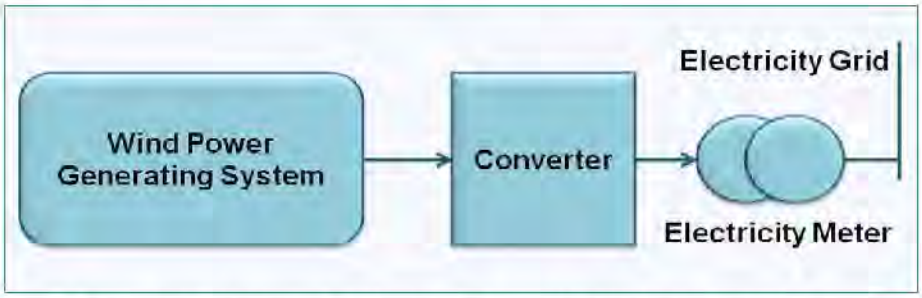


Fig. 2: Concept of Grid Connected Standalone Renewable Electricity Genaration System

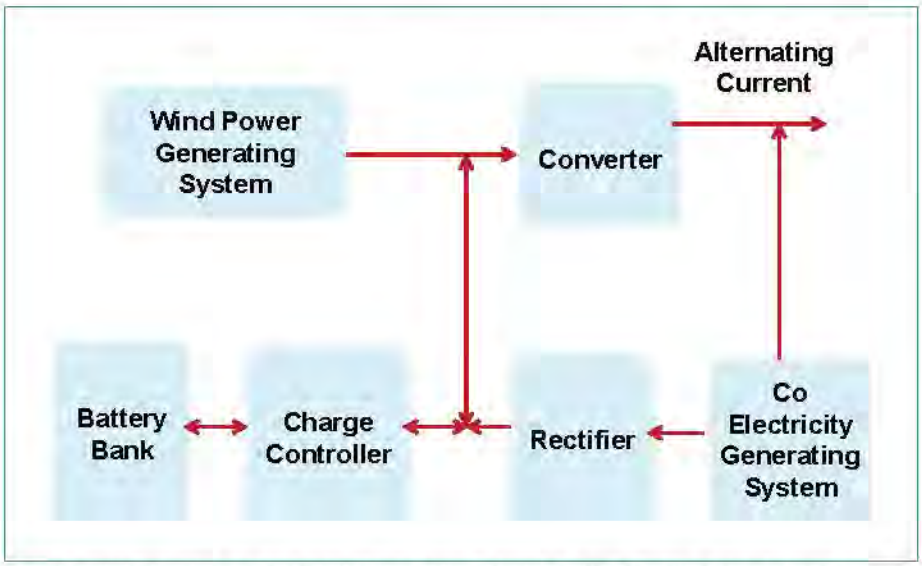


Fig. 3: Hybrid System of Electricity Generating System with other Co-Generating System

through a charge controller and this direct current from battery bank is utilised according to demand of electricity. Role of battery is to store power to cover short lull in wind power. For meeting the demand of alternating current (AC), direct current is converted into alternating current using a converter system. Renewable electricity generating source may be wind turbine, solar power or any other source.

Concept of standalone renewable electricity generation system is shown in Figure 1.

Grid Connected Standalone Renewable Electricity Generation System

In this method, output of standalone renewable electricity generation system is directly fed into grid. There is no need of any electricity storage battery bank in such electricity generating systems. Energy metering system is established for having account of electricity import and export by utility, which is able to tell how much amount of electricity has been used by the utility and how much electricity has been fed into the grid. Let us consider that we have a wind turbine renewable electricity generating system connected with electricity grid.

To handle the situation of moments, when wind velocity is low or there is no wind at all, it becomes necessary to start another electricity generating source to get power or that area is connected to a power grid.

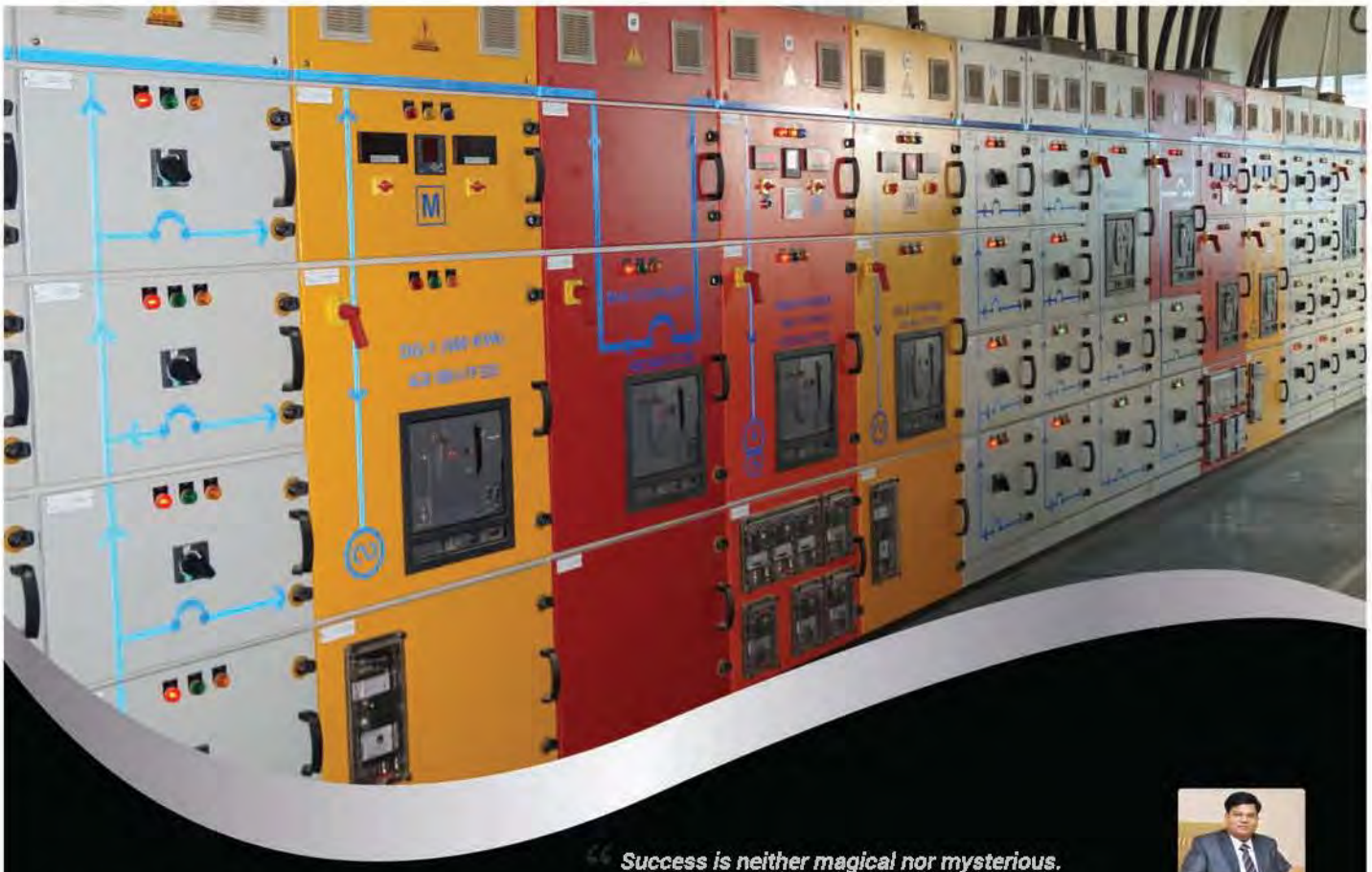
Concept of grid connected standalone renewable electricity generation system is shown in Figure 2.

Standalone Renewable Hybrid System

In this method, a renewable electricity generating system has hybrid system with other cogeneration system. Direct current generated by wind turbine is stored in battery banks in the form of direct current (DC) through a charge controller and this DC from battery bank is utilised according to the demand of electricity.

For meeting the demand of alternating current (AC), direct current is converted into AC using a converter system. Alternating current power generated by co-generating system can be used directly as AC or can be converted into DC using a rectifier and is stored in the same battery banks.

Figure 3 shows concept of hybrid system of renewable electricity generating system.



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Wind–Hydro Electricity Hybrid Power System

In wind-hydro electricity hybrid power system, electricity is generated with the combination of wind turbine and pumped storage hydro power plant. Whole wind power potential or major part of it is used for pumping water from a lower water reservoir to store it in an upper water reservoir. Water thus pumped in upper reservoir is used to produce electricity during peak power requirement, when wind is not blowing. In pumped storage hydro power plants, reversible units are used. The same machine works as pump while pumping water and a turbine while producing electricity.

Wind–hydro electricity hybrid power systems are very useful for those islands situated in seas/ oceans, which are not connected to any power grid. Sea/ ocean itself acts as a lower reservoir in such case. Such type of scheme was constructed in 1960s in Netherlands. IJasselmeer was made as its lower reservoir and wind turbine was installed at its dike. Feasibility studies for such schemes were carried out at Ramea Island and Lower Brule Indian Reservation (South Dakota) Island. Construction work was started in year 2010 in Greece Ikaria Island. World's first wind-hydro electricity hybrid power system is being constructed at El Hierro Island.

Wind–Hydrogen Hybrid Power System

In this system, hydrogen is produced by doing electrolysis of water using electricity produced by wind turbines. Hydrogen thus produced is stored. Later on, this stored hydrogen is converted into electricity by using fuel cell technology or with the help of fire engine connected to electricity generator, when wind power is unable to meet demand of electricity. However, successful storage of hydrogen is very difficult. Concept of working of wind–hydrogen hybrid power system is shown in Figure 4.

Wind-hydrogen hybrid power system are being developed in many countries. 'Wind Hydrogen' company has planned to install such systems in Australia and UK. It manages energy sources in those rural areas for domestic and transport needs, where cost of other energy conversion systems are high.

Test centres for wind-hydrogen hybrid power systems in the World are:

- At Newfoundland in Canada with wind power capacity is 0.3 MW.
- At Prince Edward Island in Canada
- At Region Zeeland in Denmark
- At North Dakota in United States of America
- At Santa Cruze in Argentina
- At 3 test centres in Scotland with wind power capacity at its one centres is 0.3 MW
- In Greece with wind power capacity of each 0.5 MW.
- In Norway with wind power capacity of each 0.6 MW.

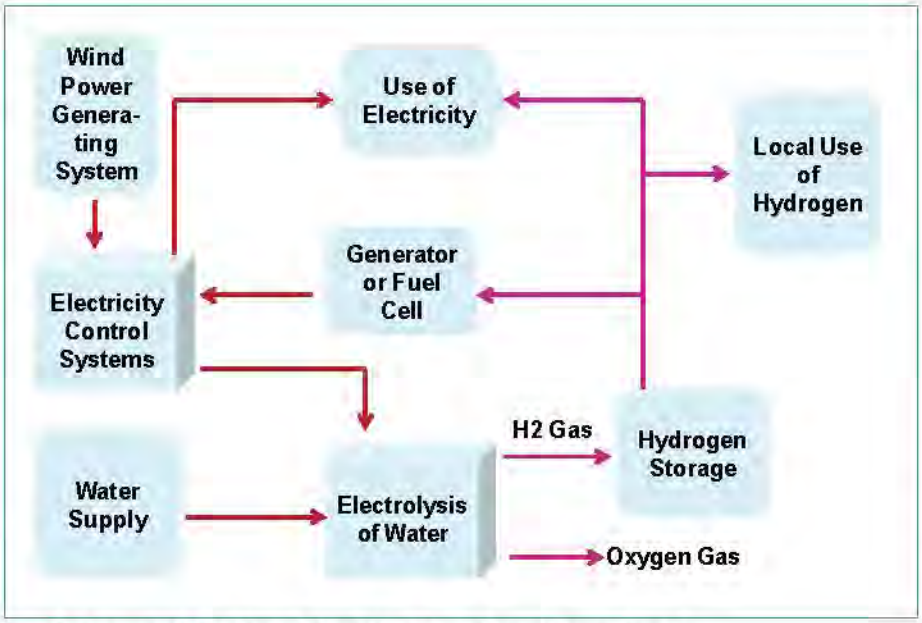

Fig. 4: Concept of Working of Wind–Hydrogen Hybrid Power System

Wind-Diesel Hybrid Power System

In a wind-diesel hybrid system, wind electricity generating system is integrated with conventional diesel generator set and works as standalone system or primary source of hybrid electricity supply system. Main objective is to make optimum use of wind energy system for production of green electricity and to reduce the use of conventional diesel generator set in remote/ unaccessible locations far from reach of electric grid. By reducing operation time of diesel engine and fuel used in it, harmful effects on environment can be minimized. Based on instant conditions, demand of electric load can be met either using wind electricity or using standby diesel generating set. This system has associated facilities/ equipment like energy storage devices, electricity converters and controlling components. Role of battery is to fill short gaps in or to start diesel generator.

General performance measurement of wind-diesel hybrid system is wind penetration, which is the ratio of produced wind power and total power given. 60% wind penetration means that 60% electricity is from wind. Wind penetration occurs either during peak or for a long time. Problem of changing production of wind can be solved by controlling wind electricity production using changeable speed turbines.

Main advantages of Wind-Diesel Hybrid System are:

- This technology is acceptable to rural area having no approach to power grid.
- It improves reliability.
- It brings down emission of harmful gases and reduces pollution of environment.

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ERDA's recently opened state-of-the-art Rabale Laboratory at Navi Mumbai is now NABL accredited for Electrical Testing Discipline, vide NABL Certificate number T-2844 for distribution transformers (upto 33 kV, 200 kVA), CT / PTs (upto 3200 A, 33 kV class), high voltage impulse testing (300 kVp,15 kJ), energy meters and transformer oil in service. These newly accredited facilities include acceptance testing of the above products as per relevant Indian and International Standards. Electrotechnical calibration facilities have also been set up. Details of the facilities recently accredited are as below:

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- Magnetic balance test
- Unbalance current test
- Impulse voltage test

B. Instrument Transformers: upto 3200 A, 33 kV (IS:2705 & IEC 60044)

- Polarity test
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- HV dry power frequency test on primary and secondary windings
- Over voltage induced test
- Instrument security factor
- Composite error test
- Knee point voltage test
- Secondary winding resistance measurement
- Temperature rise test

C. Energy Meters (As per IS:13779)

- HV proof test
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- It maintains continuous supply of electric power.
- It increases the life of operation of power plant.
- It reduces the cost of power.
- It increases the efficient use of electricity.

Main components of this system are:

- Wind power generator
- Battery bank
- Control unit
- Bi-directional electric power conveter
- Diesel generator set as a standby source of power.

Electricity converter unit receives low voltage direct current from wind electricity generating turbine. Battery bank stores it and converter converts it into alternating current at usable level of 230V 50 Hz. Diesel generator set produces electricity, when wind generating station is unable to generate electricity during poor availability of wind. A number of wind-diesel hybrid power systems have been developed in several places in the World.

Wind-Compressed Air Hybrid Power System

Wind-compressed air energy hybrid systems use compressed air energy storage system to generate electricity. In these systems, wind energy is used to keep air at pressure and this compressed air is stored in facilities created underground such as cavern or mines, which are not in use. During high demand of electricity, air is passed through turbines to generate electricity, generally using supplemental natural gas. Such systems are in operation at Mackintosh Alabama German and Japan. Lova Stored Energy Park, expected to be started in year 2015, would utilize wind energy form compressed energy storage system.

Compressed air energy storage hybrid systems have following drawbacks:

- Some energy is lost in compressed energy storage systems.
- This system does not remain completely renewable alternative energy source, as it makes use of fossil-fuels like natural gas as complementary fuel.

Wind-Solar Hybrid Power System

In wind-solar hybrid electricity generating system, electricity generated from wind parks is combined with electricity generated from solar electricity generating system/ photovoltaic modules. Among all renewable electricity generating systems, hybrid system of wind electricity generating system with solar/ photovoltaic electricity generating system is considered the best with the point of view of weather changes. Domestic or small scale wind generators can be installed easily on towers and high roofs of high buildings. Due to high moment, this wind generator is able to generate electricity in wind of velocity even lower than 2.5 m/s.

Complementary Nature of Solar Electricity & Wind Electricity

On daily and weekly time scales, tendency of high pressure area is towards clear sky and low speed surface winds. Tendency of low pressure area is towards cloudy sky and high speed surface winds. On weather time scale, solar energy is on peak in summers.

In many places, wind energy is less in summers and more in winters. In this way, the unavailability/ instability of solar and wind power are opposite to each other. In other words, when availability of one of these source is less, the availability of other source is more and at that moment, electricity is generated by that source, which is available more. Therefore, at least one of the sources of electricity generation is available at all the times and electricity demand is met using then available option. During non-rainy periods, wind electricity and solar electricity generating systems can act as complementary to each other in the following ways:

- During rainy season, availability of solar radiations is poor and thus low electricity generation from solar generating system can be compensated with higher generation from wind electricity generation.
- After winter season, wind availability is poor and thus low electricity generation from wind generating system can be compensated with higher generation from solar generating system.

Main Components of Wind-Solar Hybrid System

Main components of wind-solar hybrid system are listed below:

Solar Photovoltaic Modules	TT	Wind Power Generator
Inverter	Battery Banks	Regulator and Control Electronics
Hybrid Power Conditioning Unit (Converter & Charge Controller)		

Hybrid electric conditioning unit is an electronic unit used to join wind electricity generating system and photovoltaic/ solar module system together. This unit is the brain of this system. It stops extra-charging and deep discharging of battery banks. When battery bank gets charged fully, it stops it charging further. When battery bank gets deep discharged, this device cuts electric load connected to it and allows charging of battery bank. Output of battery bank is direct current. Therefore, to supply electricity to electric load (such as compact fluorescent tubes, street lighting system, televisions etc), this direct current is first converted into alternating current. A converter is also installed in hybrid electric conditioning unit to convert direct current into single phase, 230 volts 50 Hz alternating current. As soon as electricity is generated by wind turbine plant and photovoltaic electricity plant, it is stored in battery bank system. Size of battery bank is decided based on the requirement of electric load and operation hours of electric load.

Design of Wind-Solar Hybrid System

Main objective of designing a wind-solar hybrid system is to match the capabilities of wind electricity generating system and solar/ photovoltaic solar panels to meet the electricity requirements of consumers at the lowest cost. To accomplish this task, the hybrid systems are designed based on the following-

Together, we can drive your productivity up and energy costs down.

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Reuiremen of electric power	Availability of wind
Availability of solar radiations	Cost of energy generation
Feasibility/viability of hybrid system	Characteristics of hybrid system
Type and size of required hybrid system	

Advantages of Wind-Solar Hybrid System

- It can be made tailor-made to suit for small or large electricity requirements.
- It would continue to generate electricity till wind/ sunlight is available.
- It avoids/ minimizes cost of installation of transmission/ distribution lines to bring electricity in remote localities and electricity losses occurring in them.
- System also reduces installation of costly cables from power mains.
- System is most environment friendly and clean source of electricity generation.
- Installation of equipment in this system is easier.
- Domestic or small wind mills can be installed at roofs of the buildings or on the earth.
- This system is completely automatic in operation.
- Components of this system and their construction works are of high quality.
- System does not require any type of fuel for electricity generation.
- System produces reliable, uninterrupted and high quality electricity.
- This system increases safety for general public and produces safe power.
- It can make electricity bill negligible.
- System requires negligible maintenance as it involves less number of moving components.

Usage of Wind-Solar Hybrid System

- This system is ideal for use in stations receiving electricity for cell-phones.
- In farmhouses, greenhouses, hospitals, hotels, laboratories, research stations & developmental centres.
- In remote and rural electrification.
- For general lighting in residential colonies and apartments
- For lighting at roads and in streets
- In transmission and broadcasting/ communication towers

Solar panels have been installed on windows of Pearl River Tower on Guangou River in China. Wind turbines have been installed at various levels on structures of this tower. Electricity demand of tower would be met with the combination of electricity produced by solar panels and wind turbines. Combination of solar modules and wind turbines housed at top of buildings have been used for lighting buildings in many parts of China. Using this system, a place already being lighted, is lighted more efficiently with a joint use of these two complimentary renewable electricity sources. Wind-solar hybrid system with battery system is shown in Figure 5.

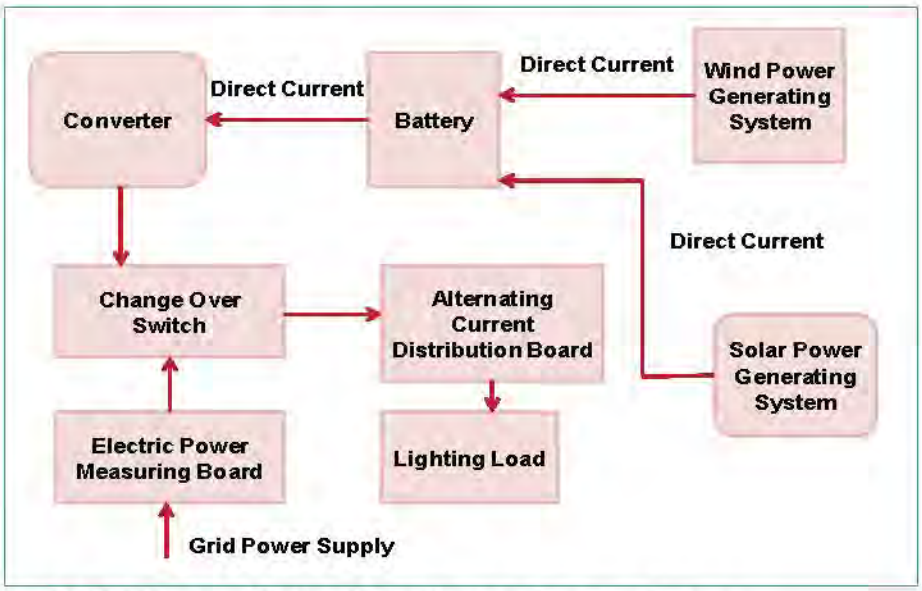

Fig. 5: Hybrid System of Wind and Solar Electricity Generating Systems

Conclusions

Hybrid systems for renewable electricity generating systems play an important role in meeting electricity demands of rural areas. They are independent from oil price fluctuations and most suitable, environmentally friendly and cost competitive/ cheaper solutions for power delivery in rural areas. They reduce conventional electricity production and harmful greenhouse emissions from fossil fuels combustion. Their increased reliability, insignificant power transmission losses, potential consumer involvement and optimal use of indigenous resources favour their uses. Many options for configuration of hybrid power systems can be designed depending on load to be served, resource available and their costs.

Profile

M P Singh

BSc Engineering (Electrical) from AMU Aligarh and MBA (Operation Research) from IGNOU has over three decade experience in planning, appraisal, construction monitoring & operation monitoring of hydroelectric stations is working as Director and Chief Engineer (I/C) in Central Electricity Authority and Commissioning & O&M of switchyard equipment and erection of E&M equipment of hydro power projects working as Dy. General Manager at Koldam HPP of NTPC. He published/ presented over 76 articles in National/International magazines/ Seminars and 6 technical books (in Hindi); awarded by Ministry of Power, Ministry of Renewable Energy Sources, Ministry of Science & Technology.

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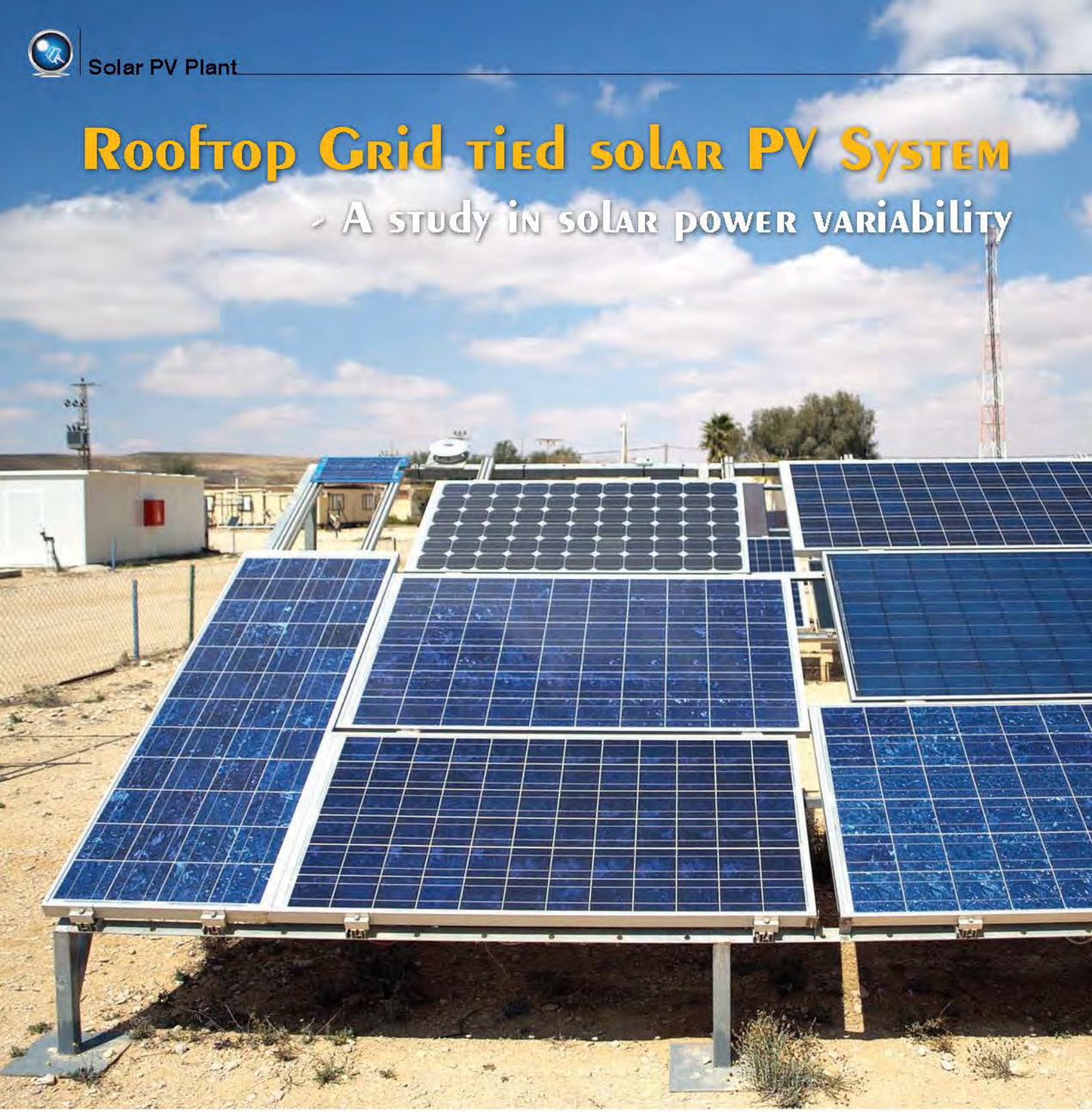
Rooftop Grid tied solar PV System

- A study in solar power variability



The main objective of this article is to review the state-of-the-art of IIT Jodhpur Rooftop installed 101 kW PV systems. This is done analyzing the operational data of 101 kW PV systems (43.30 kW located in Block 1 and 58.08 kW in Block 2). Performance analysis depends on three basic term of solar PV. How much energy do they produce? What level of performance is associated to their production? Which are the key parameters that most influence their quality?

Vikas Pratap Singh, Dr Vivek Vijay, Dr D K Chaturvedi & N Rajkumar

During the year 2011, the PV systems in Jodhpur, India have produced a mean annual energy of 1290.64 kWh/ kWp in block-1 and 1290.64 kWh/ kWp in Block-2. As a whole, the location of Solar PV system is the main reason of energy variability and system output. The overall mean Performance Ratio is 75% in both Blocks. Solar power variability depends on the two variables, deterministic and stochastic variable. In last few years researcher work on finding deterministic variable such as system losses (module efficiency, DC cable losses, inverter losses and AC cable losses) but these deterministic variables are not enough to give accurate forecasting so with the help of combined effect of these both variable give accurate plant performance and reliable solar power forecasting for solar power scheduling and dispatchability.

In 21st century the energy management and environmental security are the biggest challenges for us. In this era the current issue is global energy problem can be attributed to insufficient fossil fuel supplies and excessive greenhouse gas emissions resulting from increasing fossil fuel consumption. Which we can see in the form of global warming. Energy demand and supply has become one of the most important problems facing humanity. The day by day increasing demand for energy is show fossil fuel supplies and record-high oil and gas prices due to global population growth. So the energy shortage has played an important role in the future for our society. The sun continuously delivers to the earth 120,000 TW of energy, which dramatically exceeds our current rate of energy needs (13TW) .This implies that covering only 0.1% of the earth's surface with solar cells of 10% efficiency would satisfy our current energy needs however, the energy currently produced from sun light remains less than 0.1% of the global energy demand . The solar energy can be broadly used in two areas: (a) PV systems which convert solar energy directly into electrical energy and; (b) thermal systems that convert solar energy into thermal energy. The solar energy is used in various application such as solar heating and cooling, Building integrated Photovoltaic (BiPV) systems and products, grid connected Renewable Energy (RE) systems Including biomass and PV systems, day lighting, solar thermal electricity generation, and solar refrigeration.

Generally PV system can be classified into three types:

- Stand-alone system
- Hybrid system and
- Grid-connected system.

A grid-connected system comprises of the modules and an inverter. The inverter converts the direct current (DC) electricity generated by the PV array into alternating current (AC) electricity that is synchronized with the mains electricity .The electric power produced by PV system then can be consumed by the connected load and no power is taken from the main grid unless load connected to the system is less than capacity of PV systems. BiPV systems seem to offer the most cost and energy effective application of grid connected PV systems. 43 kW grid-connected Amorphous PV system and 58kW grid-connected Crystalline PV system are recently installed at academic block-I and II building Indian Institute of Technology Jodhpur, Jodhpur. Jodhpur city which is called as SUN CITY has 320 days of sun availability in a year i.e. there is huge potential in the field of solar systems which can be harnessed to solve numerous local problems such urban and rural electricity, cooling and water related problems. The above installed grid-connected PV system is going serve as test bed to the future proliferation of solar systems. So, it becomes almost necessary that, data regarding their performance must be studied in local climate conditions and a comparative conclusion may be drawn, because the energy produced by a grid connected PV system depends on local climate factors such as; incident solar radiation, ambient temperature, wind velocity, etc and module temperature. Energy yield, working point, operation threshold and the coupling system to the grid, which depends on the characteristics of the energy produced by the inverter on grid stability and availability. In this installation, the measured data were the ambient temperature, module temperature, DC voltage, DC current, inverter output

Fig. 1: Academic block ii building, located at "IIT, jodhpur" Jodhpur

Fig. 2: C-Si based 58 kW rooftop grid tied solar photo voltaic plant

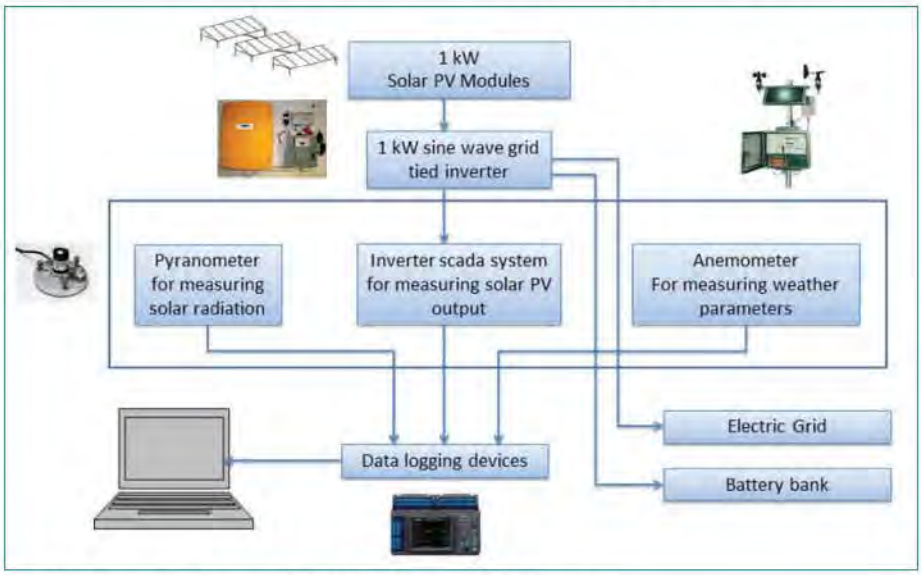


Fig. 3: Schematic Diagram of the Grid Connected PV System.

the solar power variability with the help of performance of PV array and PV losses.

