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- Winding Resistance-Meter
- Ultra Sound detector
- X-Ray Imaging

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- Insulation Tester
- Thermo vision camera
- Corona Camera
- LCM
- Winding Resistance-Meter
- Power Quality Analyser
- HV Detector
- Fault Passage Indicator
- X-Ray Imaging

Industries

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- DC Earth Fault-Locator
- Gas Check Detector
- Ultra Sound-detector
- Thermo vision-camera
- Power Quality-Analyser
- Winding Resistance-Meter
- Earth Tester
- Corona Camera
- HV Detector
- X-Ray Imaging

Railways

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- DC Earth Fault Locator
- Corona Camera
- Insulation Tester
- Earth Tester
- Gas Check Detector
- LCM
- HV Detector
- Thermo vision camera
- Winding Resistance-Meter
- Ultra Sound Detector
- X-Ray Imaging


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> A spate of transmission lines and power projects being dedicated

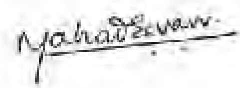
Global cable market valued at $188.3 billion in 2013 is expected to reach $205 billion in 2014 and $297 billion in 2019, at a CAGR of 7.7%. Power is carried through a transmission network of high voltage cable lines. August month saw a spate of transmission lines and power projects being dedicated to the nation. A write-up on 'Cables for Use in Photovoltaic Solar Installations' explores the energy deficit and an awareness with respect to renewable energy world over has led to the development of Solar Parks. Apart from roof top photovoltaic installations, solar Parks are PV modules installed in groups next to a substation of the utility power network.

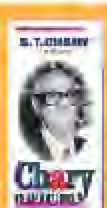
Recent developments in energy storage technologies provide new opportunities, to operate the electric grid efficiently using energy storage systems. The article 'Energy Storage at Generation and Transmission levels' analyses that emerging deployment trend of renewable sources and trade in liberalized markets make higher demands upon the transmission network. This creates excellent opportunities for energy storage.

Understanding the prevailing national & regional power position and costly usage of DG set sometimes, with no other alternatives as standby is a stark reality. Long back, we used DG set few hours in a week in the industry but now we are forced to use old DG set. A study, 'Reduce the Diesel Consumption Today, in Your DG Set' provides ways on how giving the priority to the ageing condition, we can comfort DG set to get more units per liter from the set.

All the more, the issue contains other interesting topics relevant to current trends on power sector and would like feedback from our patrons, readers, advertisers and subscribers.

Do send in your comments at miyer@charypublications.in





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CONTENTS

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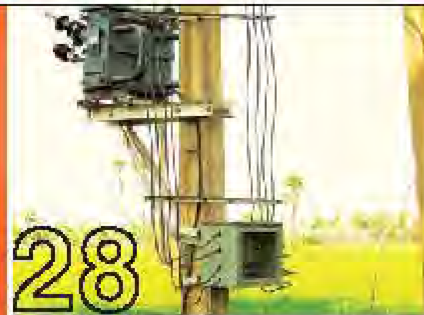

Departments

Interview

52

M G Raoot
Managing Director & CEO
Power Exchange India Limited

Power Transmission lines and Power Projects in the Offing

> Bridging the gap of indigenous coal availability through coal imports

Gopal Krishna Anand

An adequate supply of electricity to provide power consistently for growth of every sector in the state and augmentation of inter-regional capacity is must for a country's economic prowess. Major steps being taken by the Government to boost power sector in country are - acceleration in generation capacity addition during 12th Plan with a target of 88,537 MW from conventional sources and 30,000 MW from renewable energy sources; bridging the gap of indigenous coal availability through coal imports for increased generation by thermal plants and promoting energy conservation, energy efficiency and demand side management measures.

The August month had been historic in so far as a series of power projects and transmission lines were dedicated to the nation by Prime Minister, Narendra Modi who laid the foundation stone of Leh-Kargil-Srinagar transmission system being executed by POWERGRID and 765 kv Ranchi-Dharmjaygarh-Sipat Transmission Line connecting Eastern and Western parts of country. The power projects dedicated are 1000 MW (2X500 MW) stage I of Mouda Super Thermal Power Project in Nagpur, Maharashtra; Chutak Hydro Power Station: 44 MW of National Hydro Power Corporation at Kargil Ladakh in Jammu & Kashmir and Nimoo Bazgo Hydro Power Station: 45 MW of NHPC at Leh, Ladakh. Under cross-border projects, 140 km transmission line is being constructed to facilitate power trade between Nepal and India. Construction of Nepali portion of Dhalkebar-Muzaffarpur began recently as Nepal to import from India, requires power trading facilities and transmission lines.