The PV System Description

The PV solar power plant describe in this article has been installed on the roof of academic block I and II, 43 kW grid-connected Amorphous PV system installed at block- I and 58 kW grid-connected Crystalline PV installed at block- II in Indian Institute of Technology Jodhpur, Rajasthan, located at Jodhpur, the second largest city in the Indian state of Rajasthan at coordinates 26 17'N 73 01'E which is 335 kilometers west from the state capital, Jaipur and 200 kilometers from the city of Ajmer.

Fig. 4: Academic Block I Building, located at "IIT, Jodhpur" Jodhpur

Fig. 5: A-Si based 43 kW rooftop grid tied solar photo voltaic system

energy and solar irradiance. From these data, the performance indicates were obtained with regards to DC power, energy produced by the PV modules, solar irradiance, module conversion, inverter efficiency. In this project we have estimated

The PV system has a nominal peak power of 43 kWp and installed on the roofs of the academic block I building (Fig. 5).

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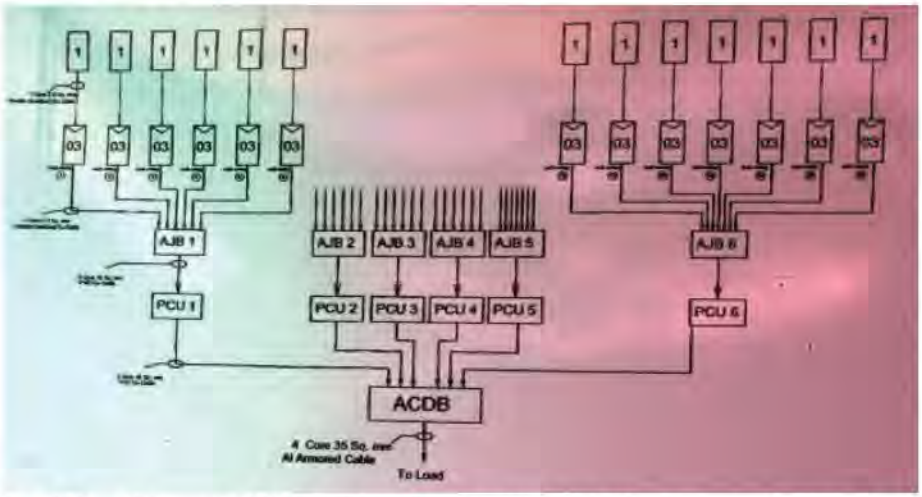

Fig. 6: Line diagram of 43 kW A-Si based rooftop Grid tied solar Photo- voltaic system.

The overall surface area is 652.34 m². It consist of 114 modules for a total of 38 array each array consist of 03 module, which is connected to the inverter, each inverter have six array in which modules are connected in series and arrays are connected in parallel. Total numbers of inverters are six.

Data Acquisition System With Online Monitoring

The system output monitored at the PV inverters by a data acquisition system controlled by a measurement and analysis Program (Sunny sensor web box) mounted on the building shown in fig. 5. Data is measured and recorded after every 15 min. The measured data are:

- Electrical power output of each PCU
- Solar irradiance
- Module temperature
- Ambient temperature
- Energy generated.

Data Observation

Figure 7 shows hourly solar insolation on the photovoltaic modules captured on 02/08/11 for 24 hours.

And the maximum solar insolation was found 771.2 W/m². and it is founded that

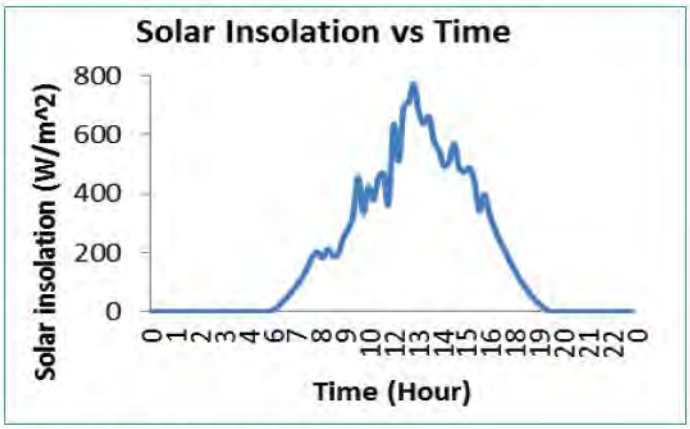

Fig. 7: Hourly solar insolation over the day

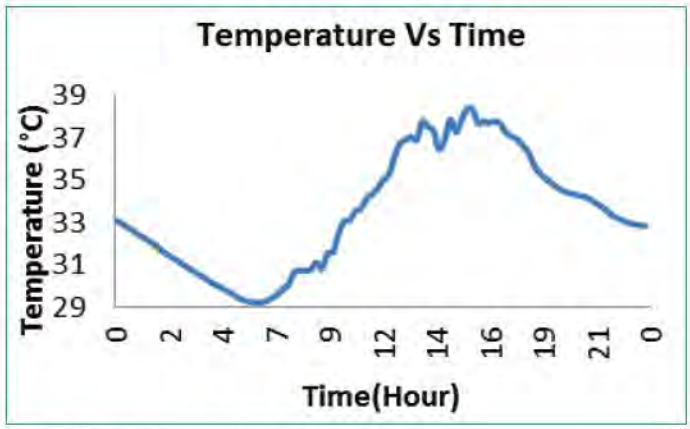

Fig. 8: Hourly temperatures over the day

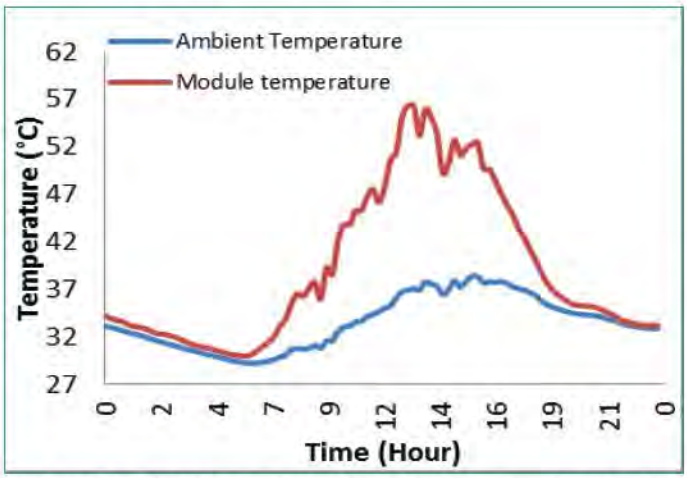

Fig. 9: Hourly ambient temperatures with module temperature for c-si module

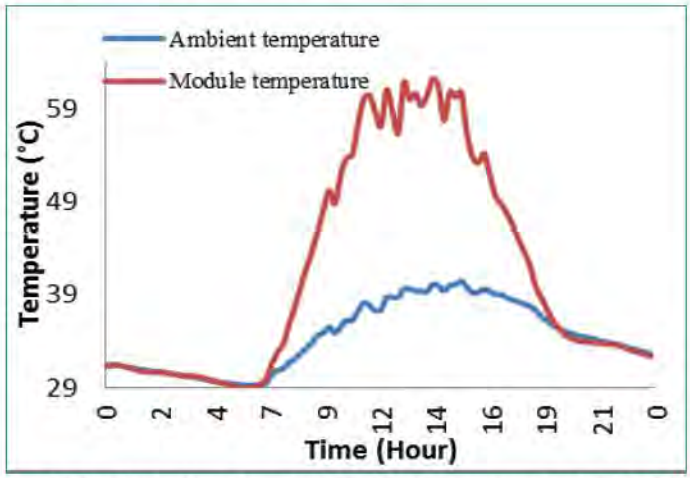

Fig. 10: Hourly Ambient Temp With Module Temperature For A-Si Module


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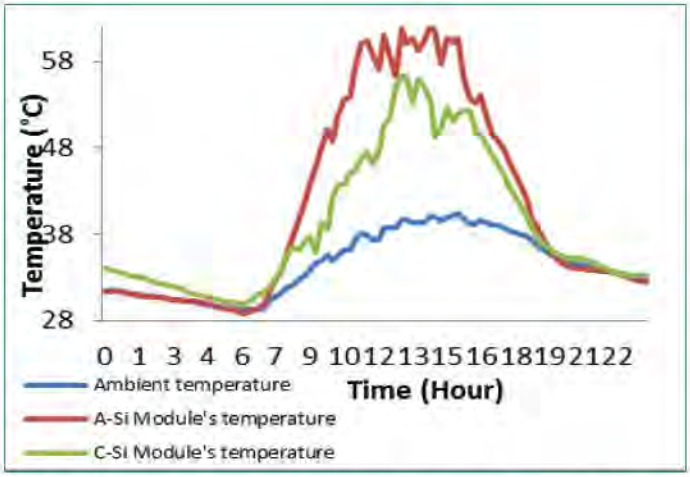

Fig. 11: Comparative analysis of ambient temperature and module temperature with respect of time

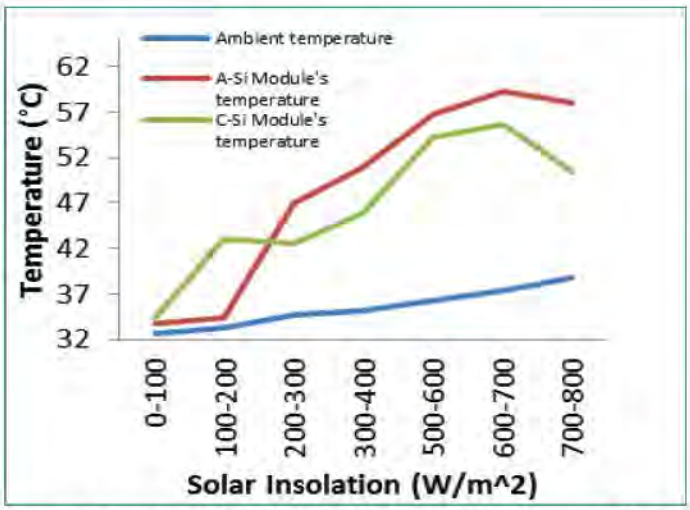

Fig. 12: Comparative Analyses of Ambient Temperature and Module Temperature with Respect of Level of Solar Insolation

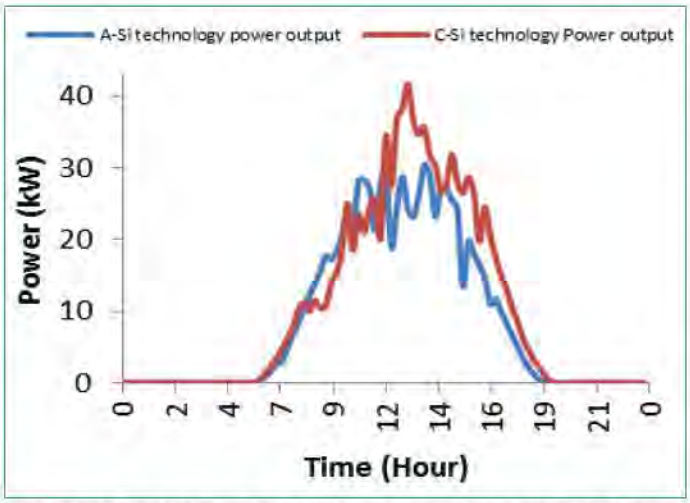

Fig. 13: Comparative analysis of power output from both power plants with respect to time.

because for weather there is variability in solar radiation is a unpredictable actor for solar power forecasting because deterministic variable can be predict well in the case for solar power forecasting and stochastic variable much unpredictable because of nature. Figure 7 shows the hourly temperature on the basis of 15 minutes interval.

Figure 8 and Figure 9 shows the module temperature with ambient temperature which is play a deterministic role in performance analysis and solar power forecasting.

Comparative Study of Energy Losses

Solar plant performance analysis needs the study of deterministic variable and stochastic variable. These are the main reasons of solar power variability. So, in way to compute the power, energy and yield related performance of electricity grid tied PV system, particular parameter are to be found as factor which are comes under deterministic and stochastic variable. And these parameters are to be calculated using data collected during the running situation of the plant. These variables are known as losses in generated.

Solar power and it can be classified in following category:

- **Deterministic losses**
- System losses
- Wiring losses
- MPP losses
- Inverter losses
- Transformer losses
- Mis-sized inverter
- Operation & maintenance losses
- Module losses
- Conversion losses
- Thermal losses
- Pre module losses
- Tolerance of rated power
- Shadows
- Dirt
- Reflection
- **Stochastic losses**
- Weather parameter
- Solar insolation
- Ambient temperature
- Cloud shadow
- Wind velocity
- Rain fall.

Figure 10 show the level of variation in module temperature when ambient temperature varies. Sunny boy temperature sensor is used to measure the module temperature and figure11 show the variation in ambient temperature and module temperature with respect of time. And Figure 12 show the PV module temperature increases at solar insolation level 300-650 W/m2. as per observation at the higher level of solar radiation module temperature goes down.

Fig. 14: Total losses in the system

Fig. 15: System losses

Fig. 16: Module losses

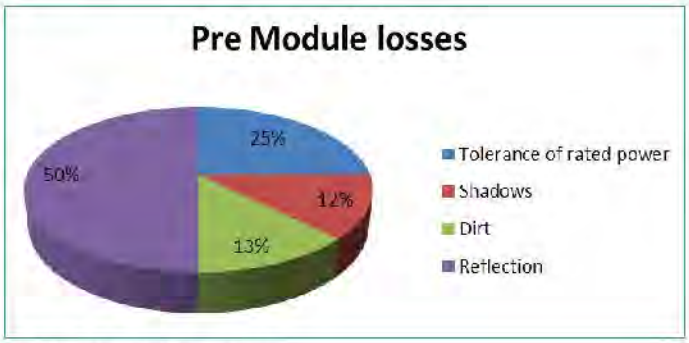

Fig. 17: Pre Module Losses

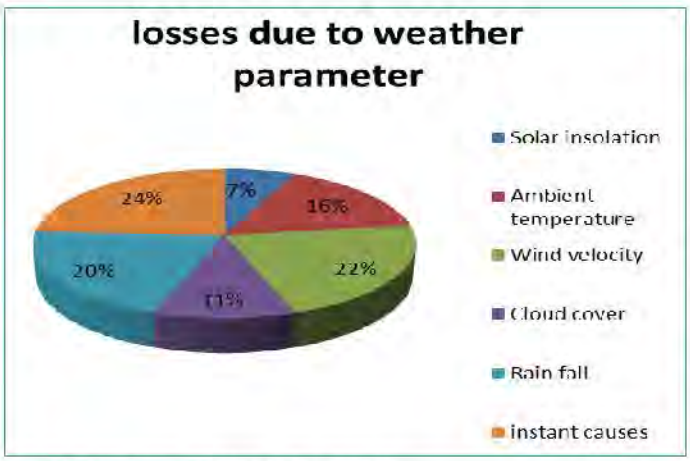

Fig. 18: Stochastic losses in the system

The ambient air temperature and module temperature are usually increased with solar insolation and after the certain level it again decreases because of ideal temperature of Module is around 25-30^{0}C.

Before the energy yield and performance analysis of the plant a study of total losses in the system is very important and it is play a key role in power variability and because of these losses variation in power generation is much unpredicted in Figure 13 it is clear that fluctuation in power generation is due to stochastic losses such as cloud cover, solar radiation, etc. these stochastic losses is based on impact and frequency of occurrence such as if solar radiation is very less or long hour because of cloud cover then losses will be very high so these losses are probabilistic in nature.

It depends on other weather parameter such as ambient temperature is depend on solar radiation or rain fall and rain fall depend on ambient temperature correlation of these parameter are very high. Figure 14 show the deterministic losses in the system.

Plant Performance Analysis on the Basis of Energy Losses

In grid tied solar PV plant performance analysis some important parameter should compute first. So these all parameter are given below:

S.No.	Parameters	Notations
1.	Plant Energy Output	E_{ac}
2.	Array yield	Y_a
3.	Final Yield	Y_f
4.	Performance Ratio	PR
5.	Capacity Factor	CF

Table 1: Parameters for Plant Performance Analysis

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- **Plant Energy Output**

The entire day plant energy output by the photovoltaic system is acquired as:

$$E_{ac,d} = \sum_{t=1}^{t=24} Eac,t \quad \text{.....[1]}$$

$$E_{ac,h} = \sum_{h=1}^{h=24} Eac,h \quad \text{.....[2]}$$

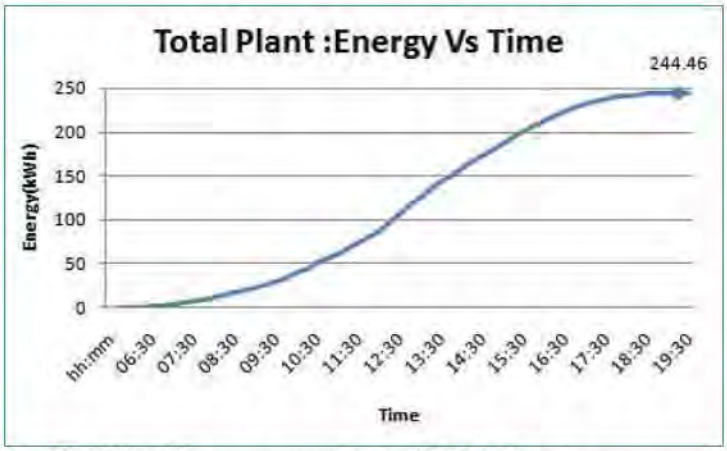

Fig. 19: Total daily energy generation by 58 kW SPV system

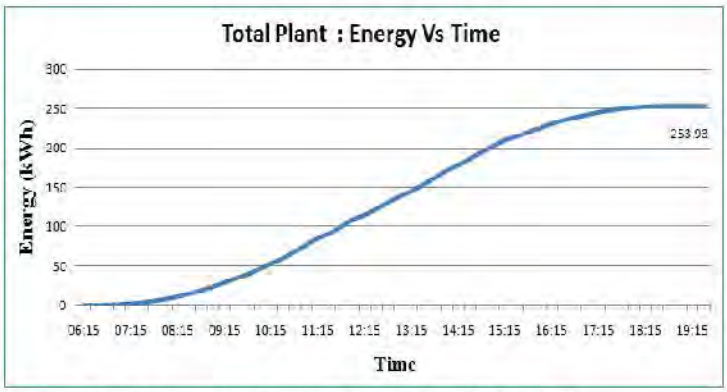

Fig. 20: Total daily energy generation by 43 kW SPV plant

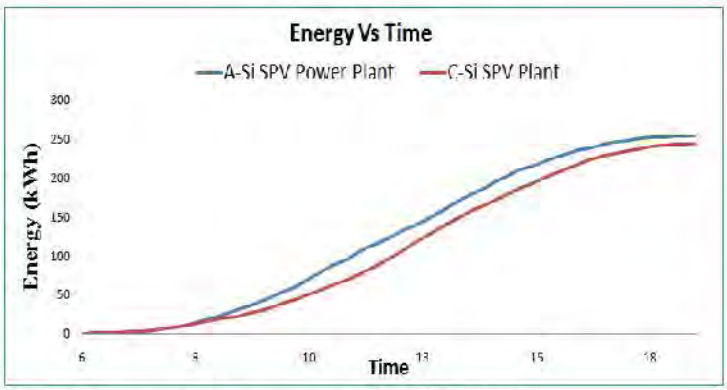

Fig. 21: Energy generation output of both SPV plant

Where h is the number of hour in the day. The instant plant energy generation was obtained by the energy output by the system after the DC/AC inverter on 15 minute interval. And Figure.19 shows the total energy generation output which is 244.46 kWh of 58 kW C-Si based solar photovoltaic system. And Figure 20 shows the total energy output of 43 kW A-Si solar photovoltaic system. And total energy generation is 253.93 kWh which is more than C-Si SPV plant.

- **Array Yield**

Array yield (Ya) is defined as the generated energy output from a photovoltaic array under a certain time (day, month and year). And it obtained by just divided by its rated power.

Equation No. 4 show the daily array yield and Equation 5 daily average hourly array yield (Ya,h).

$$\mathbf{Ya} = \frac{Edc}{Ppv,rated} \quad \text{.....[3]}$$

$$\mathbf{Ya,d} = \frac{Edc,d}{Ppv,rated} \quad \text{.....[4]}$$

$$\mathbf{Ya,h} = \frac{1}{\mathbf{N}} \sum_{\mathbf{h=1}}^{\mathbf{h=24}} \mathbf{Ya,d} \quad \text{.....[5]}$$

- **Final Yield**

The final yield of the plants is defined as the daily, monthly and yearly net AC energy output of the plant divided by the theoretical power of installed photovoltaic array at standard test conditions (STC).

And the daily final yield (Yf,d) is given as:

$$\mathbf{Yf,a} = \frac{Eac,a}{Ppv,rated} \quad \text{.....[6]}$$

$$\mathbf{Yf,d} = \frac{Eac,d}{Ppv,rated} \quad \text{.....[7]}$$

- **Performance Ratio**

The performance ratio show the overall effect of losses on

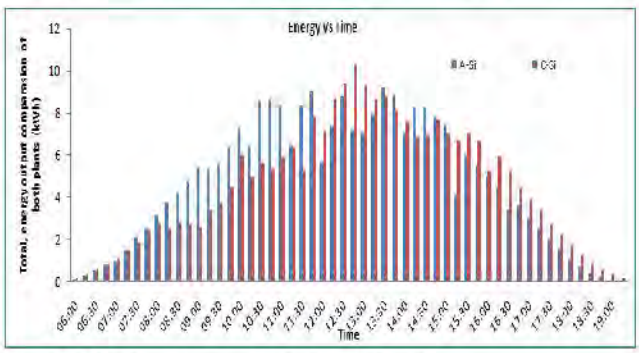

Fig. 22: Total energy generated over the day

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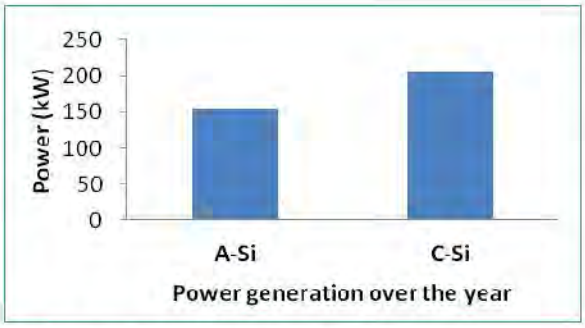

Fig. 23: Power generation over the year

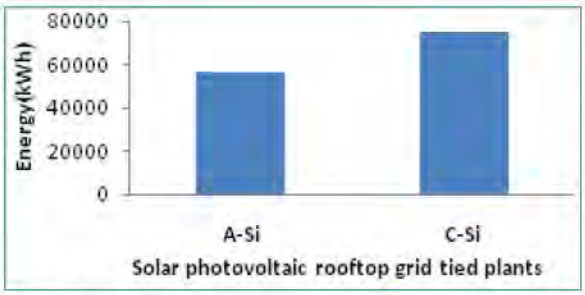

Fig. 24: Energy generation over the year

photovoltaic array's nominal power output depending on deterministic and stochastic losses and the performance ratio of the photovoltaic system show how accurate it effort in ideal operation conditions. Performance ratio basically represents the total losses in the Photovoltaic system during converting DC to AC and performance ratio is expressed as:

$$PR = \frac{Ereal}{Eideal}$$

= η deterministic/stochastic losses .....[8]

- **Capacity Factor**

The capacity factor (CF) is basically present the energy produce by the SPV plant. And plant produces the full installed power regularly. Then capacity factor should be unity. And it is a ratio of the net yearly energy generated to the net amount of energy the PV plant would generated. The capacity factor for a grid tied Photovoltaic plant is given as:

$$CF = \frac{Yf,a}{24 * 365} \quad \text{.....[9]}$$

$$CF = \frac{Yf,a}{24 * 365} \quad \text{.....[10]}$$

So on the basis of these factor and losses. figure.23 show the comparative bar chart for annual power generation of both power plant. And Figure 24 shows the annual energy generation of Solar PV plants.

The compare in commission result from different technology based solar photovoltaic system. The power is Watts (W) or kilowatts (kW) and energy in Watt-hours (Wh) or kilowatts. Hour (kWh). And the plant annual net energy yield is given as:

$$Yf = \frac{E\ real}{Ppv,rated} \quad \text{.....[11]}$$

Conclusion

The 58kW and 43kW grid tied power plant installed in Indian Institute and technology Jodhpur, Rajasthan was monitored for a single day which is 2nd August 2011 and 24 hour. And plant data during the operating time showed that theoretical solar irradiance, ambient temperature, module temperature, wind velocity, and were 5.2 kWh/m^2/day, 34.4^{0}C, 39.8^{0}C, and 3.9 m /s respectively. From this study it is clear that daily energy yield of 5.2kWh/kWp/day is extremely dependent on stochastic losses.

Acknowledgement

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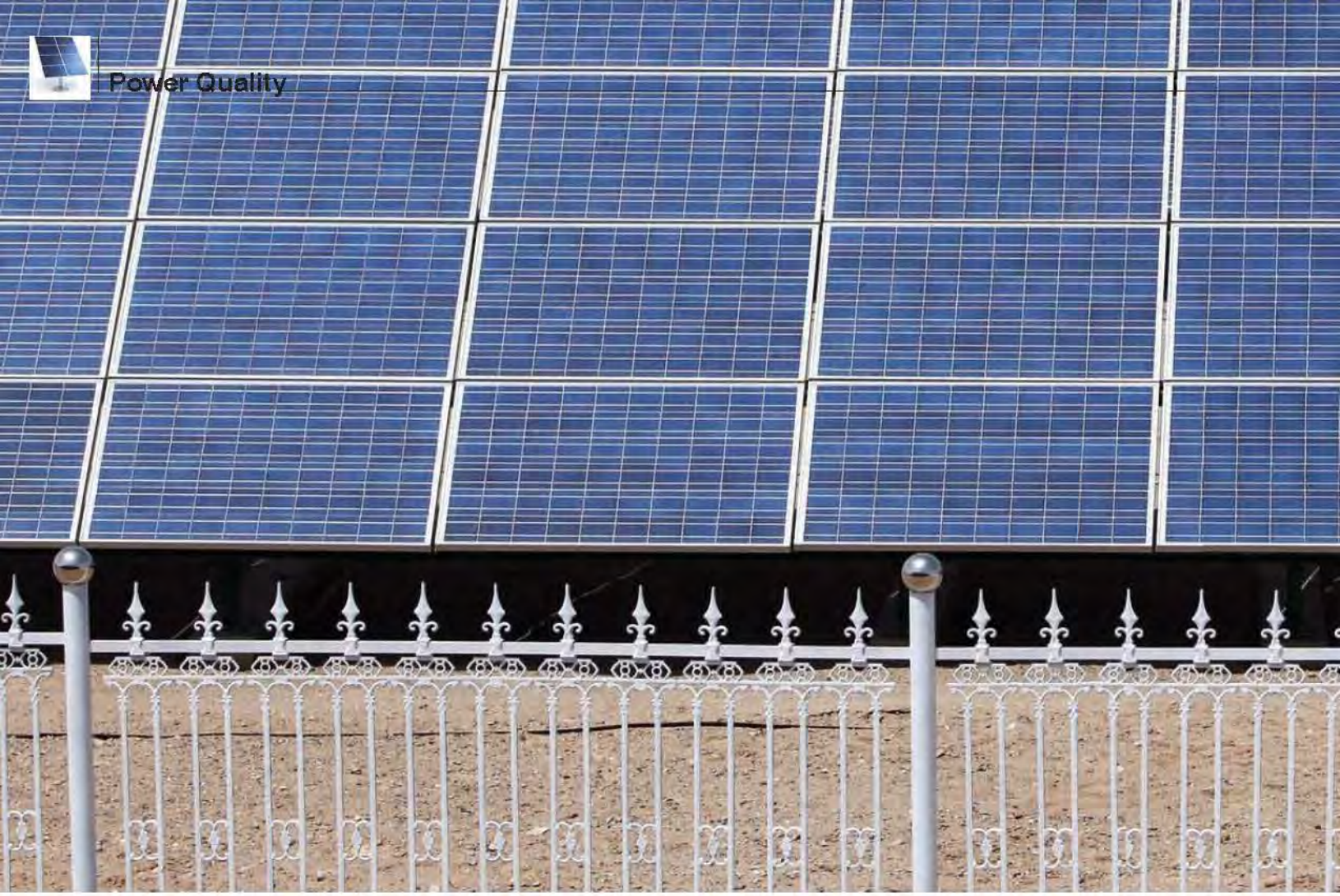
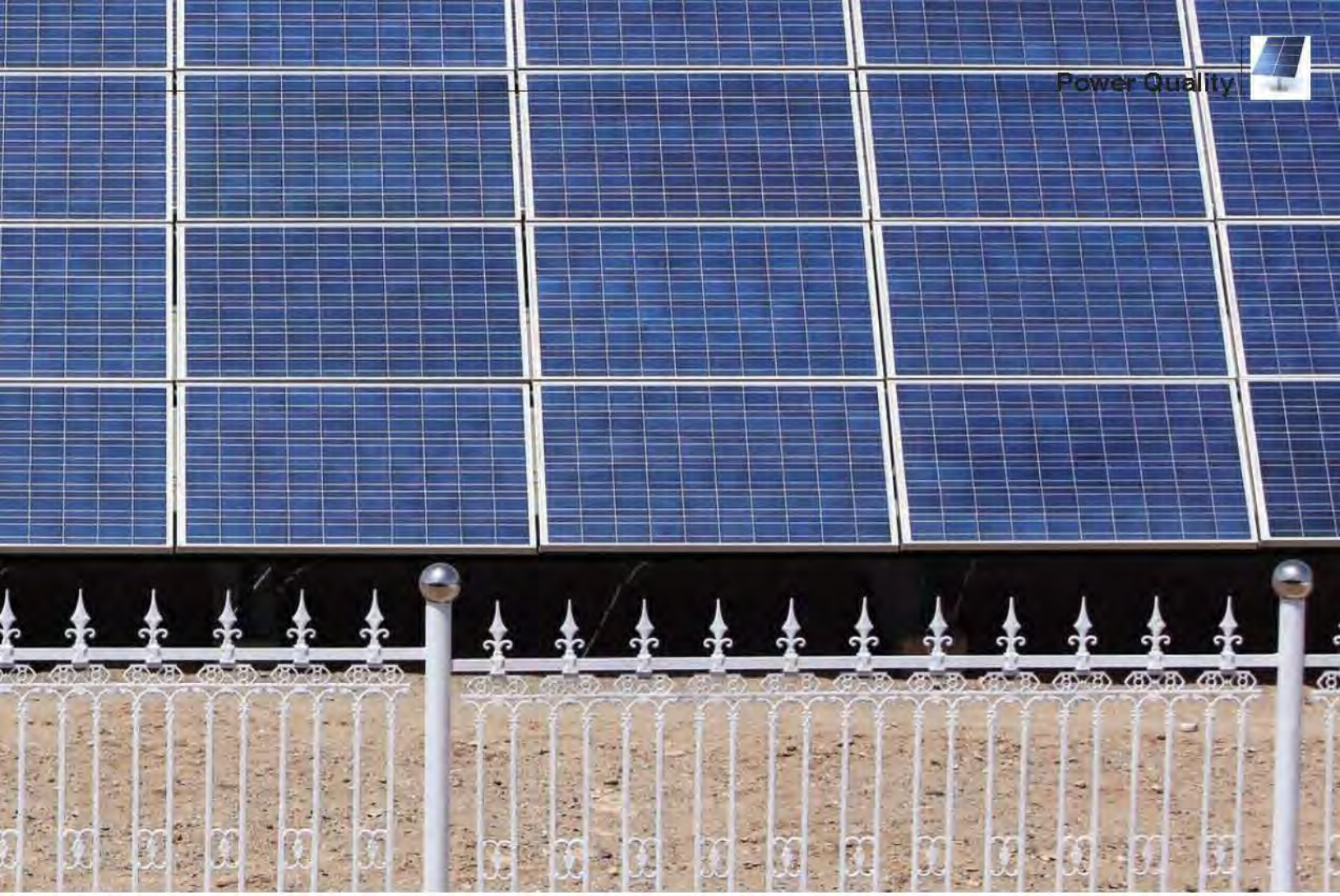


Study on Power System issues in Solar PV Interface using
Automated Power Quality Analysis

Electric power quality is an emerging area of research in the field of electric power distribution system. It has acquired intensified importance since the advent of highly sensitive electrical and electronic equipment. The power quality in the latest power distribution system mainly stresses on the issues of sinusoidal waveform fidelity, absence of high and low voltage fluctuations and other AC waveform distortion. M.M. Morcos and J.C.Gomez, enumerates power quality issue as any occurrence manifested in voltage, current or frequency deviation that results in damage, upset or failure of customer's equipment. Timothy J. Browne and G. T. Heydt viewed electric power quality as the capacity of electric power system to supply electrical energy to any electric load such that the customer may utilize that energy without any equipment failure. Dugan, Mc Granhan, Santoso and Beaty illustrates the term power quality as those characteristics of electric power distribution system which are considered to be responsible for the smooth functioning of electric equipment.

Dr L Ashok Kumar & R T Karthick



Elaborating it further, one can state the power quality as an electric power problem manifested in voltage, current or frequency deviations that results in failure of load side electric equipment. From electric utility point of view, the power quality is the supply of electrical power as per specified standards, whereas from the end user sight, it is the smooth functioning of electrical equipment without any disruption.

In the deregulated and competitive environment, both the electric utilities as well as the customers are becoming increasingly concerned about the quality of electric power. The major reason for increased concerns is that the availability of sophisticated technology has developed extremely sensitive electrical/electronic equipment. Any sort of variation in electrical parameters greatly changes the characteristics of such delicate equipment. Secondly, the innovation in the application of some electrical appliances has been restricted because of extra emphasis on increasing the efficiency of electric power distribution system. Thirdly, the awareness about power quality problems like transients, flicker, sag, and interruption has increased rapidly in the last decade. Lastly, the expansion in the electric power distribution system and the utilization of latest electrical systems has increased the sensitivity of distribution system. Under such circumstances, failure of any electrical equipment may cause significant impact on the overall performance of electric power distribution system.

In today's competitive environment, industrial consumers strive to increase their production with reliable electric supply. Industrialists need efficient equipment and machines that help them to increase their production rapidly. Majority of these applications face the power disruptions and usually become the cause of power quality problems. In most countries, commercial power is made available via nation- wide- grids, interconnecting many generating stations to the loads. The main grid must supply basic national needs of residential, lightening, heating, refrigeration, air-conditioning as well as critical supply to government, industrial, financial, commercial, medical and communication communities. Commercial power literally enables today's modern world to function at its busy pace. Sophisticated technology has reached deeply into our homes and careers. With the advent of e-commerce, it is continually changing the way we interact with rest of the world.

Critical technologies demand power that is free of interruptions. In industrial automatic processing, whole production lines go out of control, creating hazardous

situation for onsite personnel and expensive material waste. Loss of processing in a large financial corporation can cost thousands of irrecoverable dollars per minute of down time, as well as many hours of recovery time to follow. Widespread use of electronic equipment to control the massive and costly industrial processes has increased the awareness of power quality. The study of power quality and the way to control it is a concern for electric utilities and electricity consumers. Equipment have become more sensitive to even minor changes in the power supply.

Today, the power quality objectives have become more and more explicit either in the form of agreements negotiated with customers, or in the form of definite goals agreed with the regulators. In fact, number of regulators already has planned to establish the power quality objectives to be met by the electricity supply systems. In some countries, regulators may even impose penalties in case of non-observance of power quality objectives. It is the key feature of meeting power quality targets that the interested parties agree on the methods of gathering and presenting the power quality data.

All the relevant power quality indices are prerequisites for assessing site and system performance with respect to power quality. These indices eventually facilitate the task of system operators with their obligation to report the power quality performance. As the system operators are at the risk of being exposed to the penalty payment for excursions in quality beyond the objective values, it is essential that the objectives are seen not only as achievable but also as being cost effective for all customers.

Optimizing the power quality performance of electrical system is one of the objectives of system operator. The role of regulator is to ensure that this objective is carried out in a cost effective manner. If customers expect power quality to be an intrinsic characteristic of the product simultaneously, they also want it at the lowest price.

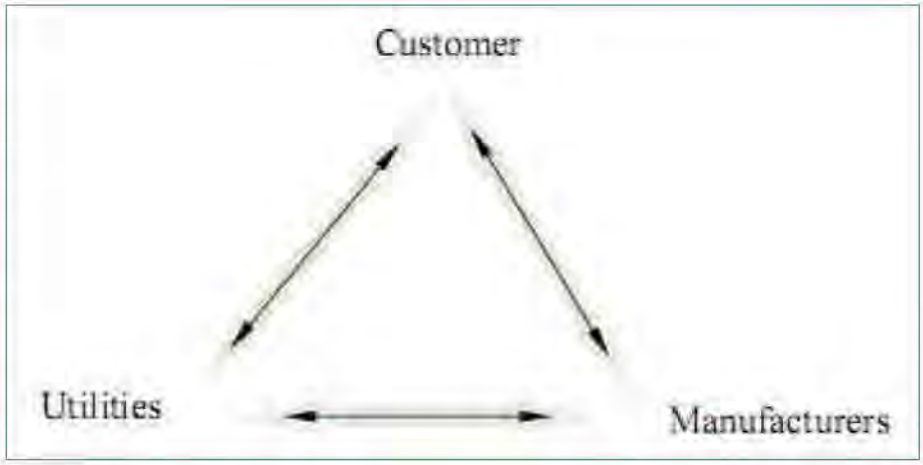


Fig. 1: Power Quality Triangle

The main participants of power quality interest are electric utilities, equipment manufacturers, and electric customers as expressed in the power quality triangle depicted in Fig. 1.

Power Quality Monitoring

The increased requirements on supervision, control, and performance in modern power systems make power quality monitoring a common practice for utilities. Power quality monitoring is necessary to characterize electromagnetic phenomena at a particular location of the network. The facts to be considered for monitoring are:

- The diagnosis of incompatibilities of the power system with the load.
- The evaluation of the electric environment at a part of the system in order to refine modelling techniques or to develop a power quality baseline.
- The prediction of future performance of load equipment or power quality mitigating devices.

For example, an important aspect of power quality monitoring is the collection of information regarding the performance of the system in terms of voltage dips and interruptions. For voltage dips, the obtained information (magnitude and duration) are usually compared with the voltage tolerance curves of the loads (for example the CBEMA curve to evaluate the influence of these events. Monitoring within a certain site (industrial, residential or domestic) can reveal the origin of problems and give the necessary information for their solution. Two cases are described. In the firrst case, monitoring revealed that a pump control system was vulnerable to voltage dips and a constant voltage transformer was installed to support the voltage. In the second case, monitoring showed that plants in the same geographical area were experiencing voltage dips of relatively long duration. This long voltage dips were effecting the operation of a number of apparatuses. The problem was solved by speeding up the protection clearance times at certain points in the zone of influence of the plants. Fault analysis in general can be benefited by monitoring. The collected waveforms of voltage and current can be also used to test protection and control algorithms.

Power Monitoring Equipment

Technological achievement in digital signal processing, microprocessors and storage devices made possible the development of monitoring systems with large capabilities. A wide variety of monitoring systems are available for different purposes. These monitoring systems are designed to accept voltage and current quantities. Typical instrument input limits are 600 V rms for voltage and 5 A rms for current. Voltage transducers and current transformers are used to obtain usable signal levels. Modern digital monitors utilize analog-to-digital (A/D) converters to convert the analogue signals

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(voltages or currents) into numeric values to be processed by the instrument. A/D converters of order up to 20 bits are available for increased resolution. Sampling rates up to 640 samples are today available thus increasing significantly the details on the variations in the waveform that can be captured. After the signals have been digitized, the processor of the monitor operates on the measurements to derive a number of power quality parameters. The measurements and the calculated parameters can be saved in the monitor or alternatively be transferred to a host computer. Intranet technologies are employed for the acquisition of the obtained information at the appropriate location. The modems that are used for the transfer can reach a speed of 400 Mb/sec.

Typical power quality parameters obtained by most monitors are:

- rms values of voltage and current
- Harmonics of voltage and current
- Total harmonic distortion of voltage and current (THD).

Typically, these attributes are calculated over a short period of time and then their averages are recorded by the monitor. Probably the most important task of these monitors is to capture power system events without running out of memory while monitoring. For event capturing, a common method for triggering is on rms changes by setting thresholds. Typical thresholds are ±10 % of the nominal voltage. Comparison of each cycle with the previous cycle can also be used for capturing events that do not cause significant rms changes. Transients are captured with this type of triggering. Alternatively, the monitor can be set to capture events for which unbalance between the phases appears.

The choice of thresholds is important in order to avoid saturating the memory of the monitor with events of little importance. Adaptive thresholds can be utilized to regulate the rate of capture in case of high rate of incoming events. A better solution is the monitor to analyse the event and then, based on the analysis results, decide whether to store it or not. Automatic processing tools are required in this case.

Scottish Power monitoring program

Scottish Power, an electrical utility in Scotland, runs an extensive monitoring program in its distribution system for several years. Aim of the company is to provide monitored data for problem assessment improve the communication with their customers and assist them with problem investigation.

The company serves over 1.7 million customers (domestic, commercial and industrial). The distribution system consists of 83,000 circuit kilometers of overhead lines and underground cables operating at 33 kV, 11 kV and 415/240 V with around 38,000 substations. About 70 % of the distribution network is underground. A large number of fault recorders is installed: around 90 fault recorders were in operation in 1997 and over 150 at present.

The monitors are triggered by voltage or current excursions and are able to capture their waveforms. In two years of operation (1997-1999) over 20,000 events were captured. The recordings are transferred by modems in the main computer in the company's headquarters (Fig. 2).

The automatic analysis of power system events are as follows:

- Segmentation of the voltage signals
- Feature extraction from the segments
- Rule-based classification using the segmentation results and the extracted features.

Power Generation

P. Carlsson et al. proposed a method to investigate the production potential of PV installations. The method considers the latitude and the horizon profile of the specific site to predict the amount of available energy. The difficult part concerns shading effects from objects close to the PV panels that cannot be treated in the same way as 'horizon objects'. In 1997 available tools for simulation of PV systems were investigated (Sundi, Radiance, PVsyst etc.) but none could perform a simulation regarding the electrical behaviour of the PV cells including individual shading. A conventional simulation tool for electronics (P-spice, Simplorer, Saber etc.) would be far too slow if every PV cell were to be simulated individually in a normal sized PV installation.

What is needed is an intelligent algorithm that sorts out which PV cells are performing equally, depending on connection and shading. Then this

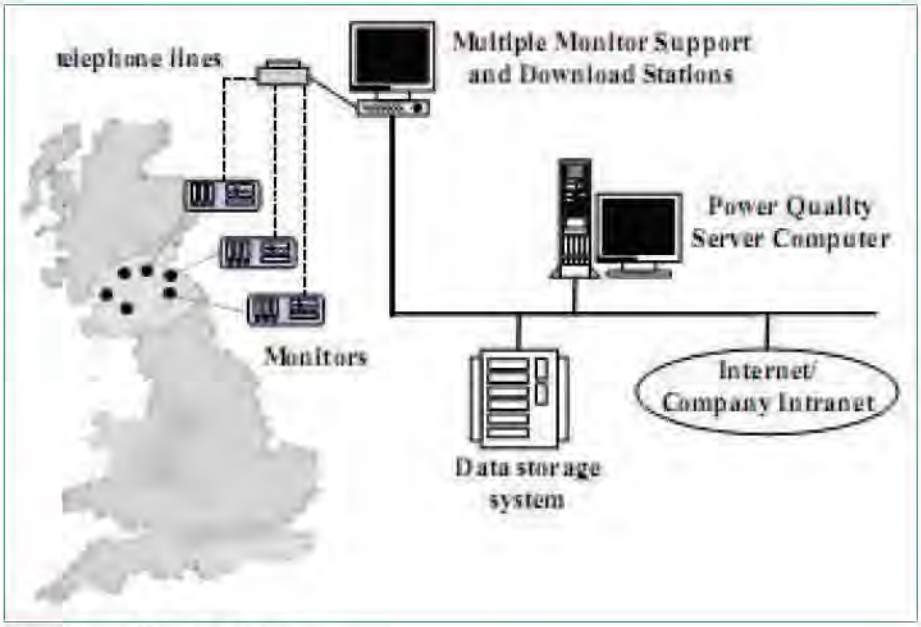

Fig. 2 Power Monitor System

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algorithm could be added to the conventional tools without increasing the amount of calculations too much.

Photovoltaic Cells

The photovoltaic effect is described in Encyclopedia Britannica as "a process in which two dissimilar materials in close contact act as an electric cell when struck by light or other radiant energy". In other words, a photovoltaic cell is a diode optimized to absorb photons from (usually) the sun and convert them into electrical energy.

Photovoltaic cells can be divided into four groups: crystalline cell, thin-film cell, dye-sensitised solar cell (DYSC or Grätzel-cell) and multilayer cell. The latter can also be considered as several layers of thin-film PV cells. The different types are described in and. The (mono- and multi-) crystalline are the dominating types with highest efficiency but the thin film cells are entering the market now. The thin-film technology has the potential to be manufactured at substantially lower cost than the crystalline cells.

The production of PV-modules using thin-film technology can be fully automated while for modules with crystalline cells, it is a bit of a handcraft. In Fig. 3 the electrical behavior of a PV cell is shown. Note that the current axis is in the other direction than for a normal diode.

At an irradiation of 1000 W/m, corresponding approximately to a cloud-free, sunny day, the upper curve shows that the open-circuit voltage of the cell is about 0.6 Volt. As the load (current) of the cell increases, the voltage decreases and at short-circuit (voltage = 0) the current is approx. 3.7 A for this particular cell (it depends on the size and efficiency).

At open circuit and at short-circuit, no power is produced. At a point called the maximum power point (MPP), maximum power is gained from the PV cell. To visualise this, a rectangle can be drawn from a point on the curve to the x- and y-axis. For the point where this rectangle has the largest area maximum power is generated.

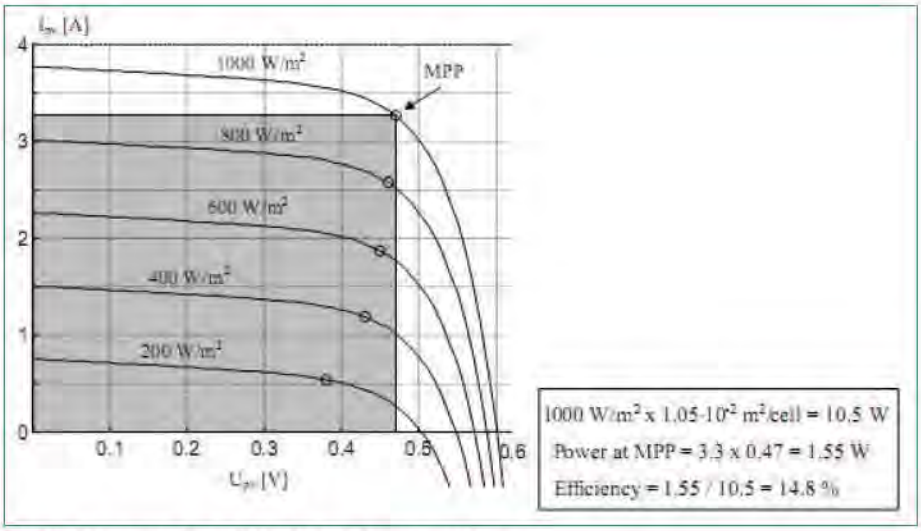

Fig. 3: IV-curves for a PV-cell at different insolations.

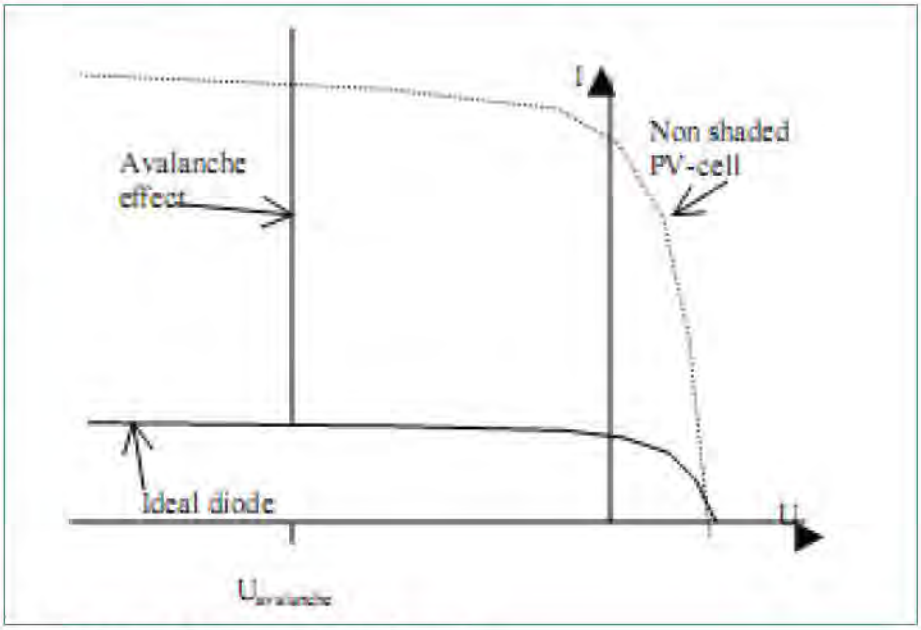

Fig. 4: IV-curve of a 25 % illuminated PV-cell

At lower irradiation, the short-circuit current decreases approximately linearly with irradiation. The open circuit voltage does not decrease as much until very low irradiation. However, the open circuit voltage is much more affected by the temperature of the PV cell.

At a higher temperature, the open circuit voltage decreases. The phenomenon has quite a large impact and decreases the output power by approximately 15% at a temperature increase from 25^{0}C to 50^{0}C.

Shading of Photovoltaic Installations

The striking conclusion when the measurements from the Sankt Jörgen's PV power plant were evaluated was the large impact shading has on energy production. The reason for this showed to be the way the PV modules were connected in combination with their spatial formation. To understand the shading of PV cells in series, the second quadrant of the iv-curve and the reverse voltage break through, or the avalanche effect of a diode, must be considered. In

Fig. 4, the IV-curve for quadrants one and two is shown.

An ideal diode can withstand any reverse voltage and in the case of an ideal PV cell it will work as a constant current load if reverse voltage is applied. In a series of PV cells this means that the least illuminated cell will limit the current from the whole series. In reality, there is a point of break-through in the pn-junction when the externally applied electric field will overcome the intrinsic electric field, known as the avalanche effect. For a silicon PV cell, this will happen at 14-30 V ($U_{avalanche}$).

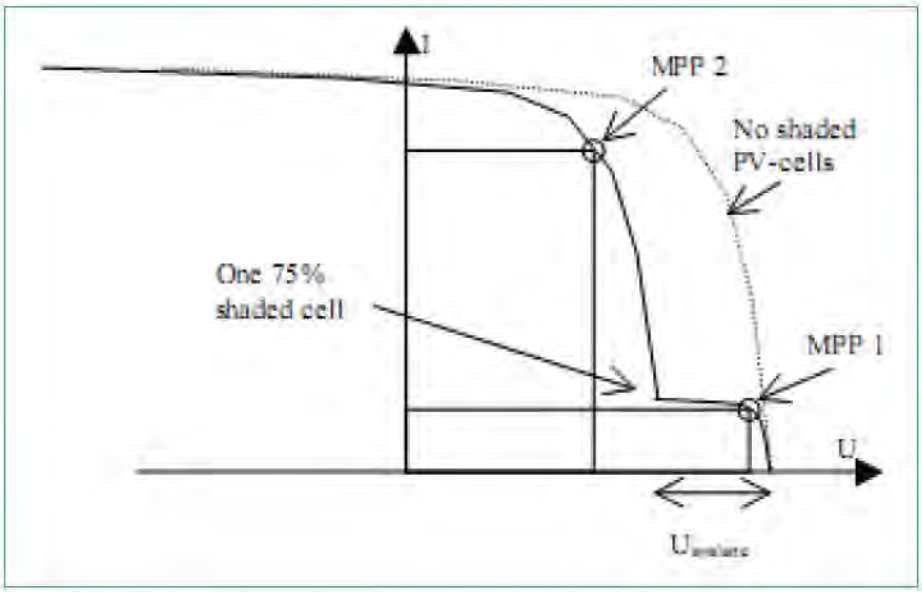

Fig. 5: IV-curve of series connected PV-cells with different illumination

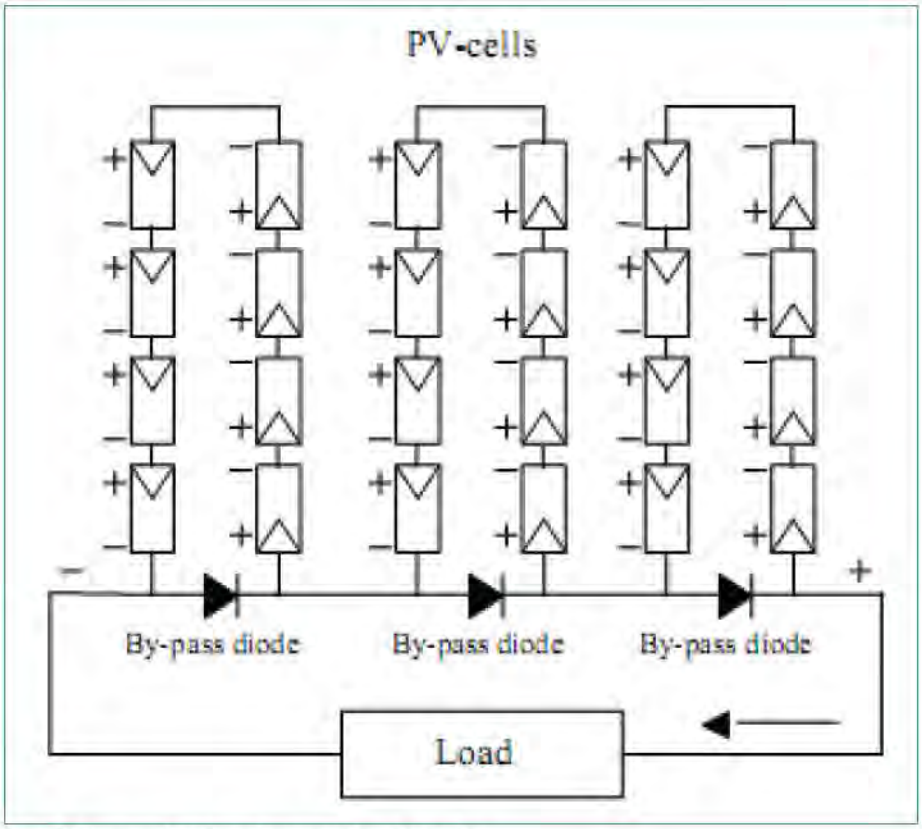

Fig. 6: Three substrings by-passed with diodes.

Subsequently, the maximum current through a series of PV cells is no longer limited by the shaded cell, but the cell will dissipate power equal to the avalanche voltage times the current.

Fig. 5 shows the iv-curve of a series of three PV cells, where one cell is shaded by 75%. It can be noted that the curve now has two local maximum power points; MPP1 and MPP2. Which one is the global MPP, depends on how many cells there are in the series and on the Uavalanche.

At MPP 1, the voltage is not reversed for the shaded cell, and produces energy at its MPP, while all the non-shaded cells just produce approximately 25% of their potential power. At MPP 2, the voltage of the shaded cell is reversed and the cell consumes energy. The rest of the cells produce more energy than in MPP 1, although not at their MPP. The somewhat paradoxical phenomenon occurs that the shaded cell heats up much more than the non-shaded cells. This could lead to damage to the shaded cells.

To avoid destruction of PV cells due to this 'hot-spot effect', manufacturers connect by-pass diodes over a group of cells, for instance over 8 cells, see Fig. 6. With this arrangement a substring with a shaded cell will be short-circuited by the bypass diode and the non-shaded substrings can work at their MPP, but the energy from the bypassed substring is lost. It is important to underline that this is normally only a method for the protection of the PV cells.

If bypass diodes are to be used to make the PV module more shade-tolerant, they should be connected to significantly fewer PV cells. Another method to gain shade tolerance is to install more power converters, as they will work independently of each other.

Decentralized PV Inverters

The most effective measure to take in

order to maximize the energy yield from a PV installation is to place the solar panels in an optimal way. Having the right direction south/north (azimuth) and elevation angle can be evaluated in simulation programmes. It is also important to keep in mind that any shading of the solar panels will lead to considerable reduction in energy yield, even if just a small fraction of the panels is shaded.

Shading can rarely be completely avoided, certainly not in urban or suburban environments. At higher latitudes (like in Sweden) the sun is often close to the horizon which makes the shading problem more severe than at low latitudes. Therefore especially for high-latitude locations and urban/suburban sites, a shading-tolerant system should be chosen. That means: selecting more power converters with a low power rating and PV panels with more by-pass diodes and avoid connecting PV-modules in parallel. Björn Lindgren proposed a 110 W Inverter for Photovoltaic Applications.

Power System

An electric power system is a network of electrical components used to supply, transmit and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power - for sizable regions, this power system is known as the grid and can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centres to the load centres and the distribution system that feeds the power to nearby homes and industries.

Table 1 gives the different categories of electromagnetic phenomena that may

Categories	Typical spectral content	Typical duration	Typical voltage magnitude
Transients Impulsive			
• Nanosecond	5 nsec rise	< 50 nsec	
• Microsecond	1 µsec rise	50 nsec – 1 msec	
• Millisecond	0.1 msec rise	> 1 msec	
Oscillatory			
• Low Frequency	< 5 kHz	0.3 - 50 msec	0 - 4 pu
• Mid Frequency	5-500 kHz	20 µsec	0 - 8 pu
• High Frequency	0.5-5 MHz	5 µsec	0 - 4 pu
Short Duration Variation			
Instantaneous			
• Interruption		0.5 – 30 cycles	< 0.1 pu
• Sag(dip)		0.5 – 30 cycles	0.1 – 0.9 pu
• Swell		0.5 – 30 cycles	1.1 – 1.8 pu
Momentary			
• Interruption		30 cycles – 3 sec	< 0.1 pu
• Sag(dip)		30 cycles – 3 sec	0.1 – 0.9 pu
• Swell		30 cycles – 3 sec	1.1 – 1.4 pu
Temporary			
• Interruption		3 sec – 1 min	< 0.1 pu
• Sag(dip)		3 sec – 1 min	0.1 – 0.9 pu
• Swell		3 sec – 1 min	1.1 – 1.2 pu
Long Duration Variation			
Interruption Sustained		> 1 min	0.0 pu
Under Voltages		> 1 min	0.8 – 0.9 pu
Over Voltages		> 1 min	1.1 – 1.2 pu
Voltage Unbalance		Steady State	0.5 – 2 %
Wave distortion			
Dc Offset		Steady State	0 – 0.1 %
Harmonics	0 – 100th Harmonics	Steady State	0 – 20 %
Inter – Harmonics	0 – 6 kHz	Steady State	0 – 2 %
Notching		Steady State	
Noise	Broadband	Steady State	0.1 %
Voltage Fluctuations	< 25 Hz	Intermittent	0.1 – 7 %
Power Frequency Variation		<10 sec	

Table 1: Categories of electromagnetic phenomena

appear in a power system. This categorization is done in terms of the frequency components (spectral contents) which appear in the voltage signals during the phenomenon, the duration of the phenomenon and the typical voltage magnitude. These phenomena are mainly caused by:

- External to the power system factors. For example lightning strikes cause impulsive transients of large magnitude.
- Switching actions in the system. A typical example is capacitor switching which causes oscillatory transients.
- Faults which can be caused, for example, by lightning (on overhead lines) or insulation failure (in cables). Voltage dips and interruptions are phenomena related to faults.
- Loads which use power electronics and introduce harmonics to the network.

Installed capacity of solar generated power is small compared with other production units and compared with the local power consumption and therefore power quality issues have not been an urgent matter.

Case study on Power-system issues

So far, the installed capacity of solar generated power is small compared with other production units and compared with the local power consumption and therefore power quality issues have not been an urgent matter. Issues around connecting solar panels to the grid have so far been a matter of energy yield optimization, safety, reliability and cost. The IEEE standard 929-2000, which addresses PV-to-grid connection, is summarized.

IEEE Recommended Practice for Utility Interface of Photovoltaic Systems (IEEE Std 929-2000)

The standard (IEEE Std 929-2000) generally describes PV systems, terminology and specially defines the circumstances, under which the PV inverters should 'disconnect'. The standard uses a longer term: "cease to energize the utility line" to allow the inverters to monitor the grid voltage while 'disconnected'. The power-quality issues involved in this standard are: voltage fluctuations leading to flicker and distortion.

For smaller power plants, defined as total power less than 10 kW, the PV inverter should trip if the grid voltage is outside the normal operation range (in the US it is 88-110 % of 120 V). The maximum time for the inverter to trip is specified for two ranges: if the voltage is outside 50-150 % of the nominal level, the device should trip in 0.1 seconds, else in 2.0 seconds (6 /120 cycles).

For larger systems, it is up to the utility to decide whether to trip at these levels or at others. The reason for this is that the utility might see the PV plant as a power source, which increases the probability to ride through a disturbance on the grid.

A short paragraph concerning voltage fluctuations (flicker) expresses that PV inverters connected to the grid should not result in larger voltage harmonics than stated in standard: IEEE 519-1992. Flicker, which is repeated voltage variations in the range 8-32 Hz, should not normally occur in a PV plant. The only reasons for such variations should either be varying shading from rotating objects (wind turbines) or instabilities in the controllers of the PV inverters.

Never the less, the customer with PV is treated in the same way as any other customer and is therefore responsible for the emergence of flicker problems. According to the standard the PV inverter should monitor the grid frequency and disconnect at certain local levels (< 59.3 or > 60.5 Hz in the US). Considerably larger frequency ranges are also mentioned for cases where the variation naturally is larger, for example for small islands.