A changing power scenario requires new technology, amendment and investments for developing efficient transmission lines to accommodate ongoings/ happenings in the area of grid stability and energy security. However, recently, Power Ministry drafted amendments to the Electricity Act, 2003 based on a committee recommendations headed by Chairman, CEA. These are expected to bring about further improvements in grid security, distribution efficiency, rationalization of tariff, and responsible regulatory framework with an objective of sustainable growth of power sector aimed at consumer benefits.


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PM dedicates 765 kV Ranchi-Dharamjaygarh-Sipat transmission line; Initiates Commencement of work on 3x660 MW North Karanpura Super Thermal Power Project

Prime Minister Narendra Modi dedicated to the nation, 765 kv Ranchi-Dharmjaygarh-Sipat Transmission Line connecting the Eastern and Western parts of the country. The transmission link was inaugurated online at Prabhat Tara, Dhurwa, in Ranchi. He also initiated the commencement of work of 3x660 MW North Karanpura Super Thermal Power Project of NTPC. The Governor of Jharkhand Sayed Ahmed, the Chief Minister of Jharkhand Hemant Soren, the Union Minister for Communications and IT Ravi Shankar Prasad, the MoS(I/c) for Power, Piyush Goyal, and the MoS(I/c) for Petroleum and Natural Gas, Dharmendra Pradhan and Minister of State for Social Justice and Empowerment, Sudarshan Bhagat were present on the occasion. He

said eastern India has remained underdeveloped, and growth should be balanced across north, south, east and west-so that common people across the country can enjoy the fruits of development in equal measure. The Prime Minister pointed out that Jharkhand would benefit enormously by Cabinet decision to increase royalty rates on minerals. He also announced that work would commence shortly on the Jagdishpur-Phoolpur-Haldia gas pipeline - which would become a major source of energy for eastern India. Initiating the commencement of work at the North Karanpura Super Thermal Power Plant, the Prime Minister said this power plant would dispel darkness not only from Jharkhand but also from different parts of the country. Addressing the function on this occasion, Union Energy Minister Piyush Goyal said that though NTPC project in Jharkhand was started more than ten years back but because of lack of coal linkage and several other issues, the power project could not take off during the last ten years. Goyal also announced that the centre is keen to provide separate feeder line to farmers in the state.

First Solar to develop 45 MW AC of utility scale solar projects in Telangana

First Solar Inc. (FSLR), the world's biggest thin film solar module manufacturer and one of the largest developers of utility scale solar projects worldwide, with a global project pipeline of more than 2500 MW, announced its first development project in India. Through its Indian subsidiary, the company plans to build, 45 MW AC capacity of solar power generation in the new state of Telangana, which will supply electricity through the grid to the Southern Power Distribution Company of Telangana State Limited (TSSPDCL), at a levelized tariff of Rs 6.49p/kwh for a period of 20 years. The project will include construction at two different sites in the Mahabubnagar district, and is expected to be in commercial operation by May of 2015."The state of Telangana has an energy deficit that demands immediate creation of incremental generation capacity. The excellent solar resource in the state combined with our CdTe thin film module technology that is ideally suited for hot climates like India, allows us to bid tariffs that brings solar energy pricing to parity with diesel/gas and potentially imported coal, for the consumers across all segments. We are optimistic that the state will enhance their plans for creating a higher deployment of solar in the overall energy mix to address the energy deficit in a sustainable manner" said Sujoy Ghosh, Country Head, for First Solar India. Mr. Ghosh said construction of the project was expected to begin by October of this year. On completion, the projects are expected to produce approximately 86,880 Mwhr of electricity each year which will be sufficient to meet the needs of over 92,000 average homes in Telangana.

Tata Power Solar to supply 1 lakh indigenous solar panels

Tata Power Solar (TPS), one of the pioneering solar manufacturers in the world, won one of the largest DCR orders of JNNSM phase-2 batch-1. The company will supply entire module requirement for the 20 MW (AC) project to be built by ACME Solar, a solar power developer in India. The 1,00,000 modules, constituting 60,00,000 cells, needed for the project will be manufactured at TPS' state-of-the-art manufacturing facility in Bangalore. ACME Solar, during the JNNSM bidding last year, won projects totalling 100 MW. Of this, 20 MW, under Domestic Content Requirement (DCR) policy of MNRE, needs to be constructed using cells and modules manufactured domestically. ACME Solar is a three-way joint venture between ACME, EDF Energies Nouvelles (EDF EN), the renewable energy arm of French state-run electricity utility Électricité de France S.A., and Luxembourg-based natural resources saving group EREN. Rahul Budhwar, VP - Manufacturing and Business Development, Tata Power Solar said, "ACME and EDF awarded the business to us after a rigorous selection process. This is a testimony to our superior and world-class manufacturing capabilities we have built over the last 25 years. We are looking forward to a strategic relationship with ACME and EDF and, in the process, contributing to the success of JNNSM by providing world-class modules at competitive prices." A total of 375 MW of solar power plants have to be built using domestically produced cells and modules. The initiative is aimed at promoting manufacturing in the country.


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Award for Excellence in Corporate Governance 2013 on Tata Power

Tata Power, India's largest integrated power utility, has been adjudged the best governed company and conferred with the prestigious National Award for Excellence in Corporate Governance for the year 2013. Minister for Finance, Defence and Corporate Affairs, Arun Jaitley presided as Chief Guest at the award ceremony organised by The Institute of Company Secretaries of India (ICSI) in Kolkata. The award was received by Ashok Sethi, COO & Executive Director on behalf of the Company. Hanoz M. Mistry, Company Secretary was also honoured as Company Secretary of the winning Company. In pursuit of excellence and to identify, foster and reward the culture of evolving globally acceptable standards of corporate governance among Indian Companies, the 'ICSI National Awards for Excellence in Corporate Governance' was instituted by the ICSI in the year 2001, to recognise and honour the best governed companies as per five key parameters viz. Board Structure and Processes, Transparency and Disclosure Compliances, Stakeholders Value Enhancement, Corporate Social Responsibility (CSR) and Sustainability. A panel of judges evaluated companies on the basis of a questionnaire covering regulatory requirements, global best practices, excellence in governance performance and futuristic orientation in governance matters. The responses were then corroborated with the responses of the independent directors as well as media reports. The jury was headed by Justice M. N. Venkatachaliah, Former Chief Justice of India. Speaking on the achievement, Anil Sardana, CEO and MD-Tata Power stated, this is indeed a moment of great pride for Tata Power and we are delighted that our efforts have been appreciated at a national platform.

Alstom to build Phase 2 of 800kV Champa–Kurukshetra UHVDC link

Alstom has been awarded €400 million (INR 32500 million) in contracts to build Phase II of the Champa–Kurukshetra Ultra-High Voltage Direct Current link in Northern India, by Power Grid Corporation of India Limited (PGCIL). This new±800kV, 3000 MW transmission link will run in parallel with the first UHVDC transmission link awarded to Alstom in 2012, increasing the total transmission capacity of the advanced UHVDC system to 6000 MW. Phase II of this UHVDC system will complete the 1,365 km long "energy highway" between Champa in central India and Kurukshetra in northern India. It will transfer clean, bulk power efficiently from the Chhattisgarh region - a hub of Independent Power Producers of thermal power - to the load centre in the northern region of the country. Alstom will build two ±800 kV, 3000MW converter terminal stations, and design, manufacture and deliver on a turnkey basis ±800 kV UHVDC thyristor valves, 32 converter transformers, 400kV gas-insulated switchgear, substation equipment, and communication and supervisory control and data acquisition systems (SCADA). The project also covers the commissioning and successful operation of both the terminal stations and their integration with Champa – Kurukshetra Line 1 bipole (from Phase I), currently under construction. All equipment will be manufactured by Alstom's facilities in India, United Kingdom, France and Italy.

BHEL develops Fuel Flexible Supercritical Boilers, a step towards managing uncertainties regarding coal