Islanding protection is discussed, and a very tough test procedure of this feature is described in the standard 929. It is important to note that this feature is optional. The manufacturer should state if his device has the "no islanding feature" or not. If it has, the inverter should be able to disconnect if the grid is lost. A test set-up is described where the inverter has a perfectly matching load (both active and reactive) and the load has a resonance circuit with the quality factor of 2.5 (handles power 2.5 times the active power) and the frequency identical to the grid frequency. This is in theory impossible, because no current will go through the circuit breaker and it is therefore infeasible to determine if the circuit breaker is opened or closed. In practice however there are ways to solve this problem. Besides, in reality the perfect match and a resonance circuit of exactly 50/60 Hz is unlikely, but still the inverter has to pass this test.

Voltage issues

In the low-voltage network no production units are normally present. When solar generators are becoming more common, new phenomena might therefore arise. B. Lindgren et al. and M. H. J. Bollen et. al. presented voltages along a feeder equipped with solar generators.

The general conclusion is that if the PV inverters inject pure active power, which is normally the case today, the voltage will vary in a considerably larger range than now. This would lead to that the utilities have to re-dimension their low-voltage network and install more transformers.

However, if the PV inverters are allowed to control the voltage at their connection point by producing or consuming reactive power, the voltage variation can be kept at the same magnitude as at present. The disadvantage of this control method is that the inverter has to be designed for a larger current than in the pure active-power case.

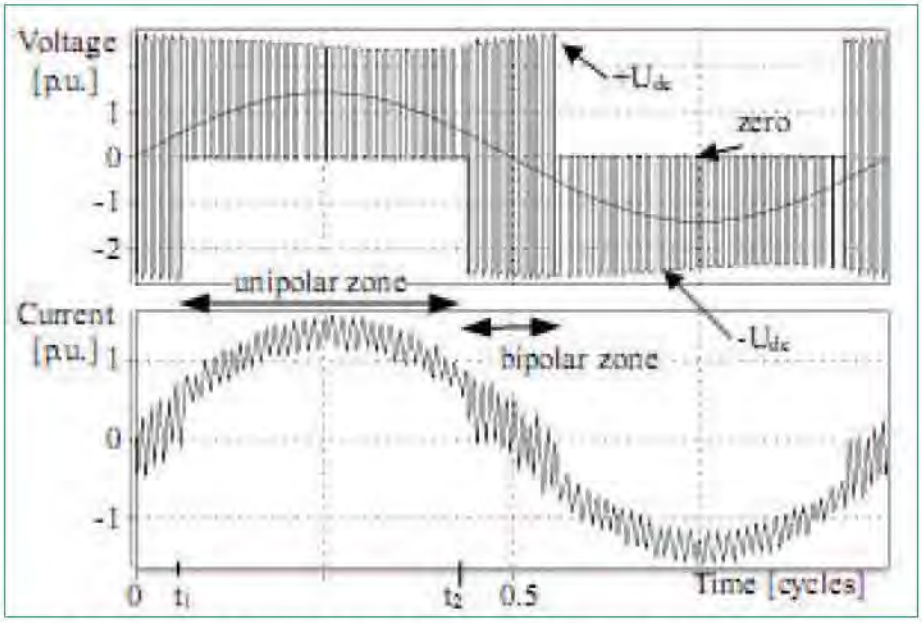

Fig. 7: H-bridge voltage and grid voltage (top) and grid current (bottom)

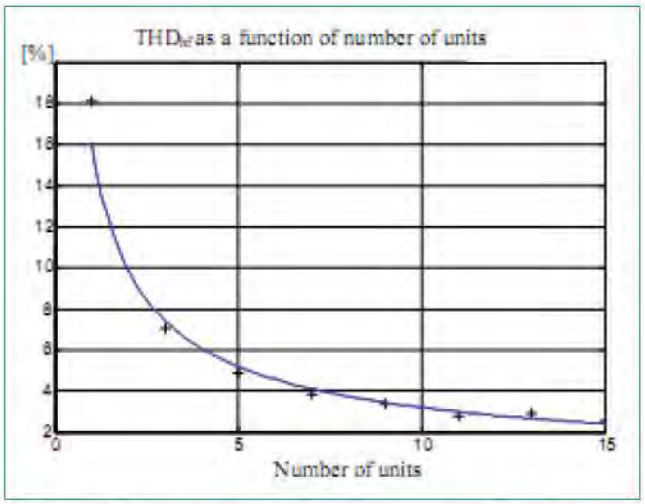

Fig. 8: High-frequency current distortion versus number of inverters

Harmonic issues

H. J. Bollen et al., discussed about PV inverters connected to the grid. Parameters in the implemented hysteresis control are varied in order to investigate their impact on the grid current. They discussed grid's impact on the inverter current control algorithm also. The feasibility of using a combination of unipolar and bipolar output voltage is investigated. In Fig. 7 the grid voltage and the switched output voltage are shown in the upper half.

The resulting grid current is seen in the lower half of Fig. 3. In the standard double pulse modulation, the unipolar zone equals half the fundamental cycle (t1=0 and t2=0.5). The result of varying t1 and t2 is that the high frequency distortion decreases with increasing unipolar zone while the odd low frequency harmonics have their lowest value when only using bipolar switching (unipolar zone equals zero). The odd low frequency harmonics increase with increasing unipolar zone but there is a local minimum approximately at t1=0.05 p.u. and t2=0.45 p.u. (as in Fig. 3) which might be the optimal choice.

The general conclusion when several inverters are studied is that the relative high frequency content decreases with the number of units.

In Fig. 8 the relative high frequency distortion is shown from simulations with one to fifteen inverters. The reason for this attenuation (or cancellation) is that even if the magnitude of the high frequency spectrum is similar for the units, the phase angles are not.

In theory the curve in Fig. 4 should be proportional to one over the square root of number of units if phase angles are totally random.

Profile

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R T Karthick

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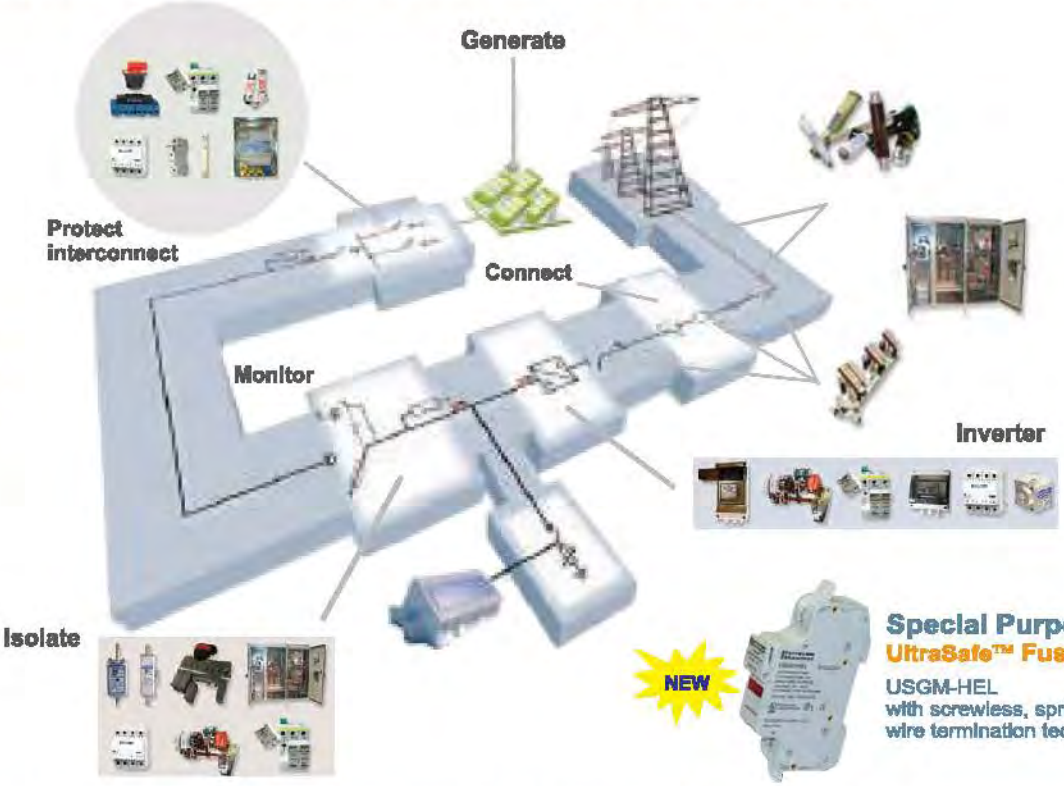

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Doubly-Fed Induction Generator in Wind Energy Conversion Systems – *An Overview*

With rapid development of variable speed wind turbine technology and significant growth of wind energy conversion system both in grid-connected and stand-alone operation, a suitable control technique and electric generator along with power electronic converter are required for obtaining the desired electrical performance in the operation of such systems. So, this article reviews some of the latest trends in the application of Doubly-Fed Induction Generators (DFIG) and associated control techniques employing power electronic controllers for effective utilisation of wind energy.

K Vijayakumar, Dr N Kumaresan & Dr N Ammasai Gounden

In the last three decades there is an increased emphasis on the exploitation of renewable energy resources for supplementing electrical power generation from conventional sources. Among these renewable sources, wind energy electric conversion systems have been found to be viable in contributing significant amount of electric power, when installed in locations where adequate wind potential is available over most part of the year. As the turbine power ratings increase steadily, electrical generator technology has also undergone tremendous change from the early fixed-speed turbine generator systems to variable speed systems, in order to obtain increased energy capture and operational flexibility. This requires the generator to be interfaced to the grid through power electronic converters. The steady-state and dynamic performance of the wind turbine generator can be improved with such power electronic converters.

The ratings of grid-connected generators have steadily grown to MW range and they feed power to the grid at constant voltage and frequency of the grid. Wind energy electric conversion systems (WEECS) for feeding isolated loads are also gaining importance and a variety of configurations have been proposed in recent times. Asynchronous generators namely Squirrel-Cage Induction Generator (SCIG), Doubly Fed Induction Generator (DFIG) and Permanent Magnet Synchronous Generator (PMSG) are more commonly employed for generating power from wind energy. In variable speed wind turbines, SCIGs and PMSGs are integrated into grid/isolated loads with full-rated power electronic converters. The wind turbines with a full-scale power converter (normally, a back to back converter) between the generator and grid give the improved performance such as independent control of the real and reactive power, wide speed operation (since the generator is decoupled from the grid, the generator can operate at a wide variable frequency range) and improved dynamic response. However, they have higher cost, circuit complexity and a higher power loss in the converters, since all the generated power has to pass through the power electronic circuits. The various components of variable speed wind energy conversion system are as shown in Fig. 1.

Doubly-Fed Induction Generators

In view of reduced power rating requirements for the power electronic converters and ease of control, DFIGs are increasingly employed for supplying the power either directly to the grid or for isolated loads from wind energy. Due to bi-directional power flow capability of the converters, the system can be operated in sub-synchronous and super-synchronous speeds. The DC link capacitor acts as a source of reactive power and, it is possible to supply the magnetizing current, partially or fully, from the rotor side. Fig. 2 shows the block diagram of the

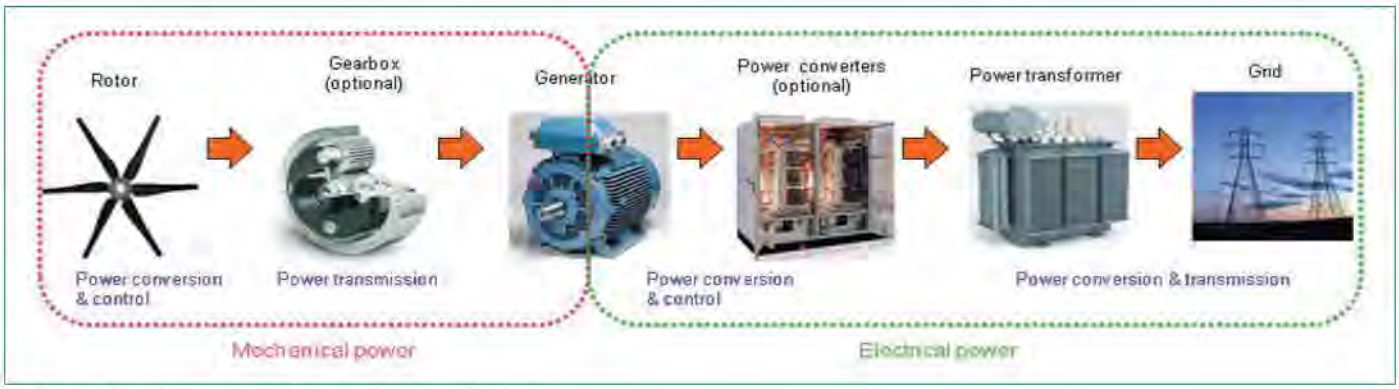


Fig. 1: Various components of variable speed WEECS

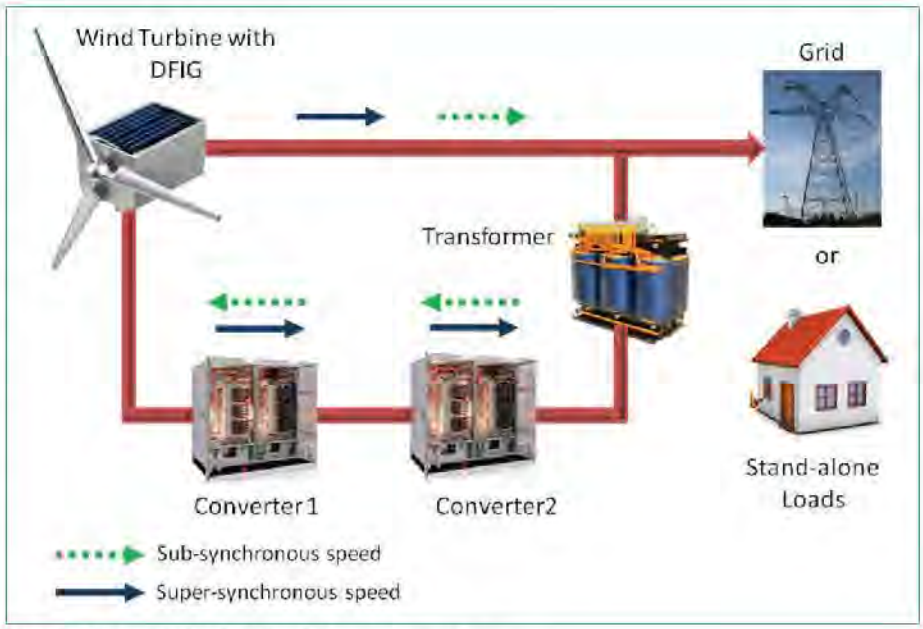


Fig. 2: DFIG with back to back converter system

conventional DFIG system with back to back converter system. The stator of the generator is directly connected to the grid or load through transformer. The rotor terminals are connected with back to back converters with a desired frequency and amplitude. During sub-synchronous speed of operation, the power is injected through the rotor terminals. The power is extracted from the rotor and feedback to the grid when the generator operates in super-synchronous speed.

Different control strategies have been employed for control of grid-connected and stand-alone DFIG employing back to back converter in the rotor side. In field oriented current controllers, the control strategy is formulated such that the real and reactive powers are controlled through the rotor side converter and the grid side converter controls the DC link voltage. Direct power control has also been proposed in the literature for the operations of DFIGs, to reduce the number of loops and dependency of machine parameter. But, the hysteresis controller employed in this scheme introduces current and torque distortions and also affects the switching frequency of the converter. Then, the rotor Flux Magnitude and Angle Control (FMAC) has been used where the rotor flux magnitude controls the reactive power/voltage while rotor flux angle controls the active power/ torque. FMAC also involves complex transformation between the rotor and synchronous reference frames.

Energy storage devices in DFIG system

Further, it is known that, the fluctuating power output of wind-farms with varying nature of wind speed would affect the operation of interconnected grids and quality of power output from the wind turbine systems. So, to improve the reliability and performance of these systems, the integration of the energy storage devices with wind turbine generator systems have been increased. In recent years, integration of energy storage system to the DC link (through bi-directional DC-DC converter) of the back to back converters is emphasized for

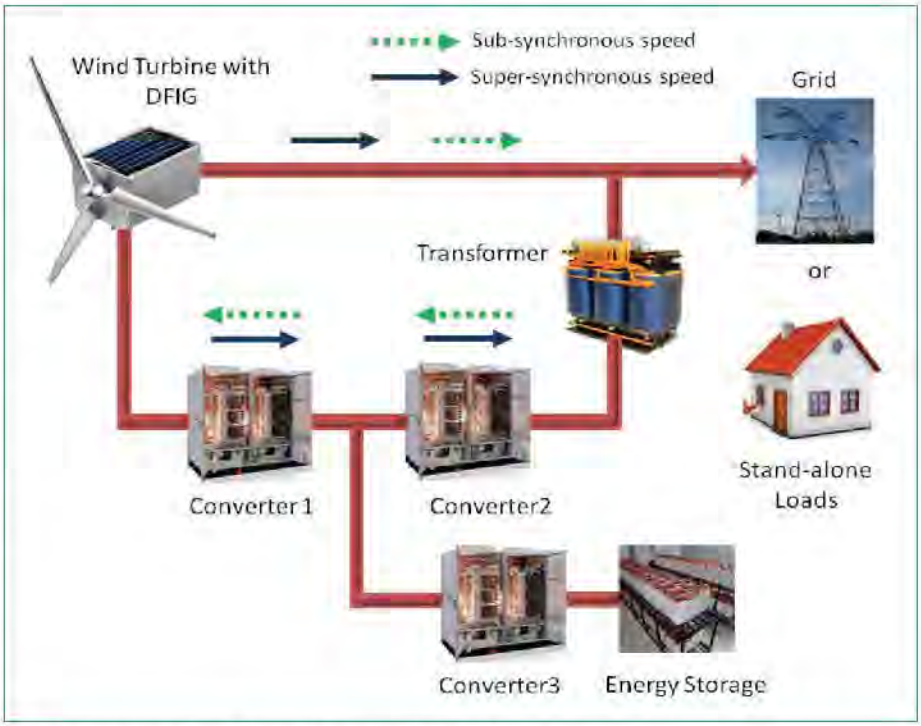


Fig. 3: Incorporation of energy storage into DFIG system

smoothing out the intermittent nature of wind power to the grid. Super capacitor (SC) and Superconducting Magnetic Energy Storage (SMES) devices are incorporated in the DFIG system to investigate the impact of power fluctuation in power network and different transient control strategies. All the energy storage technologies mentioned above can operate as an auxiliary energy source for a short duration, typically less than 6 s. However, battery storage systems are known to provide an adequate behaviour with high power or energy requirements.

Furthermore, lead-acid batteries are the oldest and most mature technology, and have shown acceptable performance in large scale applications. Batteries are used in the turbine tower in order to improve the quality of the power output from the turbine and its ability to support the grid. Moreover, the battery banks are interfaced to the DC link of the DFIG system through a multiphase bidirectional fly-back DC–DC converter. In such back to back converter schemes, a fast regulation of DC link voltage is necessary for improving the quality of the output current of grid-side inverter systems. Hence, it is to be noted that the energy storage device has been connected through the extra power electronic interface circuit which causes the complexity in control as well as circuit topology. Further, the complicated control of the grid-side converter with individual wind-farm generator is no longer required because of FACTS controllers such as STATCOM, UPFC etc, being employed at the point of common coupling for power quality problems. The DFIG system along with energy storage devices is as shown in Fig. 3.

DFIG with single inverter battery system

The schematic of the proposed DFIG based wind energy conversion system along with single inverter-battery at the rotor side is shown in Fig. 4. The rotor is fed through SPWM inverter supplied by batteries. In grid connected system, the real and reactive power at the stator side of the DFIG is controlled by appropriately adjusting the rotor voltage magnitude and frequency irrespective of rotor speed and mechanical input power. In case of stand-

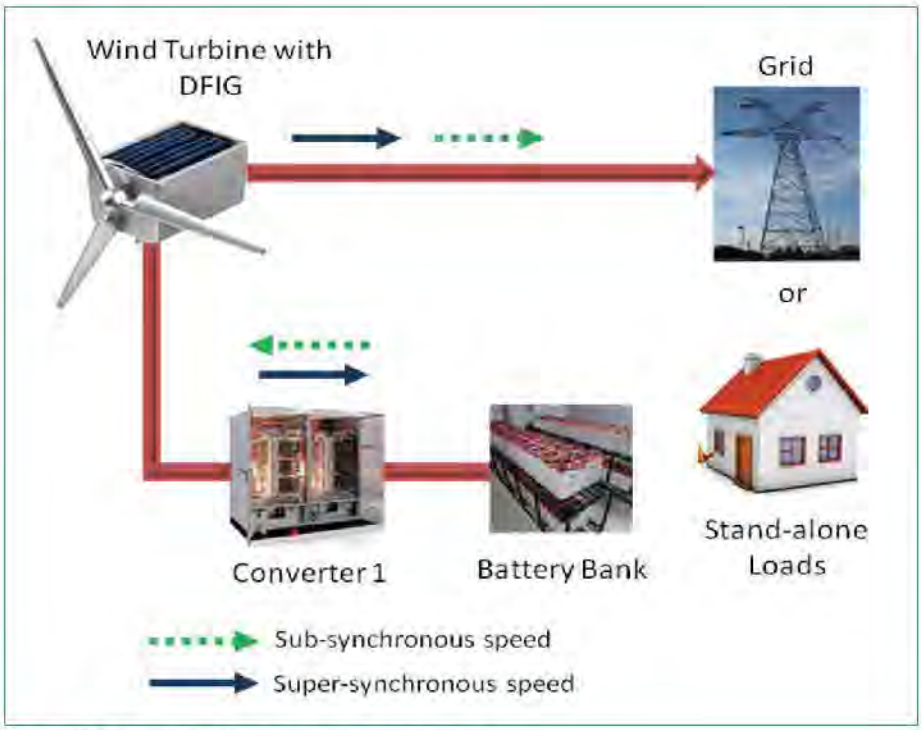


Fig. 4: DFIG with single inverter-battery system

alone application, the stator voltage and frequency are maintained constant by appropriately controlling the rotor voltage and slip frequency. The rotor voltage magnitude and frequency are varied by generating appropriate modulation index and modulation frequency of SPWM inverter. It is known that at super-synchronous speed, the slip power is extracted from the rotor terminals of DFIG. To operate the machine as a generator at sub-synchronous speed, the slip power is injected into the rotor terminals. This concept is used for charging / discharging the batteries through the same SPWM inverter depending on excess / deficit power from the wind i.e., the difference between the wind power and the load power is either stored in or extracted from the battery. Moreover, the control strategy employed for this system uses the concept of controlling the rotor voltage magnitude

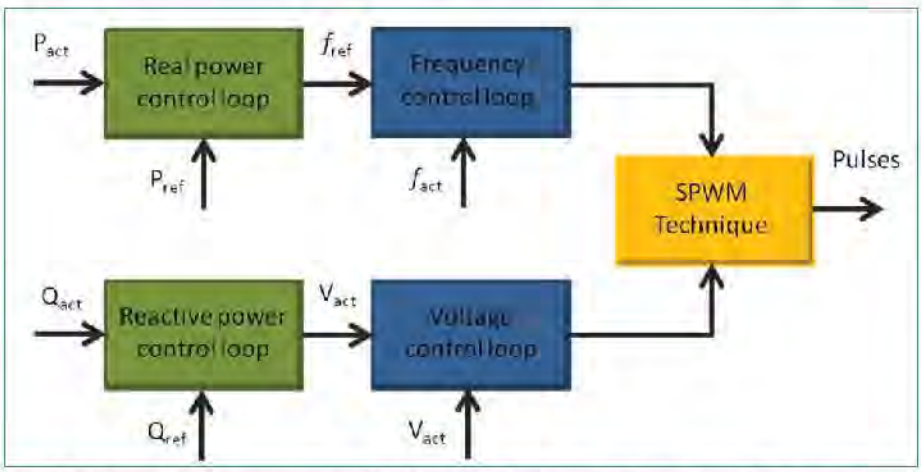


Fig. 5: Real and Reactive power controller for grid-connected single inverter-battery based DFIG system

and frequency. This does not involve any complex computation such as rotor flux and air-gap emf estimation. Since it depends only on voltage and current measurements on the stator side, it is insensitive to the parameters of the machine. The detailed explanation of the controller has been presented in the following section.

Grid-connected operation

The single inverter-battery based DFIG system is capable of smoothing out (i.e., supplying constant dispatchable power to the grid with desired power factor) the fluctuating wind power to the grid, since the system has been incorporated with battery storage. Hence, the dispatchable power at stator terminals is possible with the system either by charging or discharging the batteries for any wind condition. The controller for the grid connected system consists of two cascaded parallel loops - one for controlling the real power fed to the grid and other for reactive power control - as shown in Fig. 5. The control philosophy adopted is to adjust the magnitude of the rotor voltage for the control of reactive power and adjust the rotor frequency for the control of real power at the stator terminals.

The stator voltages and currents are used for calculating the actual value of real and reactive power at stator side. Comparing these actual values with the corresponding references (i.e., P_{ref} & Q_{ref}), the PI controllers provide references for the rotor voltage magnitude (V_{ref}) and frequency (f_{ref}). Then the V_{ref} and f_{ref} are compared with the actual quantities for obtaining the rotor voltage magnitude and frequency. These two quantities are multiplied for obtaining the reference sine wave (i.e., modulating waveform) corresponding to the set value of real and reactive power at stator terminals. Then this modulating wave is compared with 5 KHz carrier signal and the resultant output is the gating pulses for the bi-directional inverter.

Stand-alone operation

A controllable AC voltage of the desired magnitude and frequency at the stator

terminals of DFIG for supplying isolated load is obtained using the battery-inverter system at the rotor side. The system operates in various modes depending upon the availability of wind and size of the isolated load. All possible modes of operation have been identified and described as below-

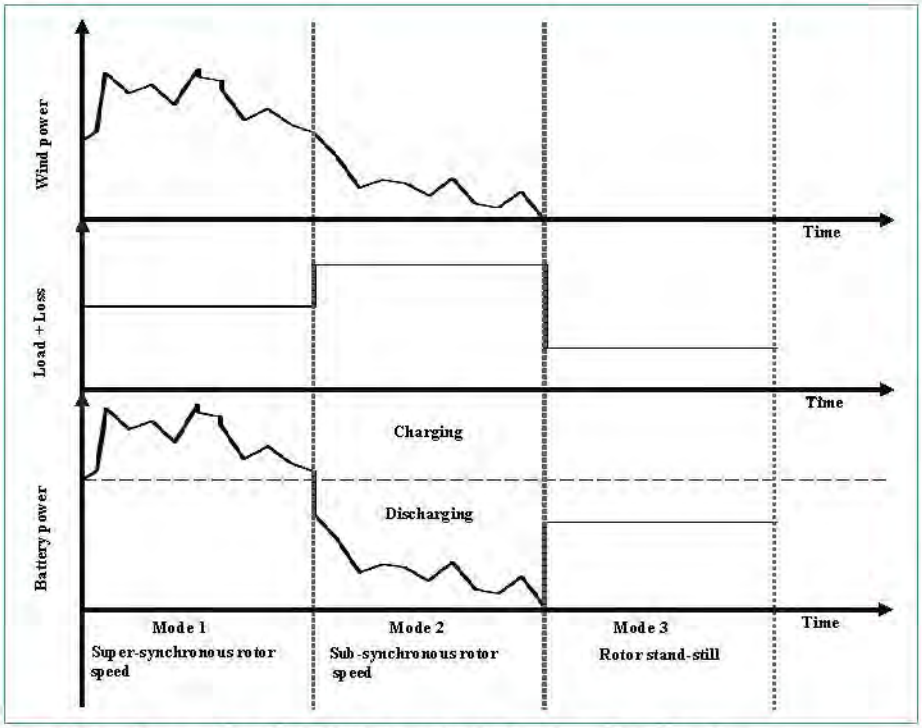


Fig. 6: Operating modes of the single inverter-battery based DFIG system
(Source : Vijayakumar, K., Kumaresan, N., Ammasai Gounden, N.: 'Operation and closed-loop control of wind-driven stand-alone doubly fed induction generators using a single inverter–battery system', IET Electr. Power Appl., 2012, 6, (3), pp. 162–171)

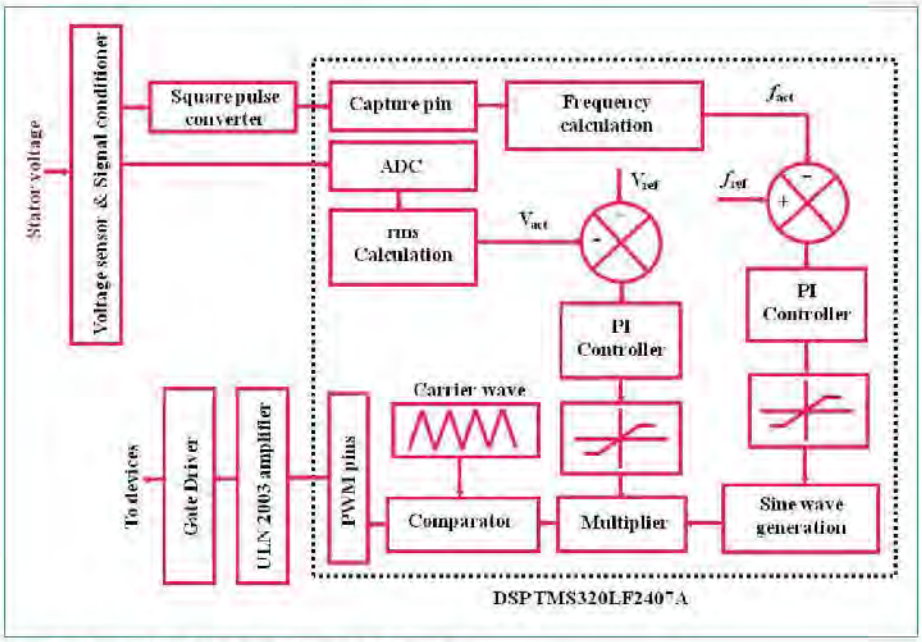


Fig. 7: Controller for stand-alone DFIG system

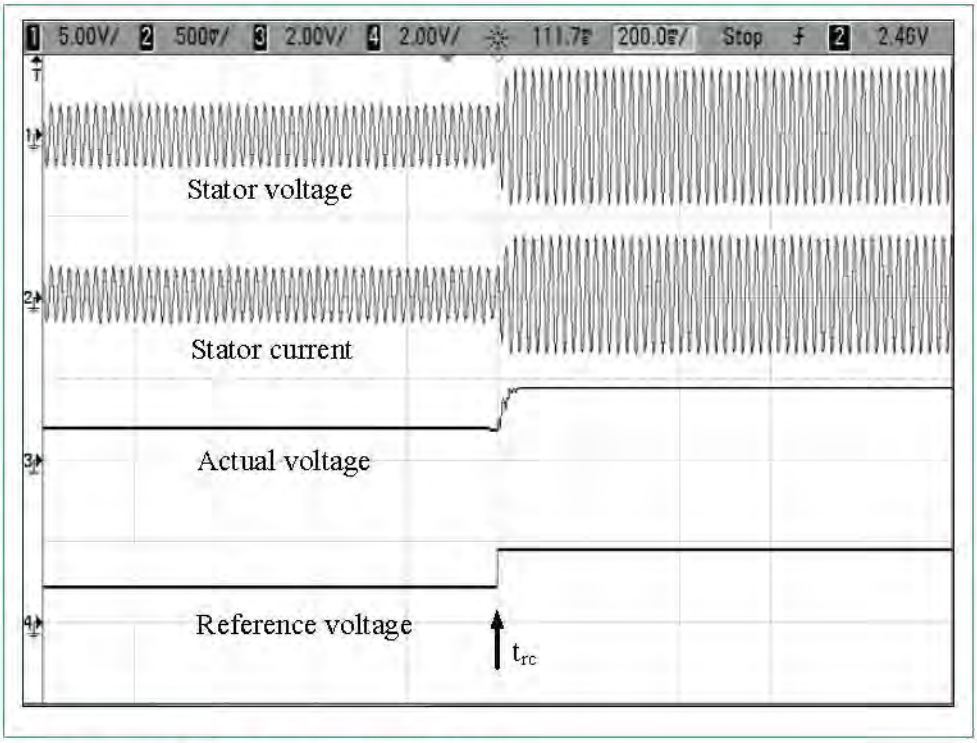
Mode 1: When the available wind power is more than the AC load requirement, the excess power is used to charge the batteries. This mode necessitates the operation of DFIG in super-synchronous rotor speed. The power balance equation of this mode is: wind power = AC loads + battery power + losses.