India's Power Generation is mainly Coal based and the Power Sector is currently plagued by Coal shortages where Power Plants are stranded due to non-availability of Indigenous Coal supplies. This has triggered a series of Companies to either resort to operating the plant on part load due to non-availability of domestic coal or make up for the shortfall by blending indigenous coal with imported coal. Being heterogeneous in nature, the properties of Coal vary from source to source. The performance of Power equipment is dependent on the coal being fed to the power plant. Bharat Heavy Electricals Limited a Maharatna PSU, has been designing boilers for 3 decades and has extensive experience of designing boilers fired with indigenous as well as imported coals exhibiting wide variations in properties. Based on BHEL's extensive in-house experience of working with a great variety of indigenous as well as imported coals over the years, BHEL has developed a new Boiler with Fuel flexibility of Indigenous & Imported Coals. BHEL is now ready to offer the new boiler design to overcome these issues. This new boiler design is based on a unique combination of indigenous and imported coals but is capable of firing both extremes of 100% domestic coal as well as 100% imported coal. It will provide developers with much needed freedom regarding the ratio of blending as well as the characteristics of the domestic and imported coal to be blended. This enables the boiler to work over the entire range of blending ratios & would protect the project developer against the vagaries in coal availability, thereby providing him with an opportunity to operate the plant throughout the year. BHEL has an advanced state of the art Coal Research Centre at its Tiruchirapally plant which will be used to identify the unique combination of blended coal after carrying out the analysis of imported and domestic coal samples supplied by the customers. The associated auxiliaries, also manufactured by BHEL, will be designed to accommodate the variation during firing of different type of fuels. With this development, BHEL is being true as a solution provider in the energy sector by addressing the major concern among Owners/ Developers about the growing uncertainty of coal availability in the country.

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Delta Electronics to broaden Energy Efficiency with its Latest Power Quality Solutions

Delta, a global leader in thermal and power management and pioneer in industrial automation solution, launched its Power Quality Solution products. People are demanding more reliable and stable power supplies with better quality. However, besides highly efficient production and greater convenience, some electronic automation equipment contributes to the issue of power grid pollution. Power quality has become a key factor for power efficiency. The power quality directly affects the speed of development and the competitiveness of industry. Effective and stable power supplies can extend the usage of electrical equipment, prevent equipment burn out due to overload, and reduce the money and labor force losses caused by power interruptions. Delta's power quality solution comprises of Power Regenerative Unit REG2000, Static Var Generator SVG2000 Series, Active Power Filter APF2000 Series and Active Front End AFE2000 Series for power regeneration, harmonics suppression, reactive power compensation and load balance ensure the excellent power quality in different sectors and domains, such as metallurgy, metal processing, chemical, automobile industries, also buildings and data centers. The Static Var Generator SVG2000 Series improves the power efficiency of industry, infrastructure, and commercial building. It replaces traditional phase – leading fixed on switched capacitors installed at the power distribution systems. Its IGBT leased fast dynamic compensation connecting both leading and lagging reactive power effectively increases power factors to 0.99 under varying load conditions. The SVG2000 has special Delta power module that one unit can support a wide power range from 220V-480V or 525V-690V and the capacity is 300 kVAR or 500 kVAR. The Active Power Filter APF2000 Series provides dynamic harmonic suppression using IGBT's to protect facilities and equipment in the factories, such as mechanical, metal processing, and automobile manufacturing. It filters 2~50th order harmonics and provides clean and sinusoidal current waveform. For system expansion, APF2000 applies parallel connection to support a wide power range from 200V-480V with capacity of 50, 100, 200 and 300 Amps.

Siemens solutions to boost reliability, stability of India's electric grid

Siemens Limited announced that it has won a crucial turnkey order (design, engineering, commissioning and installation) from Power Grid Corporation of India Limited (PGCIL) worth approximately Rs 411 crores. The order is for Static Var Compensators (SVCs) for three of PGCIL's substations: Ludhiana in Punjab, Kankroli in Rajasthan and New Wangpoh in Jammu & Kashmir. An SVC is a high-voltage system that dynamically controls the network voltage and keeps the network voltage constant. The order is for one of a series of SVC projects planned by PGCIL to improve grid stability across India. "The delivery of stable, reliable power supply to meet the increasing demands from industry and urban centers is crucial for India's sustainable progress. It is a matter of immense pride for Siemens that we have been chosen by Power Grid Corporation to be an integral part of this project," said Sunil Mathur, Managing Director and Chief Executive Officer, Siemens Limited.

Global Telecom Cable Market 2014-2018

Research and Markets has announced the addition of the "Global Telecom Cable Market 2014-2018" report to their offering. Telecom cable is an insulated strand of wires used to transmit high-frequency electrical signals over long distances. Today, telecom signal transmissions use digital signals. The analysts forecast the Global Telecom Cable market will grow at a CAGR of 7.01% over the period 2013-2018.The Global Telecom Cable market can be divided into two segments: Metallic Telecom Cable and Fiber Optic Telecom Cable. These are the major types of telecom cable currently available. The report, the Global Telecom Cable Market 2014-2018, has been prepared based on an in-depth market analysis with inputs from industry experts.