Mode 2: When the available wind power is not sufficient to feed the connected AC loads, the additional power required is obtained from the batteries. In this mode, the DFIG has to operate in sub-synchronous rotor speed and the power balance equation is: wind power + battery power = AC loads + losses.

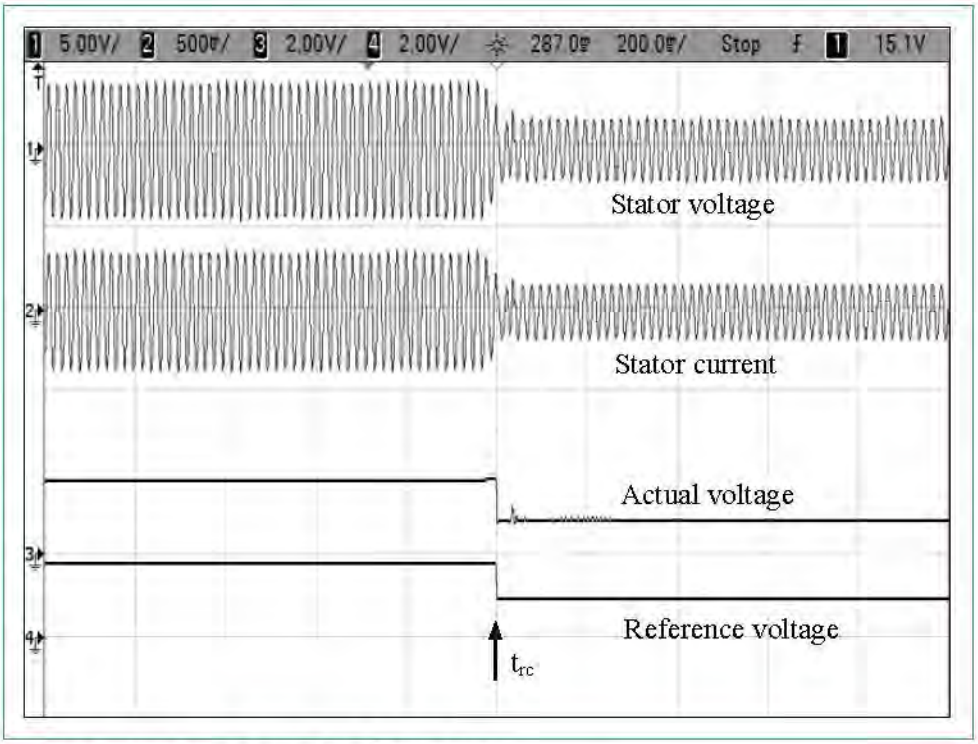
Mode 3: When the wind speed is less than the cut-in speed of the wind turbine, the battery will feed the loads; for a duration depending upon the capacity of the battery and the size of the load. During this mode, the rotor of DFIG is stalled by applying mechanical or electromechanical braking. Hence the power balance equation for this mode is: battery power = AC loads + losses. The above operating modes are depicted in Fig. 6.

When the battery is fully charged, a dump load or auxiliary load across the stator terminals / battery terminals may be used to dissipate the extra power available from the wind. Auxiliary load like water pumping is a better option than dump load because harvested energy is not wasted.

The controller for the stand-alone system as shown in Fig. 7 consists of two parallel loops- one for regulating the stator voltage and the other for frequency. In the voltage control loop, the difference between reference voltage, V_{ref} and the measured voltage magnitude, V_{act} is processed and a control signal corresponding to the required modulation index is generated. In the frequency control loop, the difference between reference frequency, f_{ref} and the actual frequency, f_{act} is processed and a sine wave of slip frequency is generated. The outputs of the two loops are multiplied to obtain the required modulating signal corresponding to the variation in rotor speed and load and then compared with the carrier signal.



(a) Stator voltage step change from 200V to 415V



(b) Stator voltage step change from 415V to 200V

Fig. 8: Dynamic response to step change in stator voltage
Stator power = 1kW and trc: instant at which reference value change initiated; For experimental waveforms: Stator voltage scale=716 V/div, Stator current scale=2.63 A/div, Actual and reference voltage scale=461 V/div, Time scale=200 ms/div

Fig. 8 (a) and Fig. 8 (b) show the dynamic response of stator voltage, stator current along with reference setting for step change in stator voltage. Initially the stator side of the machine was connected with balanced load of 170 Ω in each phase and operated with 200V, 50Hz supply. At t_{rc}, the reference voltage of stator side is increased from 200V to 415V (For this the reference is changed from 2.0V to 4.15V). Fig. 8 (a) shows that the stator side voltage is changed from 200V to 415V. The steady-state value has been reached within 3-5 cycles. It can be observed that the frequency has been maintained at 50Hz. A similar response has been observed in Fig. 8 (b) for step decrease in stator voltage reference from 415V to 200V (For this, the reference is changed from 4.15V to 2.1V).

SSIG operation of stand-alone DFIG

In single inverter-battery based DFIG system, it should be noted that if AC load at the stator terminals is not present (i.e., open circuit at stator terminals), the system fails to charge the battery with the available wind energy. So, for better utilization of available wind power for the stand-alone application, it is proposed to charge the batteries through rotor side inverter by short circuiting the stator terminals, when the ac load is not present.

This Shorted Stator Induction Generator (SSIG) operation for the present system is termed as mode 4 and the power balance equation is: wind power = battery power + losses. The SPWM inverter-battery system shown in Fig. 11 functions as a virtual grid, by maintaining the constant voltage and frequency at the rotor terminals, for SSIG operation. In SSIG operation, the extracted wind energy is used for charging the batteries.

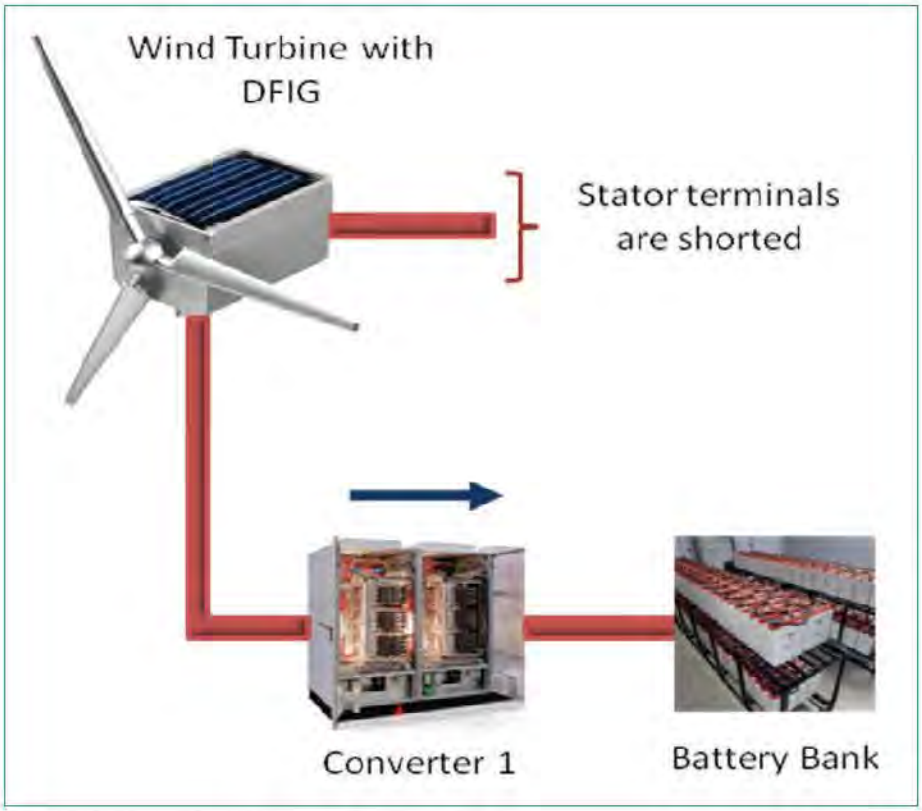


Fig. 9: DFIG with single inverter-battery system

Conclusion

With a view to develop a sustainable, pollution free, electrical power generation system, many governments have started increasing their percentage share of the total electrical power generation from renewable sources. Among the renewable energy sources, wind energy electric conversion system is fast growing and its operation, control and maintenance is matured enough comparable with conventional power plants. This article has described such wind energy electric conversion systems employing DFIGs both for grid-connected and stand-alone power supplies. Energy storage elements such as battery banks have been integrated with these DFIG systems for improving the reliability and performance from the intermittent power output of the wind. This leads to the DFIG operateing in super-synchronous and sub-synchronous rotor speeds leading to charging/discharging the batteries depending upon the excess/ deficit wind power. Thus, the configurations discussed in this article for wind-driven generators will certainly improve the effective utilization of wind energy.

Profile

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DC Microgrids:
A Technical Perspective

Traditional grid architecture is migrating from centralised to decentralized energy supply with utilisation of distributed generation sources due to environmental considerations, technological developments and government incentives for renewable energy resources. DC microgrid concept represents a decentralization of the grid and is key for growth and implementation of smartgrid network. DC microgrids are more efficient, reliable and more compatible with fastest growing segment of load today i.e. electronic devices.

Jayesh G Priolkar

DC microgrid is beginning to change the paradigm from a centralised generation and distribution system of power delivery to a system that is more flexible and more accommodative of load. Because of small size and modular nature of emerging distributed generation units, generators can be positioned near the consumers which can reduce the amount of energy transfer across the lines. Microgrid can be very effective in reducing green house gas emissions, distribution losses, energy cost, improvement in service quality and reliability of power supply.

Most of the alternative energy sources like Solar photovoltaic (PV), fuel cells as well as many energy storage devices such as batteries, super capacitors, super conducting magnetic energy storage are all DC by nature. Nowadays loads like lighting systems and electronic equipment (Computers, communication devices, television systems, laptops, data centers among others) represent 40 to 50% of electricity consumption in residential and commercial sectors. All these loads have front end converter to transform AC

Variable frequency drives operate by taking AC power at 50 Hz frequency and then converting it to DC and again converting it back to AC power with variable frequency in order to control the motor speed.

energy to DC. It is also expected that this type of consumption will increase in near future with integration of hybrid electric vehicles into the grid. Another element of growing DC load is variable speed drives for electric motors. DC microgrids are gaining interest due to reduction of number of conversions and because of higher system efficiency. DC microgrids avoid intrinsic AC problems like reactive power, harmonics and synchronization.

Thus design of DC microgrids is fundamental since the DC loads and Distributed generation sources (DG) could be easily integrated into the network, minimizing the conversion losses. By using an appropriate DC voltage to supply electronic loads, rectifier and power factor correction circuits can be removed from the loads, reducing energy losses without reducing the power quality. DC microgrid can support plug and play functionality.

The research level in DC microgrids lags behind faraway from research in field of AC microgrid systems. Standards, guidelines and control techniques needs to be developed so that DC microgrids can be promoted and used on large scale.

Conversion Losses

Load profile for domestic and commercial sector has shifted from AC to more and more DC loads. The driving factor in efficiency for many of today's devices is conversion from AC power to DC power. It is not possible to get 100% efficient conversion from one form to other. Energy is lost to either heat, magnetism or shunted to ground depending on conversion techniques. As DC loads are increasing the amount of these losses are also increasing at the same rate.

Majority of lighting is either fluorescent lighting or solid state (LED) lighting. These devices must rectify distributed AC to DC and then undergo a DC to DC conversion, incase of solid state lighting to produce suitable voltage for the lamp.

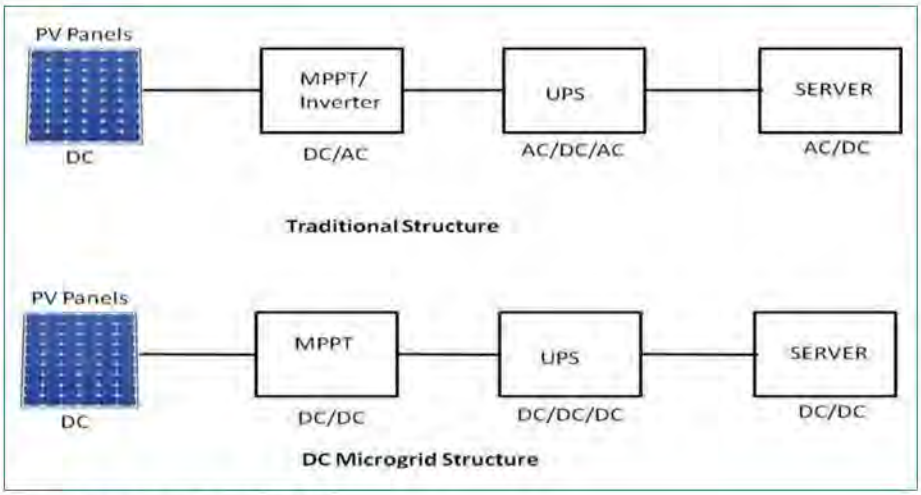


Fig. 1: Conversion steps for load

Variable frequency drives operate by taking AC power at 50 Hz frequency and then converting it to DC and again converting it back to AC power with variable frequency in order to control the motor speed. Induction motor control requires an AC to DC & then DC to AC conversion for their normal operation.

Uninterrupted power supply: These devices in normal operation takes AC power convert it to DC to charge the batteries and then convert it back to AC for use on load, where it is commonly converted back to DC for use. System operates at only 80% efficiency when accounting for conversion losses. Figure 1 shows various conversion steps for a particular load.

With changing load profiles to increased DC power, benefits of localized DG sources in distribution system become more relevant. If the DC sources like PV, Fuel cells are available then it can be used directly thus helping in achieving additional savings over double conversion processes. DC system is simpler and reliable as many conversion steps are avoided and each step causes losses and reduces reliability of systems.

Components of DC Microgrid

Microgrid is an integrated energy delivery system that consists of an interconnected distributed energy resource, controllable loads and can operate in synchronism or isolated from main power grid. In DC microgrid distributed generation sources, energy storage and loads are interconnected and their control is through power electronic converters and protective devices. Advanced power electronic interfaces and their control makes it possible to achieve a desirable coordination among DG, storage systems, DC links and the surrounding power systems. Figure 2 shows topology of typical microgrid.

- **Distributed generators:** are small capacity power generating units that produce electricity from various renewable and nonrenewable dispersed energy sources such as solar photovoltaic, wind, fuel cell, diesel

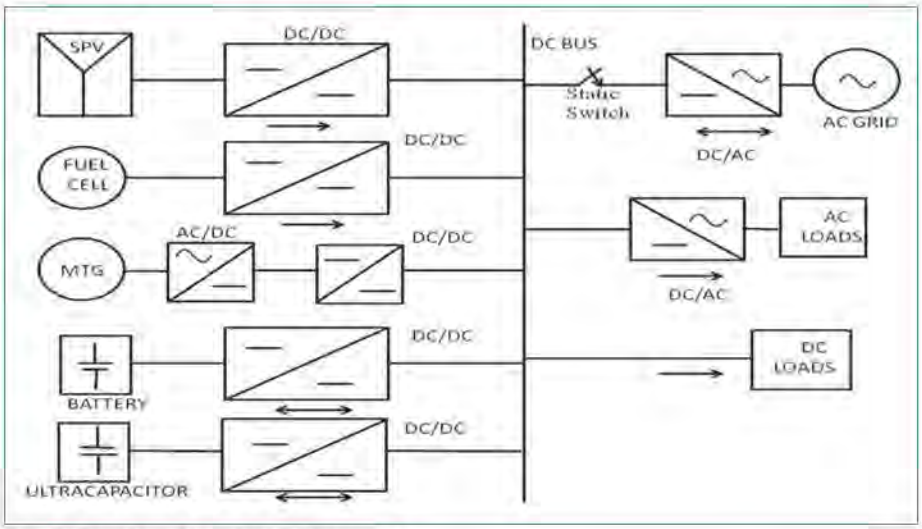


Fig. 2: Topology of typical DC microgrid

engine generators, cogeneration units and microturbines. Typical microgrids comprise of distributed generation units with power electronic interfacing and incorporate control systems that enable flexible operations.

- **Storage system:** It can supply generation deficiencies, reduce load surges by providing ride through capability for short periods, reduce network losses and improve protection system by contributing to fault current. Energy storage devices include batteries, super capacitors, flywheels, fuel cells, superconducting magnetic energy storage that can be used to match generation with demands in microgrids.
- **DC link Interface and controls:** The DC/DC converters are necessary components in interfacing distributed energy resources to the DC bus. For example the output of solar PV depends upon solar radiation, temperature which varies during the day. Output voltage of PV does not match the voltage level of loads. There is DC/DC interface (Maximum power point tracker with boost or buck converter) between PV panels and loads for proper control. The variable frequency power generated by wind turbine or high frequency power produced by gas turbine generator by gas turbine can be converted to DC power through bridge diode rectifier, followed by DC/DC power which is able to regulate the power from the DG source.
- **Static switch:** The static switch plays a important role in the interface between the microgrid and the rest of the utility system. It is provided to protect microgrid in both modes of operation during faults.

Benefits of DC Microgrids

The advantages of microgrid can be categorised as system efficiency, reliability of power and safety. Potential energy savings are there greatest merit. Advantages having electrical power transmitted through DC distribution systems are relatively higher efficiency, absence of reactive power component and fact that many appliances operate using DC voltage.

- System efficiency becomes higher because of reduction of conversion losses of inverters between DC output sources and loads.
- There is an increased reliability from having onsite power by eliminating possible points of failure in large distribution system.
- There is no need to consider synchronization with utility grid and reactive power.
- When a blackout or voltage sag occurs in utility grid, it does not affect DC bus voltage of DC microgrid.

Issues in Practical implementation of DC Microgrids

Standardization, stability, grounding, protection and control are the issues during the practical implementation of DC microgrids. It is needed to construct private DC distribution lines for DC microgrids.

- **Standardization:** To promote wider use of DC Microgrid global standards needs to be developed. DC is dealt at various points but no system wide standards for devices, power supply, DC power distribution exists. Safety, equipment, operational, electrical and commercial application codes and standards needs to be developed. For example development of DC appliance connector to meet voltage and safety standards.
- **Protection system design:** Overall function of DC microgrid protection system is to detect and isolate faults fast and accurately in order to minimize effects of disturbances. Protection in DC system is more difficult than that of AC system because there is no zero cross point of voltage in DC system. The various protection issues arises when the integration of DG is done with distribution level network, there is change in faults current level of network, possibility of sympathetic tripping, loss of relay coordination and unintentional islanding. Design of protection system depends upon type of fault which can occur, their consequences, type of protection devices required, need of backup protection, detection methods, measures to prevent faults and measures to prevent incorrect operation of protection system. Converters used in DC microgrid have limited steady state fault current capability due to their semiconductor switches. Power electronic converters are very sensitive to overcurrent and if they do not have current limiting capability, they require very fast protection. Examples of such devices are fuses, hybrid circuit breakers and power electronic switches. Batteries

and loads do not require such fast protection and therefore simpler and cheaper devices are used. To achieve the selectivity in grid it is necessary to coordinate different protection devices. For design of an effective protection schemes for DC microgrid; grounding system, protection devices, power converters, battery protection and feeder protection, effective coordination and control approach should be adopted.

- **Stability:** Stability is an important area of concern in microgrids. Microgrid should be operated in such a way that its stability is not affected by intermittency of source or any other perturbations occurring in the power system. The major factors affecting the stability of microgrid are
- Control strategy used
- Energy storage system
- Loading conditions and network parameters
- Type of fault occurred. Control strategy used and gains of the controllers affect small signal stability of microgrid. Energy storage system is used to supply energy and reduce voltage oscillations but during faults (transient disturbance) this creates more fault levels. Loading conditions and network conditions also show considerable effect on stability. Type of fault level occurred dictates fault level and hence the stability.

Conclusion

This article presents an overview of various technical aspects of DC microgrids. Environmental benefits, cleaner power productions, social benefit of providing energy access, energy security to remote areas, sustainability are the primary motivation for moving towards decentralized renewable power sources. The economic and environment benefits of distributed generation and DC microgrid network is motivation for research and development efforts towards resolving issues of this new and fast growing technology. To promote and use DC microgrids on wide scale, standards, guidelines and techniques needs to developed and investigated at right forum.

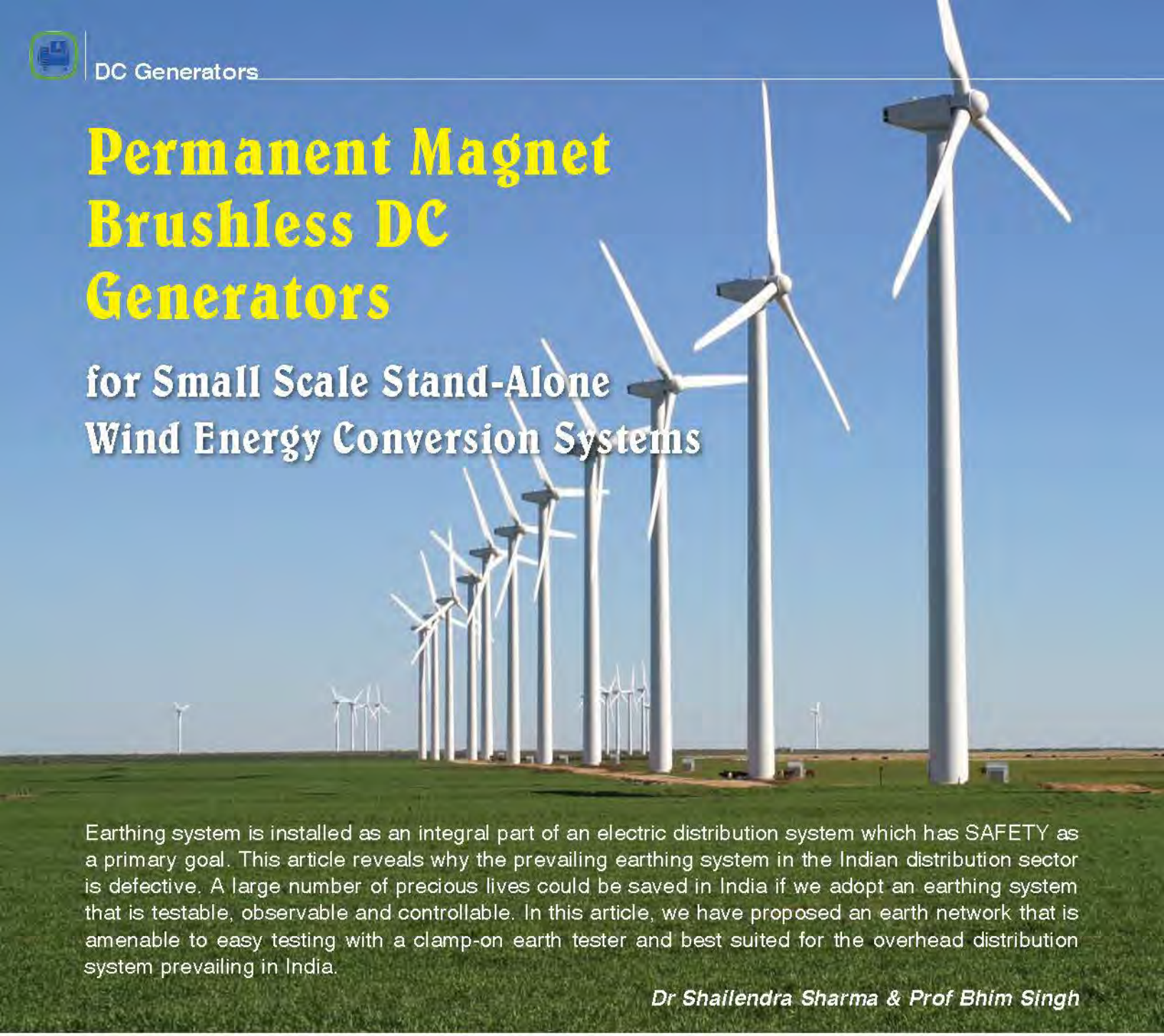
Profile

Jayesh G. Priolkar

is working as Assistant Professor in E&E department in Goa College of engineering, Farmagudi Goa. He is BE in Electrical engineering from Goa College of engineering and MTech in Energy systems and engineering from Indian Institute of Technology, Bombay. His research interests are in microgrids, power system protection and energy management.

Permanent Magnet Brushless DC Generators

for Small Scale Stand-Alone Wind Energy Conversion Systems



Earthing system is installed as an integral part of an electric distribution system which has SAFETY as a primary goal. This article reveals why the prevailing earthing system in the Indian distribution sector is defective. A large number of precious lives could be saved in India if we adopt an earthing system that is testable, observable and controllable. In this article, we have proposed an earth network that is amenable to easy testing with a clamp-on earth tester and best suited for the overhead distribution system prevailing in India.

Dr Shailendra Sharma & Prof Bhim Singh

In India, large-size wind installations are growing at a reasonable pace and by the end of 2012, the installed capacity has exceeded 17 GW and it has been ranked 5th in world. However, it is far behind the on-shore estimated wind thrust, which is more than 100 GW. The unexplored wind potential is the indicator of growth for wind-installations in upcoming years. Most of present wind energy conversion systems (WECSs) feeding to the grid. The technology for harnessing wind power through small-size turbines are under experimental phase. Use of small-size WECSs installations with blade diameters less than 6 m (for wind power in less than 5 kW) is one of most sustainable and reliable technology for generating electricity. The estimated daily electrical output from such small-scale wind installations are up to 10 kWh, under mean wind speed of 4-10 m/s. The range of output is considered more than sufficient to meet the daily electricity needs for a household situated in rural or remote areas. These small-scale wind installations do not require large space and may install on a roof-top.

The selection criteria for such stand-alone systems are low investment cost with high degree of

reliability. The maintenance-free operation is desired in view of suitability for rural and less developed areas, considering operation by unskilled persons in residential areas. Small turbines are generally equipped with fixed blades for small rating installations. These stand-alone wind energy conversion systems are designed for low-voltage AC output. They are mostly equipped with battery energy storage, generally a lead-acid battery of suitable capacity. The design of small size wind energy conversion systems should realize low cut-in speed, simple speed control with maximum power point operation with rated power limitation by a passive acting mechanism.

Permanent magnet synchronous generators (PMSG) are considered most suitable for small-scale stand-alone mode due to its grid building properties. PMSG are classified as sinusoidal voltage output generator and trapezoidal voltage output generator. The trapezoidal output voltage generator is known as permanent magnet brushless DC generator (PMBLDCG). In PMBLDCG, due to the surface mounted PM on the rotor of a PMBLDC machine, the shape of EMF induced at stator terminals are trapezoidal in nature. The PMBLDCG has 15% higher power density than a PMSG with sinusoidal output. Further, due to trapezoidal EMF, the rectified DC output voltage has reduced ripples. The stator windings operate close to unity power factor and hence transfer only an active power component of currents. This reduces the size of the machine for a given power rating as compared to conventional synchronous machines and induction machines.

This article explores a PMBLDCG based small-scale stand-alone wind energy conversion system (SS-SWECS) to feed three-phase three-wire (3P3W) loads, three-phase four-wire (3P4W) loads and single-phase two-wire (1P2W) loads.

System Configuration and Principle of Operation

Schematic diagrams of three-phase PMBLDCG based small-scale stand-alone wind energy conversion systems (SS-SWECS) feeding 3P3W, 3P4W and 1P2W consumer loads are shown in Figs. 1-3. These SS-SWECS consist of a PMBLDCG, a three phase diode bridge rectifier, a DC-DC converter, a battery energy storage system (BESS) and a vector controlled pulse width modulated (PWM) voltage source inverter (VSI) feeding consumer loads. The output voltage of a PMBLDCG is in trapezoidal in shape and its frequency is also varying under change in the rotor speed. Due to trapezoidal nature of a PMBLDCG output voltage, generator currents are also rectangular in shape feeding to uncontrolled diode bridge rectifier. An intermediate DC-DC converter is operated in power controlled mode to extract the maximum wind power through a PMBLDCG. A BESS is used at the output of a DC-DC converter to achieve load levelling. During high wind speed and reduced load conditions, the BESS absorbs the difference of generated power and consumer load

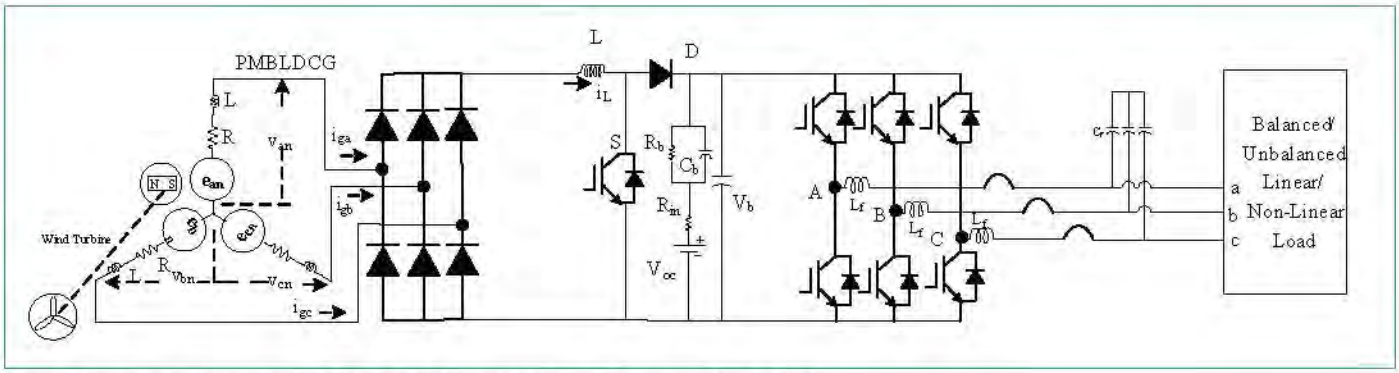


Fig. 1: System Configuration of PMBLDCG based SS-SWECS feeding 3P3W loads

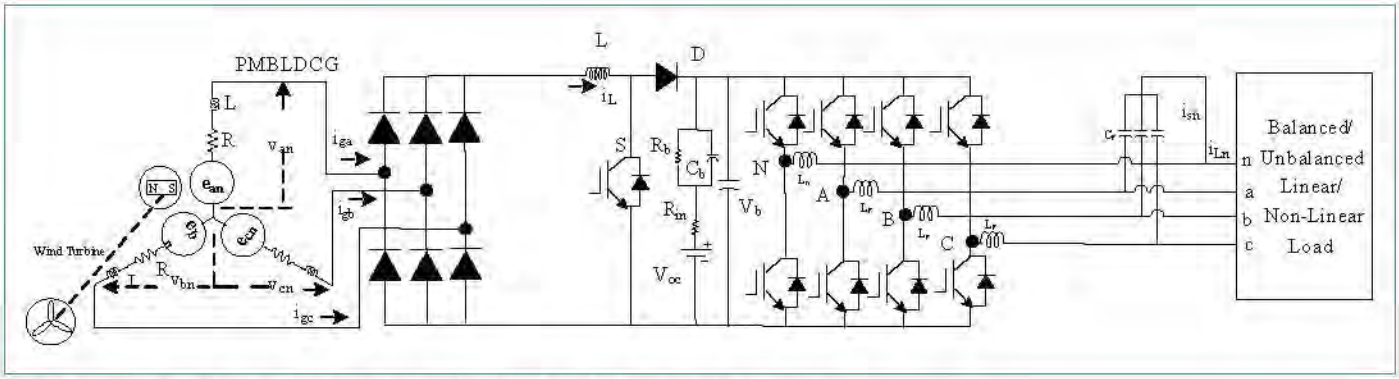


Fig. 2: System Configuration of PMBLDCG based SS-SWECS feeding 3P4W loads

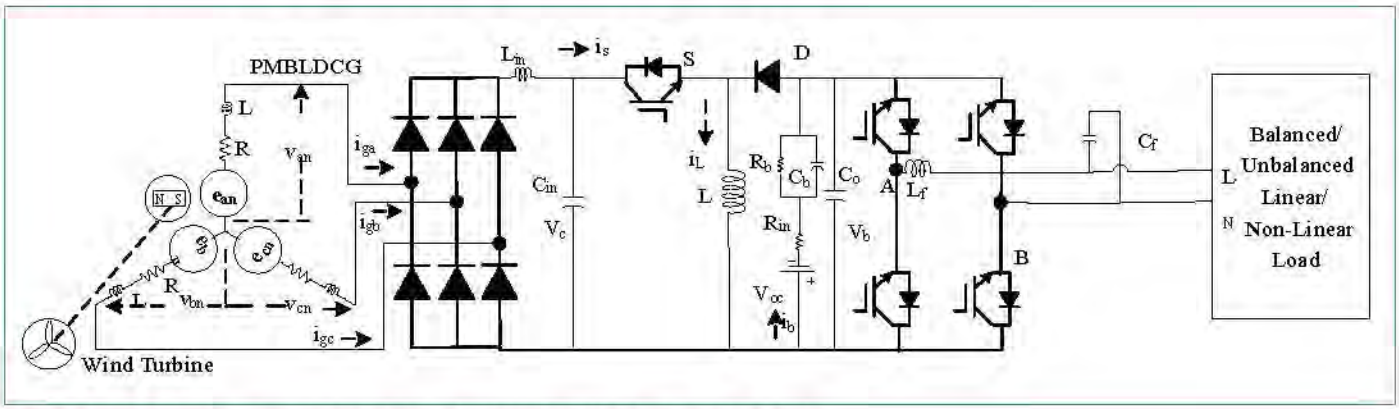


Fig. 3: System Configuration of PMBLDCG based SS-SWECS feeding 1P2W loads

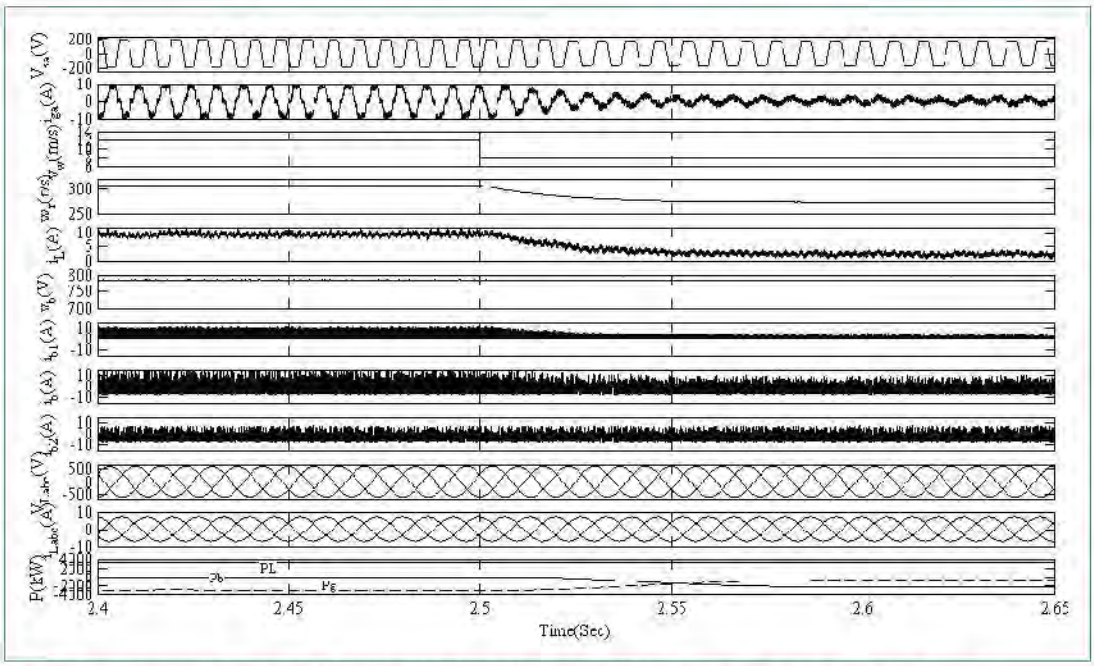


Fig. 4: Performance of PMBLDCG based SS-SWECS feeding 3P3W loads under fall in wind speed

demand. When the wind power is low or consumer load demand is high, the BESS supplies the deficit load power. A vector controlled VSI is used to feed regulated voltage at reference frequency to consumer loads.

Results and Discussion

The performance of a PMBLDCG based SS-SWECS is observed in terms of generated voltage and current for phase 'a' of a PMBLDCG, generated power (Pg) in W, wind speed (Vw) in m/s, generator speed (wr) in rad/s, boost inductor current (iL), battery voltage (Vb), boost converter battery current (ib1), battery current (ib), LSI battery current (ib2), load line voltages (VL), load currents (iL), generated power (Pg), load power (PL) and battery power (Pb).

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- **Performance of PMBLDCG Based SS-SWECS Feeding 3P3W Loads Under Fall in Wind Speed:** Fig. 4 shows the performance of a 3.4 kW, 6-pole, 11 Nm, 3000 rpm, PMBLDCG based SS-SWECS under fall in wind speed (12 m/s-8 m/s) at fixed three-phase consumer loads of 3.4 kW of 0.9 lagging power factor supplied from a LSI. The wind speed is 12 m/s up to 2.5 s and due to rated power generated and rated consumer loads, average battery power (Pb) and its battery current are negligible. The wind speed falls to 8 m/s and there is a reduction in the wind speed and a PMBLDCG speed to keep tip speed ratio constant. Due to reduction in the wind speed, a change in inductor current iL is also observed to reduce the generated power. The load voltage and its frequency are observed constant under these conditions.
- **Performance of PMBLDCG Based SS-SWECS Feeding 3P4W Linear Loads:** The performance of the 1.5 kW, 6-pole, 5.2 Nm, 3000 rpm PMBLDCG based SS-SWECS supplying balanced/unbalanced linear loads at fixed wind speed are shown in Fig. 5. A linear resistive-inductive load of 400 W, 0.89 lagging power factor is connected between each phase and the neutral terminal through individual circuit breaker. The wind speed is 11 m/s and the generated power is 1.1 kW, while the generator is running at 300 rad/s. Till 3.3 s, balanced loads are connected and load power is 1.2 kW. These loads become unbalanced after switching off phase 'b' loads at 3.3 s and phase 'c' loads at 3.35 s. It is observed that the load power demand is reduced but the PMBLDCG is delivering the same power. Load voltages are remain balanced even load currents are unbalanced during 3.3 s-3.5 s. The zero sequence load current is compensated by a fourth leg of a LSI as seen in these results. The load becomes balanced again after switching in loads on phase 'b' and phase 'c' at 3.5 s and 3.55 s.
- **Performance of PMBLDCG Based SS-SWECS Feeding 1P2W Non-Linear Loads:** Fig. 6 shows the performance of a 3 kW, 7 Nm, 6 pole, 4000 rpm PMBLDCG based SS-SWECS under a non-linear consumer load at load bus and wind speed is kept constant at 12 m/s. A single-phase diode rectifier feeding resistive-inductive element is used as a non-linear load. Till 1.9 s, a 2 kW load is present on the load bus and the terminal voltage is observed ripple free. At 1.9 s, the load is completely removed from the load bus. It is observed that even with minimum current on the load bus, the load terminal voltage is constant and sinusoidal. However with these conditions, the battery is absorbing the generated power. The load is switched in again at 2 s and there is a reduction in a BESS charging

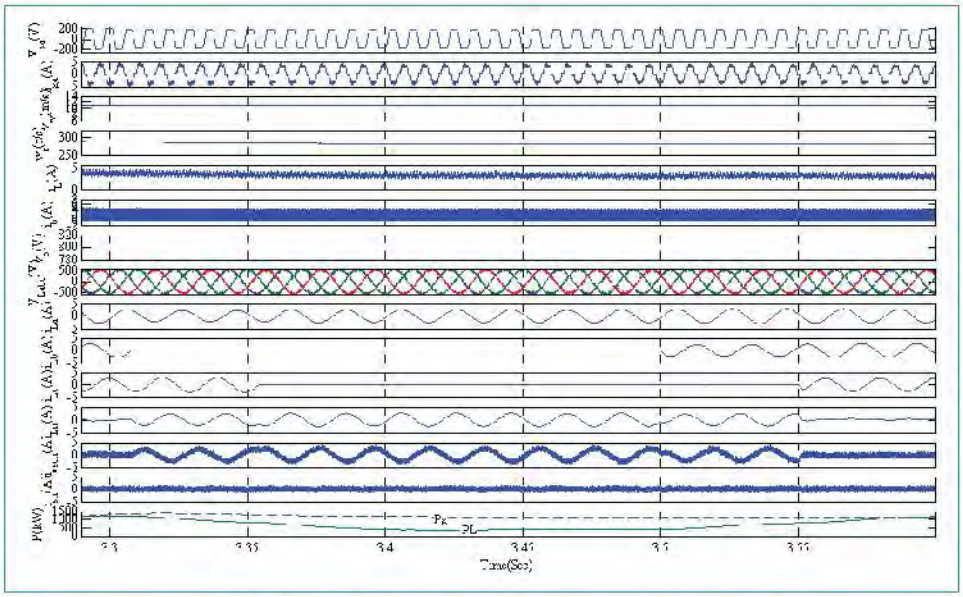


Fig. 5: Performance of the PMBLDCG based SS-SWECS feeding 3P4W linear loads

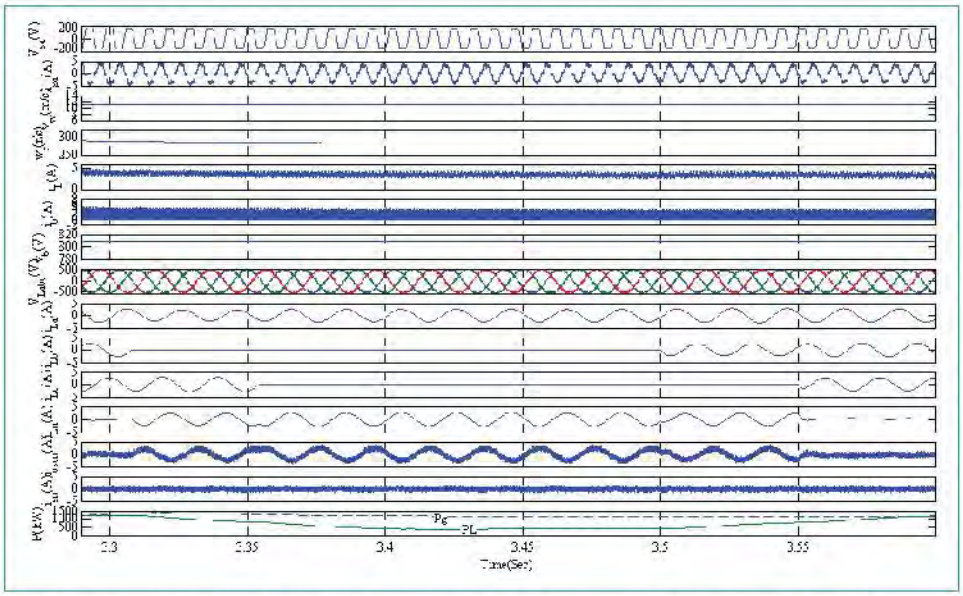


Fig. 6: Performance of the PMBLDCG based SS-SWECS feeding 1P2W non-linear loads

power. Even with such a large load current perturbations, the terminal voltage is constant.

Conclusions

A state of art on permanent magnet brush-less DC generator based small scale stand-alone wind energy conversion systems have been reported for feeding 3P3W, 3P4W and 1P2W consumer loads. These SS-SWECS have been designed using an uncontrolled diode bridge rectifier, a DC-DC converter and a load-side inverter. A battery energy storage system has been used for the load levelling. Maximum power point tracking has been achieved through the proper control of a boost and buck-boost converter topologies. For feeding 3P3W, 3P4W and 1P2W consumer loads, a three-leg LSI, a four-leg LSI and a single phase full bridge LSI have been used respectively. The performance of investigated PMBLDCG based SS-SWECS has been found satisfactory under steady-state and dynamic conditions.

Profile

Dr Shailendra Sharma

ME in Electrical Engineering with specialization in power electronics from Shri Govindram Seksaria Institute of Technology and Science (SGSITS), Indore, received PhD from Electrical Engineering Department, Indian Institute of Technology Delhi. He has seven years of industrial experience as an Erection and Commissioning Engineer with Dhar Textile Mill Ltd, Indore. Presently, he is an Assistant Professor with the Department of Electrical Engineering, SGSITS, Indore. He has to his credit one Indian patent. He has published thirteen research papers in journals including IEEE and IET. He also published thirty research papers in various national and international conferences. He is a member of IEEE and an associate member of the Institution of Engineers, India.

Prof Bhim Singh

BE (Electrical) from University of Roorkee, MTech and PhD from IIT New Delhi. He was Reader in Electrical Engineering, University of Roorkee. Thereafter he joined Department of Electrical Engineering, IIT Delhi and became a Professor. He has guided 40 PhD dissertations 125 ME/ MTech theses and 60 BE/BTech projects. He has been granted one US patent and filed nine Indian patents. He has executed more than sixty sponsored and consultancy projects. He is a Fellow of the Indian National Academy of Engineering (INAE), the National Science Academy (NSc), the Institute of Engineering and Technology (IET), Institution of Engineers (India), and Institution of Electronics & Telecommunication Engineers and other socities. He is recipient of J.C. Bose and Bimal K. Bose etc, awards (IETE). He was the General Chair of IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES'2006) and (PEDES'2010) held in New Delhi. He is also a life member of the Indian Society for Technical Education (ISTE), the System Society of India (SSI), and the National Institution of Quality and Reliability (NIQR).

Vikram Solar Commissions 100Kw Solar Mini Grid System at Bahal, Haryana

Vikram Solar, internationally acclaimed Tier 1 enterprise which specializes in manufacturing of photovoltaic (PV) solar modules and EPC contracts for solar power plants has commissioned a 100 KW Solar Mini Grid system at Bahal, Haryana. The mini-grid will help power six residential blocks consisting of 35 households in the village. These households have been connected at load end with auto changeover.

The Intelligent Mini Grid System has used state-of-the-art equipments including crystalline solar PV modules manufactured by Vikram Solar and inverters by SMA (Sunny Boy). One set of off-grid inverters charges a set of batteries during the daytime when sun is available. These batteries create a "DC Bus" inside the Control Room.

Another set of string inverters which are installed in the PV yard sense this dummy grid and synchronise. The total power is now made available through the dedicated grid to the consumers. Again, during night time the consumer load is fed by the off-grid inverters with batteries acting as a back-up. Intelligent sensing options both at the power generating source end as well as the at the consumer end manages the load variation and helps in keeping the system balanced all the time.

The advanced system commissioned by Vikram Solar has been load tested for connecting to the entire 35 households in six residential blocks. Presently all the loads of the solar control room and the six blocks are running on solar power with auto grid changeover facility for ensuring redundancy. Also keeping in mind to meet the scalable consumer load in the near future, the entire system can be easily expandable as the design is modular in nature.

According to Gyanesh Chaudhary, Managing Director, Vikram Solar decentralised renewable energy solutions like this can be powerful game changers in the remote and rural areas of India where large number of villages are still not reached by the electricity grid.

Safe Earthing System for Distribution Sector

Earthing system is installed as an integral part of an electric distribution system which has 'Safety' as a primary goal. This article reveals why the prevailing earthing system in Indian distribution sector is defective. A large number of precious lives could be saved in India if we adopt an earthing system that is testable, observable and controllable. Here, we have proposed an earth network that is amenable to easy testing with a clamp-on earth tester and best suited for the overhead distribution system prevailing in India.

Jaymin Patel, Pushkar Bhokri & Vithal Narasinha Kamat

Over the years, humans have made some truly remarkable discoveries, one of which has been the importance of grounding electrical systems. Electricity has provided countless benefits to people, but its network still remains one of the most deadly elements in human society, and unless there is an appropriate grounding provided to the electrical systems, there is a rather large risk to human lives. But unfortunately, in today's times, good earthing practice has been put to disuse!!

Earthing simply means connecting a part of an electrical appliance to the earth or soil. Good earthing practice is an important requirement for sound electrical system protection, and though every electrical engineer would claim to know it well, it is a topic that is less understood and often taken for granted. Without a good earthing practice, even the best of protection gadgets may fail to operate, putting at risk the lives of human beings and animals.

Earthing Basics

A century back, when electricity was first generated and engineers wanted to have a common reference for their supply, the earth's conductive surface was the only convenient one available. One of the supply conductors would be connected to earth or ground, later to be considered as a reference – a practice called system earthing.

When a fault within an electrical device connects a live wire to an exposed conductive surface, then, anyone coming in direct contact with it while standing on earth would complete a circuit back to the earthed supply conductor and receive an electric shock. However, if this exposed conductive surface would have been connected to earth, a practice called equipment earthing, then it would offer a low resistance parallel path to not only prevent such a shock but also to offer a return path for the fault currents which would now be high enough to operate a protective mechanism that would clear / isolate the faulty circuit.

Types of Earthing

Depending on its usage and purpose, earth can be categorized into two basic types

Protective Earth and Equipment Earthing

A protective earth (PE) is a conductor that grounds an equipment, and is used to prevent accidental electric shock. Such an earth keeps the exposed conductive surfaces of the equipment at earth potential and under normal conditions do not carry current. However, on a low impedance line to ground fault, heavy currents would flow causing a fuse to blow or a circuit breaker to trip, thereby protecting the circuit. Even if we have a high impedance line-to-ground fault, the small levels of fault currents through earth is still sufficient to trip a residual current circuit breaker (RCCB) and help protect lives. PE is also called an 'equipment grounding conductor'.

The process of connecting a PE to the non-current–carrying metal parts (e.g. metallic enclosure) of the electrical equipment is called equipment earthing.

Functional Earth and System Earthing

A functional earth connection serves a purpose other than shock protection, and may carry current under normal conditions. It is typically used for measurements in measuring instruments or for noise filtering in EMI filters or quenching surges in surge suppressors. Probably the most widely used example of functional earth is the Neutral in an electrical supply system which is a current carrying conductor. The neutral conductor is connected to earth often at only one point to avoid earth currents. For this reason, a neutral is also called a grounded supply conductor.

The process of connecting a neutral conductor to earth is called system earthing

Earthing Arrangements

For describing earthing arrangements, the following notations are used [1]:

- T : Direct connection of a point with earth (terra)
- I : Isolated, or no point is connected with earth
- N : Direct connection to Neutral

The IEC60364 distinguishes 3 families of earthing arrangements that are in place around the globe using the two letter codes - TN, TT & IT. While the first letter indicates the connection between earth & the power supply equipment (generator or transformer), the second letter indicates the connection between earth and the electrical device being supplied (on the consumer side)[2].

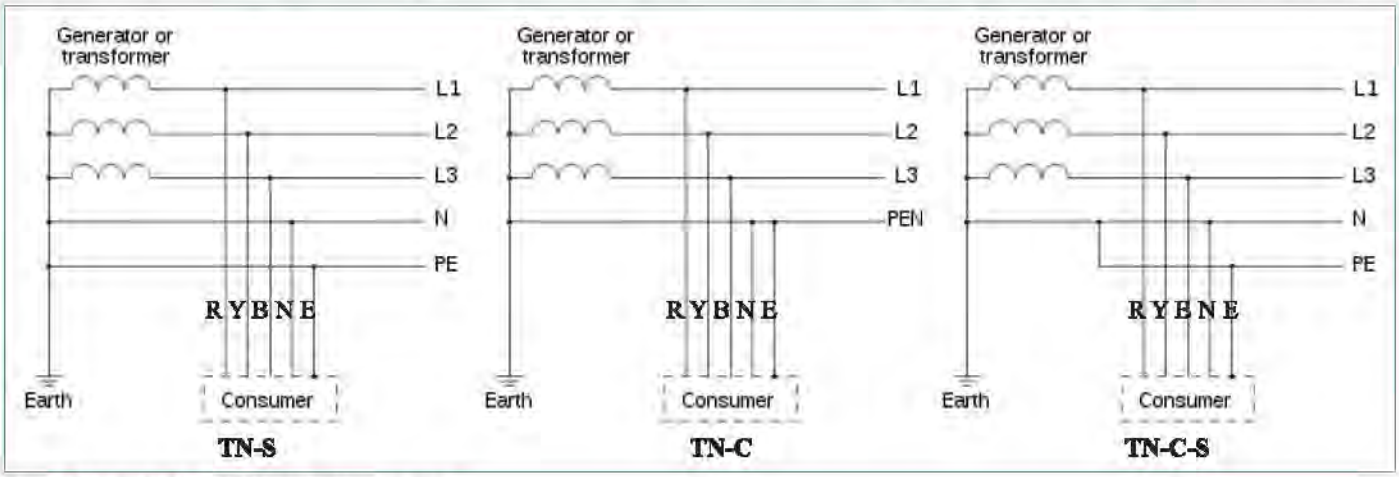


Fig. 1: Variants of the TN earth arrangement.

TN networks

The TN networks are of 3 types- TN-S, TN-C, TN-CS. Figure 1 describes the nature and functioning of these networks.

Networks with Consumer Earth

Under the above notation system, if the second character is a 'T', then it refers to a local earth connection of the consumer at his/her premises that is independent of the earth connection at the generator (see Figure 2). Such networks can be further classified into TT and IT networks.

Comparison of Earthing Systems

From Table 1 we find that from the safety angle, the TNS is seen to be the safest. The TNS is also the most expensive system due to the addition of a separate PE conductor.

At the other end the earthing system with the least cost is the TNC, which is also the least safe. In the TNC system the C suffix stands for the 'Combined' PEN conductor that fulfills the functions of both a PE and an N conductor. Inspite of the cost benefit, the TNC is rarely used, as potentially hazardous rise in neutral potential (due to flow of return currents) could be observed on the surface of the consumer devices connected to such an earth.

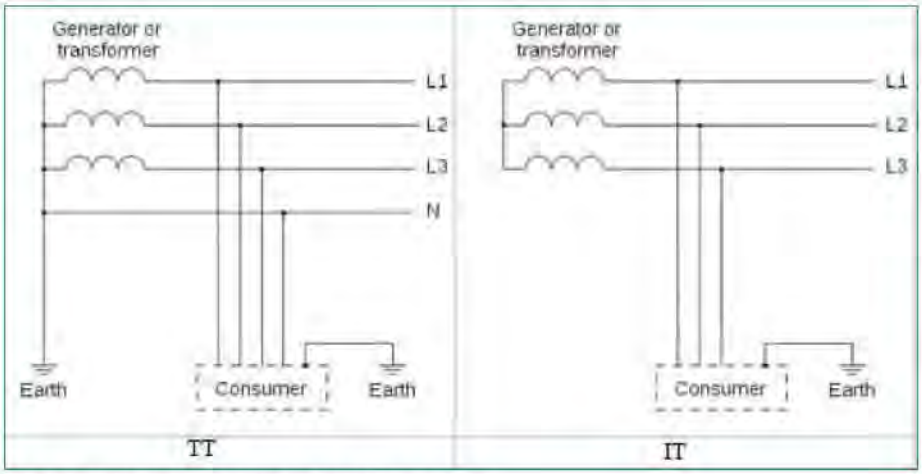


Fig. 2: Systems with Earth on the consumer side

Problems with the Existing Earthing System in India

The TT earthing system is currently being used by the state distribution companies in India particularly in rural areas, with overhead wiring.

However, a survey has indicated that approximately 60 percent of the consumers do not have an earth provision at their premises. And amongst those who do, the earthing system is ill maintained. This means that the earth network reduces to a TN-C. Ironically, the TN-C is the very network that is rarely used in other countries. All the disadvantages of this potentially dangerous system are frequently observed in India.

Some of the utilities that were established during the British era, like the Torrent Power in Ahmedabad have underground cables with the TN-S. Due to weathering, the sheaths of these underground cables have corroded and, therefore, have stopped providing good earth connections. Thus the installations where 'bad earths' are found have got converted to TN-C-S.

In this section, we shall see how an inappropriate choice for an earthing system coupled with a total disregard for Indian Electricity Rules can prove to be a recipe for disaster.

Parameter	TT	IT	TNS	TNC	TNCS	MEN / PME *
Earth fault loop impedance	High	Highest	Low	Low	Low	Low
RCD preferred?	Yes	No	Yes	No	No	After N and PE Separates
Need earth electrode at site?	Yes	Yes	No	No	No	No
PE conductor cost	Low	Low	Highest	Least	High	Least Cost. Earth conductor size is 6mm2
Risk of broken neutral	No	No	No	Highest	High	No
Safety	Safe	Less Safe	Safest	Least Safe	Safe	Integrity of earth at customer installation needs periodic checking.
Electromagnetic interference	Least	Least	Low	High	Low	Low
Safety risks	High loop impedance	Double fault, overvoltage	Broken PE	Broken neutral	Broken neutral	Can result in electrocution if earth is broken polarity is reversed.
Advantages	Safe and reliable	Continuity of operation, cost	Safest	Cost	Safety and cost	Inexpensive. It is effective in keeping neutral pd at zero potential along the line.

Table 1: Comparison of the various Earthing Systems found around the globe
**MEN – Multiple Earthed Neutral, PME- Protective Multiple Earthing*

Safety Issues with TN-C system

In a TN-C system, the RCD devices are quite vulnerable to unwanted triggering from contact between earth conductors of circuits on different RCDs or with real ground. If the threshold settings of the RCDs are increased, then they are far less likely to detect an insulation fault. It is also unsafe to isolate the neutral core in a TN-C system, and hence the RCDs should be wired to interrupt only the live conductor and not the neutral, a convention that is not followed.

On an event of a neutral break, in a single phase system, all parts of the earthing system beyond the neutral break would rise to the potential of the L conductor. In case of an unbalanced three phase system, the potential of the earthing system would move towards the most loaded live conductor. In the Indian consumer premises, we frequently observe the use of plug/socket connections and flexible cables where there is a high probability of contact problems. Instead of a 3 pin plug/socket, consumers are found to frequently use a 2 pin plug/socket where live (L) and neutral (N) could get interchanged. The use of TN-C or TN-C-S system should be banned in such premises. For instance, in the UK, the use of TN-C-S is banned while TT system is recommended for outdoor wiring.

Disregard for the Electricity Rules

Rule 29 of the Indian Electricity Rules, 1956, mandates that the electric supply lines and apparatus should be of sufficient rating for fault currents, and that the same shall be constructed, installed, protected, worked and maintained to ensure safety of human beings, animals and property. Why then do we commonly hear of fatal accidents and damage to property. We still carry in our mind the vivid picture of an engineering student from our institute at Vallabh Vidyanagar who got electrocuted due to earth fault when his bicycle got too close to a guy wire (used to keep an electric pole upright). We dedicate this paper to this innocent young student.

How often do we see a danger notice with skull and bones? Rule 35 of the IE Rules mandates that such notice be affixed in conspicuous locations of medium or high voltage installations. Similarly, Rule 31 requires that the electric utility provide a cut out on every service line in the network and at the customer premises, just as Rule 33 requires that the utility provides and maintains an earth terminal for the consumer's use at an accessible position in his/her premises. Earlier, the utilities would make lame excuses such as, 'cut-outs are convenient points for energy pilferage'; or else they would take recourse to admitting that their utility is sick. However, of late, after the setting up of the electric regulatory commissions, the health of the utilities has seen a dramatic improvement. Isn't it time that the authorities connected with electricity start giving human lives and their property the due importance?

How do we know that the earthing system is functional! Does the system facilitate easy testing! These questions would get answered if we address the issues of Observability, Testability and Controllability (OTC).

Which Earthing System to Choose!

In the United States and Canada, the TN-C-S system is used. In Argentina, Australia (MEN) and France (TT), the customers must provide their own ground connections. Japan uses TT earthing in most installations. UK has shifted from the TN-S to the PME. Modern homes in Europe have a TN-C-S earthing system. Norway is shifting from an IT to a TN-C-S system. TT networks are commonly used when the cost of an additional PE conductor outweighs the cost of a local earth connection, typically in older properties or in rural areas.

Even in the developed countries, until the mid 1990s, power outlets generally lacked protective earth terminals. Therefore, devices needing an earth connection used the supply neutral. Some used dedicated ground rods. Many appliances had polarized plugs to maintain a distinction between live and neutral, but using the supply neutral for equipment earthing was highly problematical. Live and neutral might be accidentally reversed in the outlet or plug, or the neutral-to-earth connection might fail or be improperly installed. Even normal load currents in the neutral might generate hazardous voltage drops. For these reasons, most countries mandated dedicated protective earth connections that are now almost universal.

Adopting Correct Earth Measurement Tool for India

To simplify our decision making process and choose the right earthing system for India, we first shift to a more basic question. Which would the right earth measurement tool for India?

Observability, Testability, & Controllability (OTC) Issue

In a tropical country like India, where humidity is high, the electrical systems corrode and need frequent maintenance. How do we know that the earthing system is functional! Does the system facilitate easy testing? These questions would get answered if we address the issues of Observability, Testability and Controllability (OTC). A laborious test procedure that involves disconnection of the earthing system for it to be tested or which requires additional earth spikes to be driven into the soil before taking the earth measurement is a deterrent to its usage. This is one of the main reasons why earthing systems, in developing countries, are hardly ever tested. The measurement of earth has dropped to such pathetic levels, that today, it is even difficult to find a working earth measuring instrument with the local utilities.

A faulty insulator on an unearthed pole could prove to be hazardous to lives. If the pole is earthed, then the potential would drop to near zero, however, leakage currents

View of an Earth Clamp Tester [4] | Calibration of the Earth Tester [4] | Using the Earth Tester in Field [5]

Fig. 3: Earth Clamp Tester and its usage

would now flow through the earth. It is necessary to check for such leakage currents and to identify and correct the faulty insulator. If this is not done, then the continued flow of leakage currents would cause the earthing to deteriorate. Also the utility would lose precious energy through this fault. In the following section we will describe an elegant, simple to use clamp-on earth tester which has the ability to measure the earth resistance or the earth (leakage) currents without disconnecting the earth wire.

Clamp-on Earth Tester to overcome the OTC Issue

A clamp-on earth tester offers the ability to measure the resistance without disconnecting the ground wire, and without the need for auxiliary earth spikes (which were part of the traditional earth testers). A clamp on tester, typically, has the ability to measure the earth resistance from 0.05 to 1200. It can also measure accurate true RMS readings of AC current including distorted waveform, typically, from 1mA to 30.0A. This comes in handy for the measurement of leakage currents through the earth wire as we shall see later. Figure 3 shows such a tester. Since the ground wire is not disconnected, this measurement procedure also offers the advantage of preserving the bonding to earth and thereby the earth connection resistance values.

Principle of Operation of a Earth Clamp tester

If we consider R_x to be the earth resistance under test, and R_1, R_2,..., R_n to be the earth resistance of other elements in the earth network such as other earthed poles, and other earthed installations, then R_1, R_2,..., R_n can be considered to be connected in parallel, and this whole combination in series with R_x. Let R_s, denote the combined resistance of the parallel combination of R_1, R_2,..., R_n. It is clear that R_s, as a parallel combination of resistors, can be regarded to be small in comparison with R_x (see equivalent diagram in Figure 4).

$$\frac{V}{I} = R_x + R_s$$

Since Rs <<Rx, $\therefore \quad \frac{V}{I} = R_x$

is established. Hence, to measure grounding resistance, we simply need to detect I while keeping the voltage injected V constant.

In case n (number of parallel earthed poles/elements) is small, then the resistance of R_s would be comparable to R_x and $\frac{V}{I} = R_x + R_s = R_t$,

where the total resistance, R_t, would represent the upper bound for R_x. If n = 0, or the number of parallel earthed poles is zero, then the clamp tester cannot be used since the measurement point is a single isolated rod without a loop. In, we show how such an isolated rod can be connected to a low resistance point like a pole ground so as to facilitate the earth measurement with the clamp tester.

While the principle of operation has been the reason for the main advantage of the Clamp-on tester, namely, its ability to take earth measurements without disconnection, it is also the reason for two main disadvantages-

- A singular earth cannot be measured.

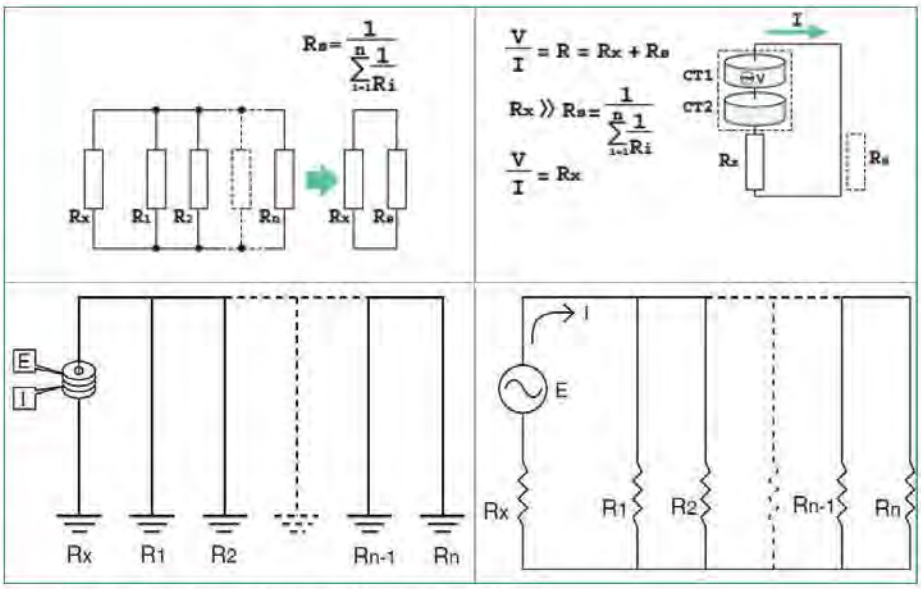


Fig. 4: Equivalent Circuit for Earth Measurement [4, 5]

The clamp on tester operates only when we have an earth loop, i.e. $R_s \neq \infty$ Moreover, it is useful only when we have Multiple Earth systems i.e. $R_s \ll R_x$

- The earth clamp tester can only measure the earth loop resistance $[R_t = (R]_x + R_s)$, and cannot bifurcate the resistance of the earthing conductor under test, R_X, from the rest of the loop resistance R_S.

However, both the disadvantages pose no deterrent to us since our proposed earthing arrangement overcomes and nullifies them. Before describing our proposed system, we analyze the major flaws in the existing one.

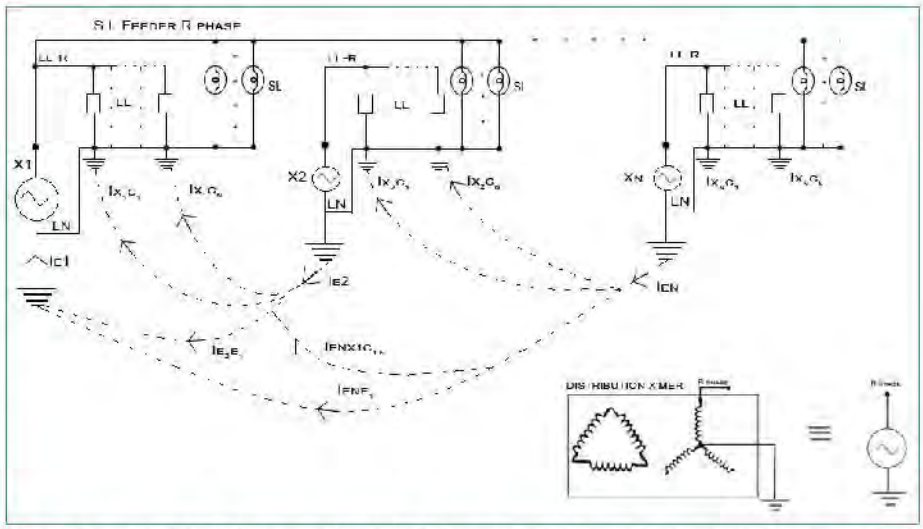


Fig. 6: Simplified Line Diagram showing Defective Distribution System with Protective Earth abused by injecting currents

Analyzing Revalent Earthing System

At present, Madhya Gujarat Vij Company Limited (MGVCL) and other distribution utilities are adopting the 5 wire system in their distribution system, namely, the three (R, Y, B) Phases, Neutral N and a separate street light (SL) wire as shown in Figure 5. We have chosen one such LT feeder of MGVCL in Anand, Gujarat, for our tests and observations. A residential area that contained the Anand Collector's bungalow was chosen as it represented a better maintained distribution system. Moreover, for simplicity we chose a small area that was covered by a single phase (1-Ø) street lighting (SL) system with approx. 80 lamps.

For further understanding, refer to the single line diagram of the distribution system shown in Figure 6. Here, X_1 represents the distribution transformer that, in addition to feeding its Local Loads (LL) – domestic or commercial, also feeds 80 numbers of street lights (SL). Most of the lamps (approx. 50 Nos.), from this set of 80 lamps, light up the areas that are having their local distribution transformers, $X_2, \ldots, X_n$, different from X_1. By local distribution transformers we mean those transformers that are feeding their respective Local Loads (LL) - domestic, commercial, or load categories other than

Fig. 5: Present 5 - wire system adopted by the Electric Utilities

SL, in its area/ vicinity. In other words, only 30 Nos. of lamps light up the area whose local loads (domestic, commercial, etc.) are also fed by the same transformer X_1.

Henceforth, for simplicity we will consider the area covered by Xn to be synonymous with X_n. Moreover, though the transformers used in the field are 3 phase, in the diagram we have restricted our line diagrams, without loss of generality, to represent only a single phase, namely R phase (see Figure 6).

One may note, from Figure 6, that in the areas $X_2, \ldots, X_n$, the Local Loads (LL-R_n phase) are having feeds that are different from the SL feed, and hence are separate. However, in these same areas ($X_2, \ldots,$ Xn) to economize on conductors, the ground path is used to provide a current return and complete the circuit back to X_1 neutral. Such a malpractice causes large currents to flow through the ground wire and earth which deteriorates the quality of the earth pit, a detailed explanation for which is given in the next section. These return currents have been indicated in Figure 6 as I_{E2E1}, ..., I_{EnE1}. Figure 6 thus shows a defective distribution system with Protective Earth (PE) abused by injecting currents.

Many a times, it is observed that the consumers connect the neutral wire in their premises to their local earth. Probably, this may be to protect their own loads from damage due to over-voltages on an occasion when the incoming neutral breaks. However, this practice compounds the problem since the street light currents also choose to return through these consumer earth pits damaging them, too, in the process. These return currents have been indicated in Figure 6 for zone X_1 as I_{X1C1}, ..., I_{X1Cn}., for zone X_2 as I_{X2C1}, ..., I_{X2Cn}, and so on.

Though the above observations are factual and supported by basic electrical laws (such as Kirchoff's laws), they are additionally strengthened here with consistent readings which are analyzed in the following section.

Field Measurements using Earth Resistance tester

We noticed that the street lights were switched ON approximately at 07:00PM in the evening and switched OFF the next morning approximately at 06:00AM. We wanted to study the impact that 11 hours of continuous injection of street light current into the earth would have on the earthing parameters. While Table 2 gives the earth loop resistances, Rt, and earth current measurements taken at 5 Nos. of distribution transformers ($X_1, X_2, \ldots, X_5$), in the evening (before and after lamps were switched ON), Table 3 give corresponding measurements taken in the morning (before and after lamps were switched OFF).

The eighty lamps on the Street Light (SL) feeder were observed to be drawing a total of 34.5 Amps of current from the transformer X_1. Measurements were taken from the static energy meter (located below X_1) used to bill the local body – Anand Municipality.

Since this current value exceeds the maximum rating, I_{max} = 30A, of the energy meter, it is not surprising that the energy meters have undergone frequent replacement on this feeder (two meters replaced during the past one year). Though this could be easily corrected by improving the power factor (PF) of the lamps, this topic is outside the scope of this paper and hence will be treated elsewhere. Here, we are interested in the path that 34.5 Amps of SL current would be taking to complete the circuit.

From the column displaying 'Earth Currents', in Table 2, we can observe that there is a marked increase in the current flowing through the local earth of each of the four transformers, (X_2, X_3, X_4, X_5), when the Street Lights are switched ON, with reference to the corresponding current values when the street lights are OFF. For example the earth current in X_3, increases to 1.45 Amps from 0.30 Amps. The increase of 1.15 Amps in the earth current can thus be directly co-related to the currents injected by the street lamps to the earth to complete the path back to X_1.

From Table 3, we can observe that the earth current drops after the Street Lamps are switched OFF. Also that the Earth resistance values are consistently higher in the morning than in the evening. This

Transformer Zone	Readings at 06:45 PM (Street Lights : OFF)		Readings at 07:20 PM (Street Lights : ON)	
	Earth Current (A)	Earth Resistance R_t (Ω)	Earth Current (A)	Earth Resistance R_t (Ω)
X1	0.08	10.4	0.10	8.5
X2	0.65	1.9	1.63	2.6
X3	0.30	1.7	1.45	1.9
X4	0.11	2.5	1.27	7.8
X5	0.11	4.2	0.75	3.2

Table 2: Earth Measurements taken in the Evening

Transformer Zone	Readings at 05:35 AM (Street Lights : ON)		Readings at 06:25 AM (Street Lights : OFF)	
	Earth Current (A)	Earth Resistance R_t (Ω)	Earth Current (A)	Earth Resistance R_t (Ω)
X1	0.09	14 to 18	0.09	13.0
X2	1.13	3.8	0.61	2.7
X3	0.52	3.1	0.34	4.0
X4	1.28	7.2	0.43	2.6
X5	0.75	6.6	0.35	5.2

Table 3: Earth Measurements taken in the Morning

means that the earthing deteriorates after injecting current continuously for 11 hours. It also means that earth has a capacity to partially heal and 'rejuvenate' after a certain period of time (in our case – 13 hours of daytime when the lamps are OFF).

There are approximately six lamps in each of the transformer zones - X_2, X_3, X_4, X_5. Assuming that each lamp draws 400 mA this would amount to a total of 2.4 Amps per transformer zone. Why then do we observe only, say, 1.15 Amps flowing through the transformer earth in X_3? Where has the rest of the current gone?

Assuming that the Street Light Feeder traverses 8 transformer zones each of which would be injecting approximately 2.4 Amps, another mystery is why is the cumulative current of say 8 Amps not returning back at SL feed transformer – X_1. The earth current at X_1 is only 0.10 Amps. Where has the 8 Amps gone?

Analysis of Readings taken by a Clamp-on Earth Resistance tester

Based on the readings displayed in Table 2 and Table 3, and other field measurements with the clamp-on tester, the following can be concluded:

- Since the earth clamp tester can only measure if the earth loop resistance $[R_t = (R_x + R_s)$ is finite, we can conclude that there exists one or more earths having a parallel resistance of R_s, in addition to the Transformer earthing conductor that has resistance, R_x, in each of the five Transformer zones, X_1, X_2, X_3, X_4, and X_5.
- Since MGVCL does not have a practice of grounding the neutral at any other point other than the Transformer, it is clear that the parallel resistance, R_s, represents the consumer earths.
- The earth loop resistance of transformer - X_1 that feeds the Street Light SL Feeder has the maximum resistance of 14 to 18 (see Table 3). This confirms our expectation that continuous flow of large amount of current deteriorates the System Earthing.
- In the Transformer - X_1 zone, i.e. the resistance, R_x, of the earthing conductor under test located below X_1, is quite large in comparison to the rest of the loop resistance Rs, i.e. $R_x \gg R_s$. This can be concluded since majority of the street light current (8 Amps) chooses to flow through R_s while only a small portion (0.10 Amps) flows through R_x. Transformer X_1 earth has been heavily damaged with resistance varying between 14 and 18 Ω.
- In the other transformer zones, namely, X_2, X_3, X_4, X_5, the resistance of the earthing conductor under test below the corresponding transformer, R_x, is almost equal to the rest of the loop resistance R_s , i.e. $R_x \cong R_s$. This is because, as we studied in the case of X_3, only half the street light current, 1.15 Amps, from the total of 2.4 Amps, flows through R_x. The rest of 2.4 Amps (i.e. 1.25 Amps) flows through R_s.
- After damage at 5:35 AM, the earth loop resistances, Rt, vary between 3.1 and 18 Ω. If we consider a typical value of R_t, to be 6 Ω, & assume $R_x \cong R_s$, then R_x and R_s, each, would be 3 Ω and their parallel combination would be $[R_t = (R]_x \| (R_s) = 1.5\ \Omega$. The fault currents would be severely limited by R_p, and would fail to trip the protection mechanisms (circuit breakers, etc.).
- The protection levels are lower (R_p is higher) at night than in the day. Less safety at night is dangerous since at night time there is less activity and hence an accident may go un-noticed posing grave threat to life and property.
- The measurements were taken in the monsoon season when the soil is wet and conditions favourable. We anticipate that R_p would be even higher at other times during the year, particularly in the summer.
- With the clamp-on tester, we could not measure the resistance of the guy wires, the transformer body earth, pole earth (if any), and a few consumer earths, due to non completion of the earth loop. The safety of the corresponding equipments could not be ascertained. Jugalkumar died due to a guy wire/ pole that became live.
- Many poles carry not only the LT distribution wires, but also the HT (11 kV feeders) on top of the pole. Inability to test the poles, guy wires, or transformer body makes the system even more dangerous. Fatal accidents are not uncommon as a consequence.

Excessive Billing by Energy Meters

From Item 2 Sub-section 5.2, it is clear that a number of consumers connect their own earthing conductor to the neutral. This they may intentionally do to protect

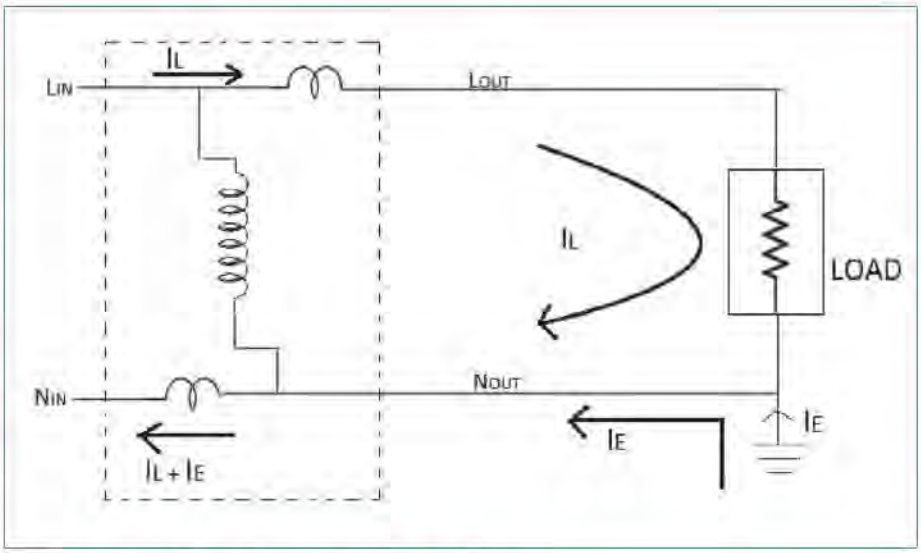


Fig. 7: Injection of Earth Currents into Energy Meters

themselves on an event the incoming neutral breaks. Else it may be due to faulty equipment which has its earthed body coming in contact with the neutral. Whatever be the reason, this connection causes the earth loop currents such as I_{X1C1}, ..., I_{X1Cn} in zone X_1, or I_{X2C1}, ..., I_{X2Cn} in zone X_2 (see Figure 6) to flow through their own neutral. This current, represented as I_E in Figure 7, adds to the consumer load current, I_L, (assuming that both belong to the same phase) and returns back through the energy meter.

Since the static energy meters are configured, on the pretext of tamper protection, to bill the consumers on the basis of higher of the two currents, namely phase and neutral currents, it follows that the consumer will be excessively billed due to the higher neutral current ($I_E + I_L$). See Figure 7 for the equivalent circuit of a static energy meter.

Flashing Street Lights after Switch Off

We observed a strange phenomenon for a period of about ½ an hour to one hour after the street light feeder was switched OFF in the morning (see Figure 8). Some of the street lamps with electronic ballasts were found to flicker with a flash every10 to 20 seconds. How is this possible when the main's switch was OFF and the circuit broken?

The only way this could be explained is by completing earth loops. We have explained earlier how continuous flow of street light current deteriorates the earth and causes earth resistance to increase to alarming levels. Under this situation, when some consumer equipment sinks current through the earth, there is a voltage drop across the earth resistance.

The finite resistance of the neutral wire also results in a voltage drop across it due to consumer loads. These voltage drops could be significant (approx. 25 to 70 Volts) and can act as voltage sources. The equivalent circuit is redrawn in Figure 9 where A, B and C represent the voltage sources that complete the circuit through the earth loops.

Good quality fluorescent street lamps with electronic ballasts usually include, in its input stage, an active power factor correction circuit that converts the input AC supply to a 400 V DC feed used by the remaining stages. Such a PF correction circuit has an ability to regulate and offer 400 V DC even when the input AC supply drops from 230 Volts to very low levels (50 to 70 Volts). As the voltage builds up across the earth resistances (see voltage sources A, B and C in Figure 9), the PF circuit too ramps up its output DC voltage to 400 V DC. The electronic ballast becomes active at some point and ignites the lamp resulting in a flash.

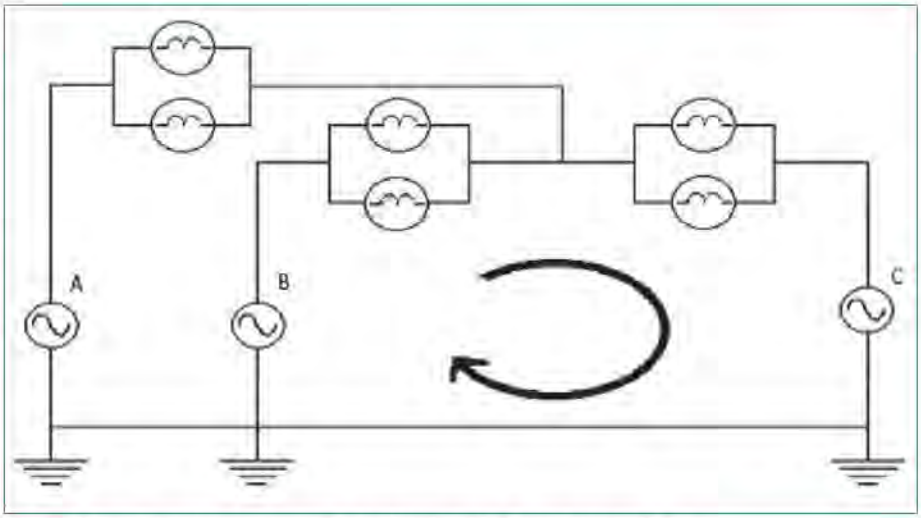


Fig. 9: Ground Loops responsible for street light flicker after switch off

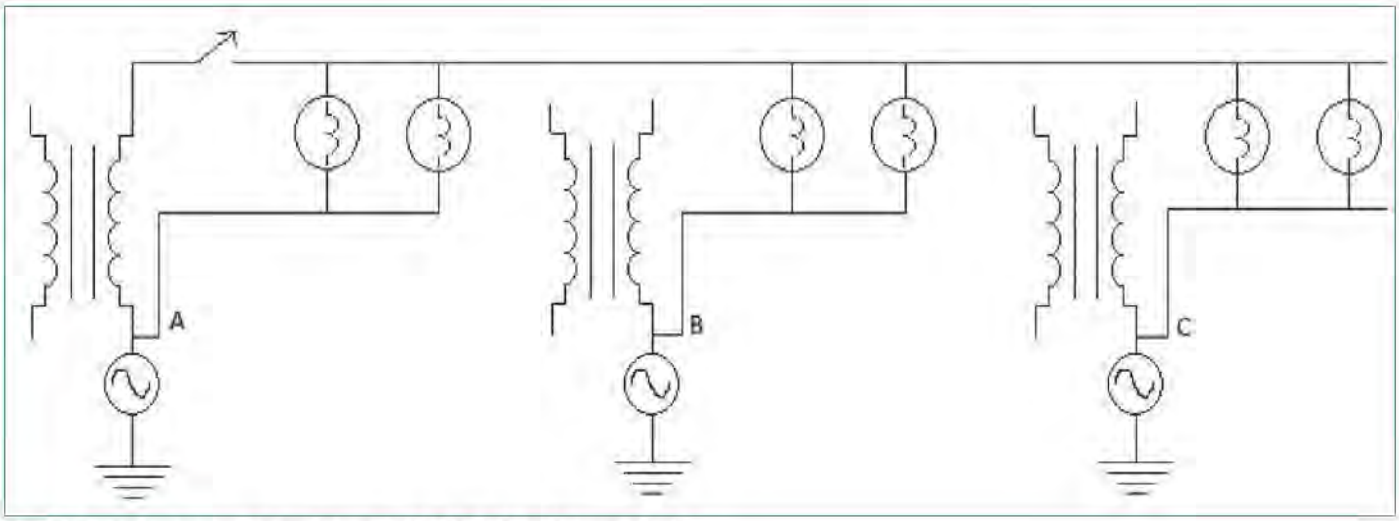


Fig. 8: Equivalent circuit to explain street light flicker after switch off

However, due to the high source (earth) impedance, it is unable to sustain the power feed, and the voltage drop across the earth resistance collapses and the lamps goes off. The cycle repeats when the voltage across the earth resistance builds up steadily once again. This phenomenon lasts only for about ½ an hour to one hour since, thereafter, the damaged earth starts healing itself and the earth resistance reduces.

Proposed Earthing System for India

It is important that the earthing system not only protects the consumer premises but also all the electrical devices in its own distribution system including the electrical poles used to carry the overhead lines. How do we ensure that each pole is protected with adequately low earth resistance that is safe for human beings or animals who may accidently come in contact with it? Such an assurance can be given only when the earthing at each pole is testable. Below we reason out the design of a safe earthing system originally proposed in.

1st requirement - Multiple Earth

A clamp on earth tester (described earlier in Section 4.2) is an elegant tool, but it cannot measure a singular earth such as an individual pole earthing (Section 4.3). This tool is only useful when we have an earth loop, i.e. $R_E \neq \infty$, and when we have a multiple earthing system, i.e. $R_E \ll R_N$.

For the earth resistance to be measureable, it is therefore necessary to link up the earth of each of the poles together [7]. This can be done by earthing the Neutral wire at each pole in which case the system would become PME/ MEN just like the networks in the UK or Australia. Though this is a modification of the TN-CS system, this has one major drawback.

The neutral currents would also find a parallel path through the earth at each pole. This constant flow of the return load currents through the earth wire would cause the earthing system to deteriorate. Unless the earthing network is frequently checked, it would be difficult to trace the sections where the earth resistance has increased. The maintenance of earth resistance to low values is the biggest challenge of a TN-CS with PME/MEN network. Moreover, the leakage faults are no longer observable. If we consider a case of faulty pole insulator, the resulting leakage current would mix with the neutral current, thereby making it impossible to trace and eliminate such a fault.

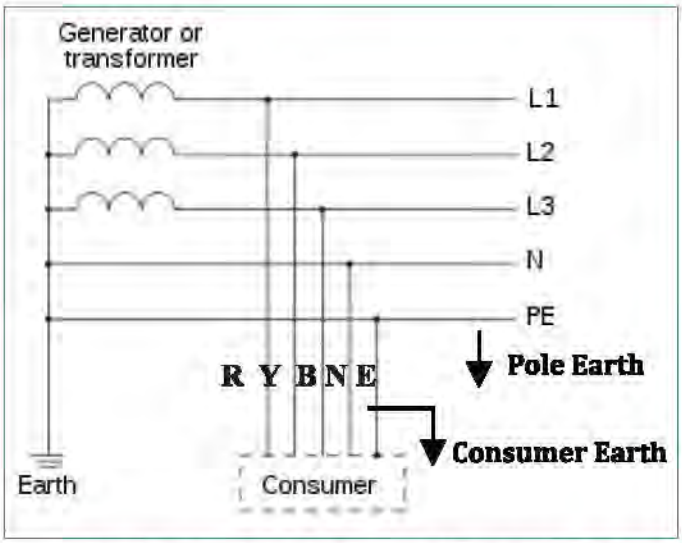


Fig. 10: TN-S-ME network showing 'Separate Multiple Earthed' wire

2nd Requirement - Separate PE Wire

An earth network that overcomes the maintenance problem of PME/ MEN described in the earlier section is the TN-S network. Each of the poles can now be connected to the separate protective earth PE wire which, under normal circumstances, does not carry any current (as per the definition of a PE). The system therefore requires very little maintenance. Both the earth resistance as well as the leakage currents can be measured with equal ease. The TN-S system is also amenable to easy test procedure without disconnection of the earth wire, using the clamp-on tester.

On the consumer side, the separate PE wire can be extended to the consumer premises. Here, the change that we are suggesting is to connect the consumer's own earth to the separate earth wire, PE (and not to neutral, N, at the consumer premises). When this procedure is repeated at each and every consumer premises, it would result in a mesh network with multiple solid earthing system, all of which together would yield a very low earth resistance. Such a network is called the TN-S-ME (see), where 'S' stands for separate earth wire and 'ME' stands for 'Multiple Earthed' using the 'Terra' or Earth wire (see Figure 10).

The TN-S-ME network, originally proposed in, has picked up all the advantages of each of the networks described earlier in Sections 2.2 and 2.3, while dropping off the disadvantages of each of them. Probably the only disadvantage of the TN-S-ME is the higher cost due to the separate fifth earth wire. But if this would result in a safe network and save lives, the incremental cost should not be a deterrent. The TN-S-ME system is best suited for the dangerous overhead distribution systems that also carry the HT (11 kV) feeders. Even with the extra cost of the PE wire, it would still be cheaper and less complicated than making a shift to underground cables (which have other earthing related challenges).

3rd Requirement - Separating SL Feed from the TN-S-ME

To prevent the Street Light circuits from injecting currents into the earth network, it is advisable to run a separate pair of wires (SL-L1 and SL-N) exclusively for street lighting (see Figure 11). This could be in the form of an Arial Bunched Conductors (ABC) which is a pair of twisted, insulated, aluminium conductors commonly used these days as they are tamper resistant.

A separate ABC pair for street lighting, taking the total number of conductors to seven (see Figure 11), would be considered to be an expensive proposition. Alternative, more elegant solutions could be to have an

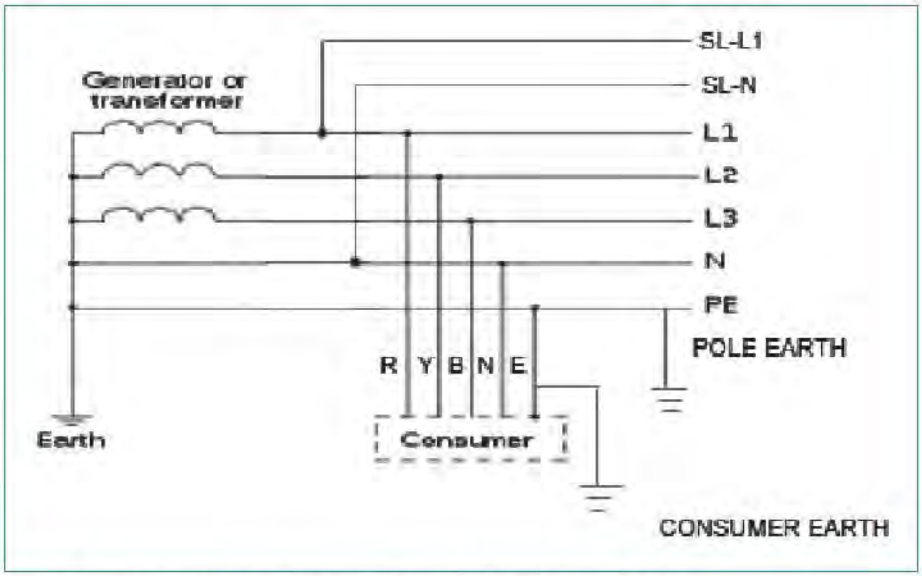


Fig. 11: The TN-S-ME network showing 'Separate Street Light - SL ' feed

independent Street Light Feeder in every transformer zone. The Local Neutral could then serve as a common return wire for the street light return current that flows back to the local transformer secondary (street light source). The issue of current injection into the local earth thus gets circumvented. And the total number of conductors would now reduce to six. To make this cost effective solution viable, wired or wireless remote signaling techniques could be used to ensure that the lamps of a particular transformer zone gets switched ON/ OFF when those in the neighbouring zone are switched ON/ OFF respectively. A detailed description of this novel concept will be described in the following article.

Conclusions

Survey shows that 60% of consumer premises are not earthed, while the balance 40% which have a local consumer earth are never tested once installed. So also the earthing of the street lamp poles and distribution transformers were never tested. It is justified, therefore, if we consider the existing earthing system to be unsafe, as it is not testable, observable and controllable.

We have analyzed some of the major disadvantages of the existing earth network configurations that make them unsuitable for the Indian overhead distribution system. A large number of precious lives could be saved if we adopt an earthing system that has low earth resistances and that can be easily tested. The TN-S-ME earth network coupled with the separation of the street lamp feeder that we have proposed here overcomes these disadvantages and is amenable to easy testing with a clamp-on earth tester.

Acknowledgements

We acknowledge the work done by Anand Kanjaria, Sumit Nakum, Rajesh Ravalia, Malde Solanki, Semel Tank and Kalpesh Nakum, students who graduated in 2012 from BVM Engineering College, Vallabh Vidyanagar, who under guidance of the 3rd author, discovered major problems in the prevailing earthing system.

Dedication

We dedicate this work to Late Shri. Jugalkumar Bhupendrakumar Shah, resident of Bayad, Sabarkantha, Gujarat, India. He was a student of G.H. Patel College of Engineering, Bakrol, Vallabh Vidyanagar, District Anand, and completed his 3rd year engineering degree course in Electronics and Communication. On June 28, 2006, he got electrocuted when he approached a 'live' guy wire near University Circle, Vallabh Vidyanagar. He was aspiring to specialize in Speech processing.

Profile

Jaymin Patel

is a final year undergraduate student of BE (Electrical) at G. H. Patel College of Engineering and Technology and an active member of IEEE. He has been a part of various Non-profit organizations in variety fields. His area of interest is Power System.

Pushkar Bhokri

Is a final year undergraduate student of BE (Electrical) at G. H. Patel College of Engineering and Technology. He is an active volunteer in IEEE. His area of interest includes Power system and analysis, Machines and Switchgear.

Vithal Narasinha Kamat

graduated from Birla Vishwakarma Mahavidyalaya, Anand, Gujarat, and completed post-graduation in Control and Instrumentation from the Indian Institute of Technology, Mumbai. He completed his Doctoral studies in Artificial Intelligence from the University of New Brunswick, Canada. His employment experience includes the Centre for Development of Telematics (CDOT), Centre for Apparent Energy Research, Centre for Embedded Software Engineering Solutions, and as a technical consultant to NXP Semiconductors. His field of interest includes high voltage protection, learning machines, apparent energy tariffs, demand side management, and embedded software. Currently, he is serving as an advisor to a Women's Engg. college – MBICT.


The Ignalina Nuclear Power Plant

Infrared Thermography helps to increase safety at nuclear power plants

The Ignalina Nuclear Power Plant is located in the north-eastern part of Lithuania, near the borders of Latvia and Belarus. The plant is of the same type as the one in Chernobyl but is even more powerful. It has an output of 1,500 MW. The site of the power plant covers an area of more than 0,75 square kilometers and employs about 5,000 people. It stands for about 80% of Lithuania's electricity production.

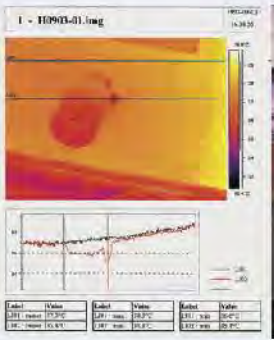
After the dramatic events in Chernobyl, a project was initiated to improve the safety of the nuclear power industry in Eastern Europe with Western European support. One of the organizations involved in this project was "the Swedish International Project Nuclear Safety (SIP)". One of their concerns was to prevent radioactive particles entering the environment through cooling water or air.

An important task at the Ignalina Nuclear Power Plant was therefore to verify that the encapsulation of the reactor building, the so-called "containment building", was air- and gastight. This part of a nuclear power plant houses the reactor, pressurizer, reactor coolant pumps, steam generator, and other equipment or piping containing reactor coolant. It is an airtight structure, which typically is made of steel reinforced concrete, three feet thick. It needs to be airtight, to prevent radiation from leaking into the atmosphere. The Swedish International Project Nuclear Safety contacted Arne Jensen AB. A company with international experience in various leak tracing methods. "Infrared was the perfect technology to use in this case.", says Arne Schleimann-Jensen of Arne Jensen AB. "Since the contaminated air is at a negative pressure and a raised temperature, it is possible to see the leaks, in the form of cooling, by using an infrared camera. To locate leaks in the enormous buildings with ceiling heights of more than 60 meters, I used a FLIR Systems ThermaCAM. This camera makes it possible to see temperature differences as small as 0.08 C and has a perfect image quality." "Infrared thermography was an unknown technology at the Ignalina plant when I first arrived, but when I discovered the first leak, a hole of only a few square millimeters and an air flow rate of just 0.3 meters per second, everyone was convinced that infrared is a great tool for this type of work."

"There are of course other techniques to find air leaks in buildings", says Arne Jensen. "But infrared technology has numerous advantages. It can be used when the powerplant is running. There is no need for a costly shutdown. Furthermore, thermography is unbeatable when it comes to having a rapid overall picture. It gives you a quick and total overview of the situation and the problem can be clearly located on the infrared image. And as we all know, a picture is worth a thousands words."

Arne Jensen has made numerous trips to Lithuania. "At first mainly to train the power plant's maintenance personnel how to use an infrared camera for leak tracing. But during this training sessions, and when walking around with the FLIR Systems ThermaCAM in the power plant, it became very clear to them that the infrared camera can be used for more than leak tracing only. Now that there is a camera on site it is also used extensively to check their electrical installations. If left unchecked, heat can rise to a point that connections and overloaded cables melt and break the circuit. This can result in fire. The people at Ignalina have been so impressed with the results of thermography that word spread rapidly to the neighboring nuclear power plant in Kola, Russia. This plant now uses infrared cameras for leak tracing and checking electrical equipment, such as transformers and circuit breakers, as well.

If more information about thermography and its numerous applications is required, contact FLIR Systems, the world leader for infrared thermography.



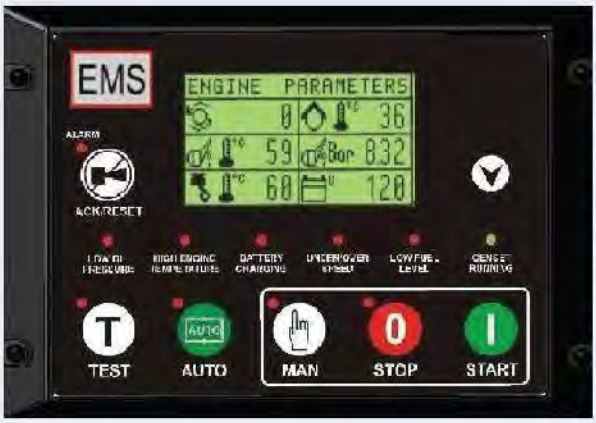
For further information contact:
www.flir.com

Integrated Electrical Asset Management for the Telecom Industry

The Telecom industry remains one of the fastest growing sectors of today's world, as a result, there is relentless competition and cost minimisation pressure. Day-by-day the number of telecom subscribers increase along with the number of telecom towers. In spite of growth in the telecom infrastructure industry, old problems associated with reliable power supply remain. Providing backup for electricity failure requires investment in batteries, generators and that expensive consumable, fuel. Managing the ever increasing system infrastructure becomes more and more complex.

Gensets

Telecom towers need reliable power 24x7 to ensure provision of seamless and uninterrupted telephony services and associated revenues. Many parts of India suffer with 15% under-supply of electricity on a daily basis and many others countries are without power for 20 hrs per day. In rural areas there is often no reticulated power at all, so the sites must be run on a generator, continuously. New technology DC gensets are finding favour in the rural applications due to reduced fuel consumption and hence lower operating



costs. Common issues for infrastructure management are fuel theft, fuel adulteration and prioritising fuel replenishment. Similarly site battery performance is critical and yet little is done to ensure integrity. Timely engine maintenance is essential and needs to be scheduled by actual demand rather than monthly review. Unsophisticated control systems do not cater to these issues.

Genset Management and Monitoring

There are a number of add-on asset management and monitoring devices available in the present market, which can monitor the telecom sites remotely by monitoring various parameters of Battery and DG sets with ancillary equipment. However the controllers manufactured by Electronic Monitoring Solutionz Ltd (EMS) incorporate these functions already. Beyond the normal DG start / stop sequencing, engine / alternator / load operating parametrics and protections, EMS controllers can be customised to address fuel management, battery integrity and maintenance schedules. Use of these products will help to reduce the overall operational cost.

Profile

Managing Director, Electronic Monitoring Solutionz Ltd

Lindsay Baxter

CHINT T&D

In 1984 Yueqing County Qiujing Switches Factory, the predecessor of CHINT was established. In 1986 Qiujing Switches Factory set up first testing lab for thermal overload relay in Wenzhou and in 1994 CHINT, was registered as a trademark. CHINT Group acquired Shanghai Xinhua Control Technology (Group) Co., Ltd. The company is also ranked in the 2011 BCG 100 New Global Challengers (The Boston Consulting Group, 2011). Nan Cunhui is President of CHINT Group, Chairman of the Board of CHINT Group.

CHINT Power T&D is a key business unit of CHINT Group specialized in power transmission & distribution equipments and EPC turnkey solution. Business Units of CHINT Group are such as Power Transmission & Distribution Equipments, Low – Voltage Electrical Apparatus, Solar Energy Products, Building & Construction Electrics, Measuring & Monitoring Equipments.

The company has around 4,300 employees, 30% with technical background. Worldwide business operation with 2,000 sales offices, agents, distributors, and local partner in domestic Chinese market and distributors & local partners in over 70 countries. International branches or regional offices set up in USA, UAE, Germany, Russia, Brazil, Ukraine, Hong Kong, UK and Kenya. CHINT stretches its business to a new frontier of solar energy by setting up a branch company specialized in the solar energy products development. The R&D center of CHINT is recognized as the National Level R&D Center run by the companies, which means the R&D level of CHINT Group has reached the leading position in the industry of China. The manufacturing facility covering 900,000m2, with an investment of 450 million USD, CHINT T&D has one of the world's largest Power Transmission & Distribution Equipment Manufacturing Centers in Shanghai, with convenient traffic facilities lead to there.

The company has wide product range such as Oil-immersed Transformers (10-750kV),HV Circuit Breaker & Switch Disconnector up to 252kV,Current Transformer & Voltage Transformer up to 500kV,Power Protection & Automation Equipments etc. The company is one-stop electrical and control solution and has expanded its core business from low-voltage products to the whole range of products including power transmission & distribution, low-voltage electrical distribution, building & construction, measuring & monitoring equipments, and solar energy products. CHINT is still searching for new related fields to broaden the products and service to their customers. CHINT has spread its business to more than 70 countries in the world, and over 2,000 distributors local partners to ensure customers can access to their service & products whenever & wherever.

For further details contact:
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Interview

"Reshape and combine proven technology with future market demands"

Dr. Martin Füllenbach, CEO
Oerlikon Leybold Vacuum GmbH

Oerlikon Leybold Vacuum is one of the most successful vacuum technology suppliers on the market, offering a broad range of advanced vacuum components and solutions. Oerlikon supports industrial manufacturing of coating and analytical processes, as well as R&D. The core capabilities center on the development of application and customer-specific systems for creating vacuums and extracting process gases. Company has best-in-class application engineering and ability to simplify customers' service processes. Customers count on them for robust vacuum solutions that set standards for best performance and return on investment. In an exclusive interview to **Electrical India, Dr. Martin Füllenbach** states, we constantly innovate our product offerings.

➢ **What is your perception about vacuum pumps market domestically and globally?**

The vacuum market can be considered as a mature market, based on proven and reliable physical vacuum technologies. Globally, there are many small and mid-sized vacuum pump manufacturers dealing with the local customer demands. This is certainly also true for the Indian vacuum market. However, on the global scale, there are only a few players who are really active internationally and are in the forefront of technological development within these mature parameters.

Living in today's world where the products we use need to meet a rigorous set of parameters, innovative production and processing techniques are enabling producers to reach these goals in a cost-effective manner. However, the processes are only as good and efficient as the components that are used in the production environment. Innovative and efficient vacuum pumps are a quintessential part of any production line by providing safe operation, meeting process conditions effectively, guaranteeing high uptime reliability, and ensuring a low cost of ownership (CoO) through minimal maintenance and service requirements. The use of vacuum pumps and technologies spans a wide range of applications.

➢ **Could you highlight about product range of the company and applications thereof?**

Oerlikon Leybold Vacuum GmbH is one of the world's most

successful vacuum technology suppliers, offering a broad range of advanced vacuum components and solutions. Oerlikon Leybold Vacuum supports industrial manufacturing of coating and analytical processes, as well as research & development. The core capabilities center on the development of application- and customer-specific systems for creating vacuums and extracting process gases. Highly trained and experienced engineers also provide customer-specific consulting and the world's largest vacuum technology service network with a variety of after-sale services takes for process stability.

The broad product range is built on the real-world experience and engineering expertise of our employees, our customers know they can count on us for robust vacuum solutions that set standards for performance and return on investment. Our products have a proven record of reliability: product brands such as TRIVAC, SOGEVAC, RUVAC, DRYVAC and TURBOVAC have become a synonym for vacuum pumps as such.

➢ **Oerlikon Leybold Vacuum uses know how of processes, technology and applications to optimize customers' manufacturing processes. Could you elaborate upon that?**

As a world leader in vacuum technology for more than 165 years, Oerlikon Leybold Vacuum has helped customers reach their goals by maintaining a close eye on the smallest details. The ability to reshape and combine proven technology with future market demands and state-of-the-art manufacturing precision are only matched by our best-in-class application engineering and our ability to simplify our customers' service process. We do not only offer simple pump as components, we constantly innovate our product offerings. Our engineering know-how enables us to offer also standardized pump systems as well as fully customized vacuum solutions. Not to mention all necessary instruments, valves, fittings, gauges and of course a full range of after sales services. The proximity to our customers is of high importance to us.

➢ **Which of the company products command major market share globally with specific reference to India market?**

For India, our focus lies on industrial applications such as transformer drying, capacitor drying, transformer oil filtration and filling. But also motor impregnation, switchgear resin filling, helium leak testing of transformer castings, high voltage insulators, and gas charging units need vacuum technology during various stages of the manufacturing process.

One of the strong points of Oerlikon Leybold Vacuum is certainly the application know-how we have with regard to these process industries. Just to mention the success we had during the last year in revolutionizing the vacuum pump systems used in the steel degassing industry. We completely re-thought the way of how to combine of the shelf standard products and came up with a system which is highly flexible, optimized with regard to energy and maintenance costs with short delivery times. Especially the Indian market has taken up this innovative concept. Several of these systems have been sold locally already.

➢ **What are your assumptions about the Indian market for dry compressing vacuum pumps and systems for coating applications in the solar industry? Could you brief its key features?**

The region has vast chances in various market segments, not only with regard to metallurgy. For photovoltaic applications, just consider the recent reports on solar microgrids which are projected to grow considerably, especially for the electrification of remote areas. India will most probably not develop into a solar panel manufacturer country, but the sales potential will be there. We follow the production trends and movements of our customers – with optimized products and a full range of after sales offerings.

➢ **Oerlikon Leybold Vacuum presents a new product line of turbo molecular pumps with integrated drive at the 2014 PITTCON Conference & Expo, in Chicago, during March. Could you detail about its features?**

The new high vacuum turbomolecular pump series TURBOVAC I / ix is specially designed for applications of the analytic and R&D market. These pumps offer the highest performance even for widely differing requirements. Through their additional compression stage, the TURBOVAC 350 i and 450 i are particularly well suited for ultra-high vacuum applications and for integration within compact pump system solutions. Offering a pumping speed for light gases which is up to 60% above that of comparative products, and a compression level which is approximately 100 times higher compared to products of the previous generation, these pumps were designed especially for processes with small backing pumps. The TURBOVAC T 350 i and T 450 i designed with classic rotors excel with regard to high gas throughput, fast run-up time and insensitivity to particulates and are therefore optimized for process applications and high gas loads. Again, also with this new innovative product line we show how thoroughly we understand our customer's requirements.

➢ **Among the stiff competition what strategy do you have to have cutting edge over other company's products in similar line of manufacturing?**

Apart from high technology, quality, reliable products with modern communication facilities, we have trained engineers who can deliver complete application support and solutions. Today, just delivering a product is certainly not enough, the after sales performance is equally important. A strong comprehensive after sales

service based in geographical vicinity to our customers with their installed base ensures the internationally consistent quality standard of our products – there might be less expensive products available, but with regard to quality and experience Oerlikon Leybold Vacuum is second to none.

➢ Where are your manufacturing facilities located? Could you share with us the technologies and certifications being used for quality production?

We have four production sites globally. Headquarter and main R&D site is in Cologne, Germany. In Dresden, Germany, the focus lies on cryo technology. In Valence, France we manufacture the renowned SOGEVAC fore vacuum oil sealed pumps. Since 1997, we have a production facility in Tianjin, China. The scope of manufacturing in China has constantly widened, as we moved oil sealed for vacuum pump technology and augmented the factory already three times in order to comply with the high demand of the Asian markets on this localized basis. Wherever we manufacture, we apply the same methods and quality parameters. All manufacturing processes and even the machinery used are globally following the same lines. Quality bears no compromise. We export and sell German Engineering, nothing less.

➢ What is your vision in the next two years?

Growth of course! Naturally, there are fluctuations in the market such as a shift from traditional lamps to LED which require no vacuum supported charging process or a saturation of the refrigeration market. But these market developments are offset by other new technologies arising.

We anticipate a growth scenario for the next year, despite some critical economic parameters. Any upswing within the industries will be most certainly be accompanied by technology of Oerlikon Leybold Vacuum and our dedicated local team.

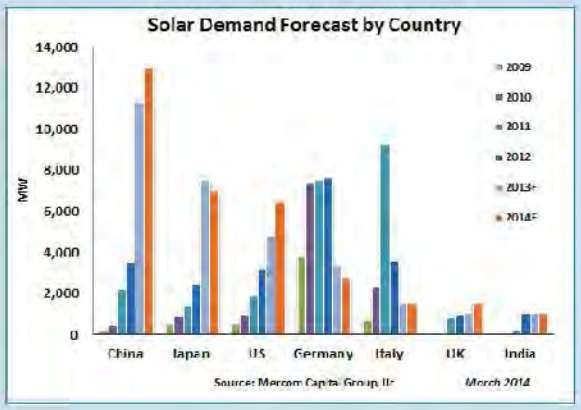
Mercom forecasts Global Solar Installations to around 46 GW in 2014

Demand outlook for solar industry remains strong and global solar installations are forecasted to be around 46 GW in 2014, according to the latest quarterly update from Mercom Capital Group, llc, a global clean energy communications and consulting firm. Global installations in 2013 are estimated to come in at 37 GW, in line with Mercom's forecast.

Raj Prabhu, CEO and Co-Founder of Mercom Capital Group, commented that the revised forecast reflects the ever-shifting market conditions and the new Chinese installation goal. "China recently announced an aggressive 14 GW installation goal, a 2 GW increase since our previous update in December 2013." Within the new 14 GW goal, China has set an aggressive target of 8 GW for distributed generation and another 6 GW for utility-scale projects with specific quotas in individual provinces. Mercom expects Chinese installations to be in the 13 GW range in 2014.

Japan is expected to install solar in a similar range (7-7.5 GW) to last year. Japan faces some challenges, however, as the Ministry of Economy, Trade and Industry (METI) weeds out projects that, although approved, are unlikely to be built. Country's feed-in-tariff (FiT) is likely to be reduced next month and a 3% sales tax increase could further dampen demand.

The U.S. solar market is forecasted to install 6.4 GW in 2014, spurred by utility-scale projects and an energetic residential sector. Solar lease has been the big driver of residential installations, with third party finance companies raising $3.3 billion in residential and commercial tax equity funds in 2013. System costs in the United States are still high compared to Germany, but innovative financial instruments, including asset-backed securities, third party finance and YieldCos, are helping bring the cost of capital down. Trade disputes, however, continue to be an issue with United States.



PV installations in Germany are forecasted to be around 2.75 GW in 2014. Germany's role in the solar market continues to decline as policy support retreats. In a bid to reduce price hikes in electricity, the latest policy proposals include bringing the installation levels closer to 2,500 MW a year. There is a proposal to replace FiT with a tender system in 2017 in addition to a requirement that new solar projects greater than 500 kW market sell electricity directly to consumers.

"Energy security is a key reason for governments around the world to review their energy generation mix and invest in domestic solar and other renewables," he said. Other markets highlighted in the update include United Kingdom and India both of which installed approximately 1 GW in 2013 and are expected to install similar numbers in 2014. Mercom revises its forecast quarterly to reflect on-the-ground conditions.

New Earth Ground Testers from Fluke

Fluke Corp, introduces their Latest range of New Earth Testers 1623-2 and 1625-2 Earth Ground Testers with advanced features and accessories that speed verification of a reliable connection to earth for grounded electrical systems, helping solve power quality problems and lowering the risk of shock to users. Routine earth resistance measurement is essential part of each industrial and commercial installations maintenance program and it is very crucial for correct operation of equipment's and personnel safety of operators. The new Earth Ground Testers help engineers and electricians meet electrical codes, engineering standards, and local regulations to ensure that in the event of a lightning strike or utility overvoltage current will find a safe path to earth. They perform all four types of earth ground measurements: 3- and 4-pole fall-of-potential, 4-pole soil resistivity, selective testing, and stakeless testing. New world-class Earth testers from Fluke with comes with user friendly accessories which can save up to 50 percent of set up and measurement time compared to other earth testers in market. Main Features & Benefit of New Fluke Earth Ground Testers are that it has onboard memory & data storage – store up to 1500 measurement with time stamps with USB port – for fast & easy downloading of results. Color coded wire sets – reduce error & save time while setup along with high short circuit current –1625-2 has 250mA, 1623-2 has 50mA short circuit current for reliable measurements.

For further details contact:
info.india@fluke.com

Megger Relay and Current Transformer Test Set (MRCT)

The Megger MRCT is a light weight, robust, portable unit used to perform demagnetization, ratio, saturation, winding resistance, polarity, phase deviation, and insulation tests on current transformers. The MRCT automatically calculates ratio errors, saturation curves, and knee points. The MRCT provides a microprocessor-controlled variable voltage and current output and precision instrumentation for automatically testing single and multi ratio CTs, reducing testing time and increasing productivity. The MRCT will directly connect to multi ratio CT's and perform all tests saturation, ratio and polarity, winding resistance and insulation – on all taps with the push of a button and without changing leads. The MRCT can be controlled via Megger's Smart Touch View Interface (STVI) controller. The unit can also be configured to come without a Megger STVI and can be controlled via laptop with Megger'sPowerDB software. Current transformers can be tested in their equipment configuration, such as being mounted in transformers, oil circuit breakers or switchgear. It is necessary for the equipment to be completely isolated from the electrical system prior to testing. Shortest test duration in the industry their patented system allows simultaneous measurement on all taps during CT saturation, ratio and polarity, winding resistance and insulation resistance testing. The MRCT eliminates the need to test each tap sequentially and independently, thereby reducing testing time by up to 50. Improved Ratio Accuracy with up to ± 0.1% ratio accuracy, the MRCT can be used to test both metering and protection class CTs. Portable and lightweight: At 35lbs, the MRCT is the smallest and lightest secondary voltage injection unit on the market. Multiple instantaneous saturation curves and their knee points are plotted and calculated on the fly as the test is being performed. All test results and saturation curves can be cataloged and stored within the MRCT.

For further details contact:
india.sales@megger.com

i 12 : 1kV Digital Insulation Tester from Motwane

Motwane took up the challenge to develop and manufacture modern features packed heavy-duty Insulation Tester with specifications compatible to international standards. The meter is power packed with many advanced features bundled into one and high level of Safety standard. i 12 is specially designed to cater to LT Motor manufacturers, Cable Testing, Industrial, commercial & residential installations, control panel testing, power distribution, Electrical Contractors and other varied users. i 12 comes with various distinctive features like Insulation resistance up to 2000M , covering large set of applications. It has an inbuilt Volt meter which is capable to measure Auto AC/DC voltage up to 600 V. The i 12 is equipped with Low resistance measurement up to 100 for precise applications, Preset Timers for hands free operation, NOGO facility which will helps testing procedures fast and simple. The Insulation tester is safe to use with live circuit detection feature and automatic discharge of capacitive load after insulation resistance test. An optional AC Mains Eliminator is provided to use i 12 on 230 VAC. The Insulation tester is equally complying to all high grade safety standards such as IP 54, CAT IV 600V, up to 8KV, IEC 61010-1/EN61010-1 / VDE0411-1 to ensure safety, EN 61326 provides protection from EMI & contamination degree II.

For further details contact:
sales@motwane.com

Giantlok Cable Ties

Giantlok offers a high quality and full range of Cable Ties for use in various different applications. By constantly refining their products and satisfying the ever-changing demands of the market, various locking technologies have been developed. They pay attention to product engineering details, which is greatly contributed to improving efficiency levels of work. Furthermore, they insist on continuously providing high quality products to minimize possibilities of operational failure, so that the cost of rework can be effectively reduced. Giantlok also offers complete series of ergonomically designed crimping tools with just the benefits the one is looking for in effort-saving and hassle free installations. Giantlok's locking mechanism is used in 90% of all their polyamide (PA) cable ties. In order to cover a variety of applications, there are different variants of this system, for example: releasable versions and in-line versions. These one-piece cable ties, that the pawl is molded as an integral part of the cable tie, thereby building in inherent strengths. Giantlok's cable ties made by Polyamide 6,6 could be heat-resistant, UV-resistant or flame-retardant. They provide a full line of high quality cable ties in a wide range of sizes, materials, colors and styles for fastening, bundling, securing and identifying in a variety of applications. All Giantlok's cable ties are engineered and manufactured to meet or exceed industry standards to guarantee maximum reliability. The entire product range of Giantlok is compliant to RoHS and REACH

regulations and has gained UL, CSA, GL, Lloyd's Register, ABS and CQC accreditations. 99.9% of our products are made of recyclable and reusable engineering plastic and metal and over 85% of them are made by Polyamide 6,6 which is low smoke and halogen free.

Website:
www.giantlok.com

Parker Hannifin's AC30V series for pump and fan control

Parker Hannifin India introduced their new series of AC variable frequency drive, the AC30V Drive. Engineered specifically for flexibility, simplicity and reliability, the AC30 series of variable frequency AC drives covering a range from 0.75 kW to 75 kW. AC30 drive has been designed to provide users with exceptional levels of control, from simple open-loop pumps and fans through to closed-loop processline applications. Its flexible and highly modular construction enables a wide range of communications and I/O modules to be easily added as required. The AC30 has been designed with simplicity in mind, but this doesn't compromise its functionality. Integrated macros for a range of applications and PLC functionality enable more capable users to create sophisticated control that would previously have required a separate PLC. Designed for operation in environment class 3C3 and 3C4 for Hydrogen Sulphide (H2S) as standard (tested at 25 ppm for 1200 hours), temperatures up to 50^0C with optional integrated EMC filter to C2 1st environment and DC link choke to reduce line harmonics. AC30V also complies with RoHS substance restrictions in accordance with EC Directive 2011/65/EU. AC30 variable speed drives give comprehensive and cost effective control of either AC induction or permanent magnet (PMAC) servo motors and are suitable for the Open- and Closed-Loop Control of Pump, Fan and many other General Purpose Applications.

For further details contact:
sales.augindia@parker.com

Metal Halide Twin Arc Long Life Lamp by Venture

Venture lighting, manufacturer of Metal halide lighting systems, has expanded their family to include super pulse start long life twin arc lamps that have two independent arc tube. While only one arc tube operates at a time, cycling of the lamp randomized which arc tube ignites providing enhanced lumen maintenance and 40,000 hours rated life. The arc tube are positioned very close together allowing the twin arc tube lamp to work effectively with in point source optical system. The effect of the second arc tube of the super pulse start long life lamp to fixture photometric has been determined to be minimal. The function and the aesthetics of light distribution are not significantly affected.

Benefits

It has a long life of 40,000 hours rated life and is available in 70W to 400W. Pulse start Quartz metal halide. It is available for open type fixtures and have faster warm up. It has better hot restart and has increased efficiency along with superior colour uniformity

Applications

Assembly shop, forging shop, cement plant, chemical plant, automobile industry, warehouse.

For further details contact:
marketing@vlindia.com

Index to Advertisers

Compact True RMS Energy Meter for Energy Monitoring

RISH EM series measures important electrical parameters in 3 phase and single phase Network & replaces the multiple analog panel meters. It measures electrical parameters like Active / Reactive / Apparent energy, power as per models. The instrument has optional output as one pulse output for energy measurement.

Features

True RMS measurement: measures distorted waveform up to 15th Harmonic.

Energy as per IEC 62053: independent Import and Export Energy counter. Active energy (kWh), Reactive energy (kVArh), Apparent energy (kVAh) measurement. Accuracy as per IEC 62053-21,IEC62053-23.

Limit (Alarm) or Pulse Relay Output(Optional): Potential free, very fast acting relay contact. Configurable as pulse output which can be used to drive an external counter for energy measurement. Configurable as limit (alarm) switch.

Configurable Error Diagnosis Mode: incorrect phase sequence, phase reversal and phase missing error detection.

LCD Display with Backlit: LCD shows 3 Parameters at a glance.

Parameter Screen recall: In case of power failure, the instrument memorizes the last displayed screen.

Hour Run, ON Hour, Number of Interruptions: Hour run records the number of hours load is connected. ON Hour is the period for which the auxiliary supply is ON. Number of Interruptions indicates the number of times the Auxiliary Supply was interrupted.

Application

Energy billing; electrical load monitoring; sub-metering; genset,test benches and laboratories.

For further details contact:
info@rishabh.co.in

Klauke K907MCSET Solar Connector Set

Klauke, has launched a custom installation kit for all PV (Photovoltaic) Solar applications. PV systems are carefully designed and the terminations are an integral part of the system; requiring a specific installation tool to ensure a quality termination or joint. PV Solar Tools are one of the most important parts of any installation project. The tool can accommodate MC4 type terminations and features an alignment mechanism which ensures the compression is achieved exactly to the manufacturer's specification. Installations made using the correct tooling will ensure a long and trouble free service life. The neat new K907MCSET features such as Dies – The most popular used MC4 dies from 1.5mm – 6mm; Stripper - High precision PV cable stripping tool; Positioner - Alignment mechanism to ensure correct connector position; Ergonomics – optimised low handle force tool frame with comfort grips; Compact – Sturdy carry case with blown foam insert for neat storage.

For further details contact:
sales.in@klauke.textron.com

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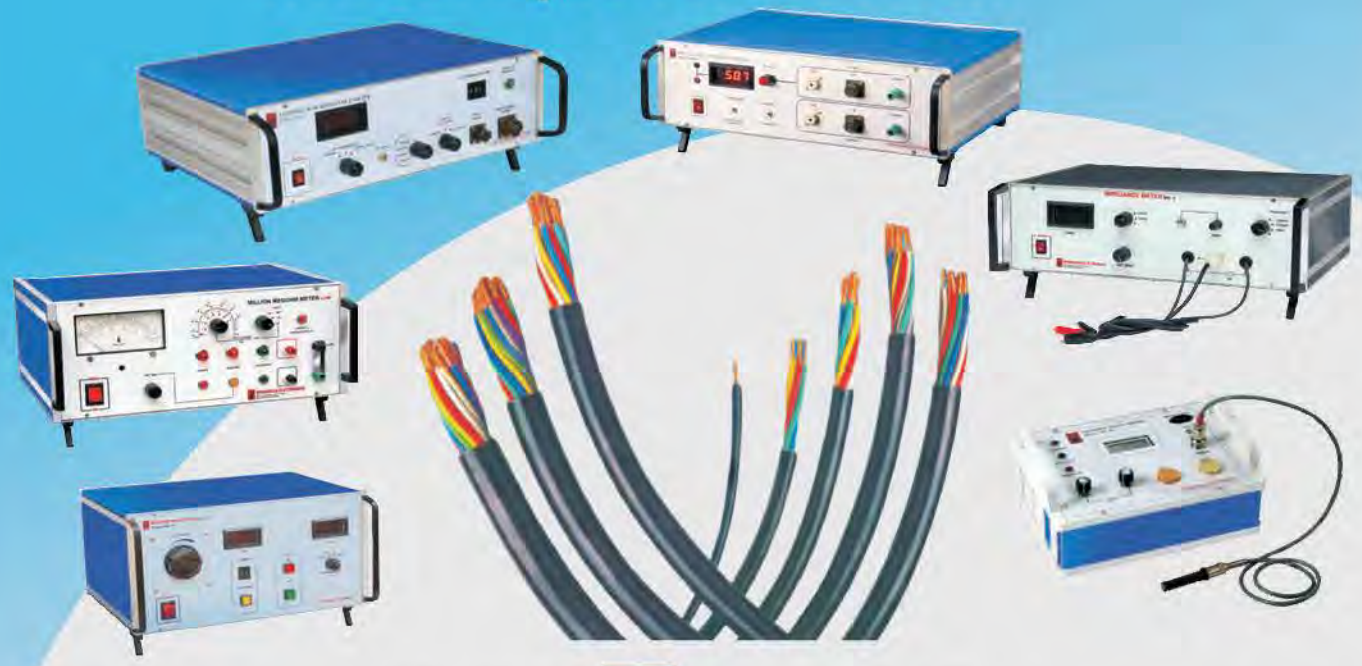

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