ACME creates record with 25 GWh output

ACME, India's leading solar power producer announced that it has achieved a record output of 25 Gigawatt hours in six months exceeding benchmark performance at its 25 MW solar power plant in Khilchipur, Madhya Pradesh. This is the highest ever output achieved by a solar power plant at given GHI in this duration and marks ACME prowess in setting-up and operating a solar power plant. On the momentous occasion, Manoj Kumar Upadhyay, Chairman & Managing Director, ACME Group said, "ACME Solar has demonstrated a continuous commitment to the development and construction of utility-scale projects to contribute to India's present and future growth in the gren energy sector. This record performance showcases our capability to build and operate world's finest green energy generation infrastructure. In line with the government's mission, we are actively participating in the drive to increase the share of solar in overall energy generation in India from a mere 1% to 3%." The company aims to conduct its business in a socially responsible, ethical and transparent manner and intend to have a positive effect on their stakeholders and workforce. This ethos has contributed to the successful delivery of their MP solar project ahead of time. ACME has a portfolio of power plants worth 197.5 MW in the states of Gujarat, Rajasthan, Madhya Pradesh, Chattisgarh and Odisha. ACME aims to achieve a portfolio of 1000 MW by year 2017.


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Ministry of Heavy Industries & Public Enterprises to support Automation 2014

AUTOMATION 2014 Exhibition in Mumbai would provide excellent opportunities to Indian Industries, who are manufacturers of focused Automation components and machinery for various sectors developing in India and globally. Indian Industries will get good exposure by showcasing products to the World through Automation-2014 Exhibition said Anant Geete, Minister of Heavy Industries and Public Enterprises, Government of India. Government of Maharashtra & MIDC has given their support for Automation-2014. Republic of Rwanda is the most rapidly growing economy in East Africa is the 'Partner Country' for Automation-2014. Republic of Rwanda is growing at 8% average year-on-year GDP growth, stable inflation and exchange rate. Rwanda has a clear vision for growth through private investment set out by President Paul Kagame through Vision 2020. Rwanda is an open market of over 11 million people with a rapidly growing middle class. Republic of Rwanda is increasingly attractive destination for foreign investments. There is a great opportunity for Indian Industries to develop a business. Rwanda is competitive place to do business in East Africa and it is 3rd in African Country as per Global Competitive Index Report 2013-2014. In Rwanda, new Special Economic Zone is operational. More zones are planned on the districts level. Rwanda's workforce is also demonstrating increasing capacity or knowledge-based industry. Govt. of Rwanda is a very Investor-friendly government committed to the market economy, which is very inspiring for Indian Industries and especially for AUTOMATION Industry. A flagship event of IED Communications, 'Automation' is the biggest show in South East Asia and the second biggest show in Asia after the 'IAS Shanghai'. The 9th edition of Automation 2014 will be held from October 15-18, 2014 at the Bombay Exhibition Centre, Mumbai.

Lanco clicks deal in thermal power sector, sells Udupi Power plant to Adani

Lanco Infratech Limited (LITL), the integrated infrastructure player in the country having business verticals in EPC, Power, Solar, Natural Resources and Infrastructure sold its Udupi Power plant to Adani Power Limited, power business arm of Adani Group for its 1200 MW Udupi power plant. The deal is valued at more than Rs 6000 crore.The Lanco Udupi Power Plant has already signed with Karnataka Government for further expansion of 1320 MW. The imported coal based thermal power plant of Lanco in Udupi, which supplies 90% of the power generated to Karnataka State and 10% to Punjab State, is the first independent power project in the country based on 100% import coal with a captive jetty of 4 million tons per annum and an external coal handling system in the new Mangalore Port Trust. The capacity can be, if required, expanded to handle another 4 million ton capacity. For Lanco Infratech, this transaction will support the company in reducing its debt and will enable Lanco to receive about 2000 crore as cash and additionally, Adani Power will take Udupi Power's long-time debt of around Rs. 4,000 crore.

Eaton launches Extended Range of 93E UPS to support Mission Critical Applications

Power management company Eaton has introduced advanced 93E uninterruptible power system (UPS) in the range of 15–400kVA. This extended range of 93 E UPS from 15 – 80 kVA will deliver superior power protection and support critical operations in various industries including heavy engineering and manufacturing. Eaton 93E UPS has been incorporated with Eaton's patented Hot Sync technology, which enables load sharing without any communication line, thus eliminating a single point of failure. It is around 30 percent smaller than competitive solutions and thus occupies minimal floor space."Our efforts have always been to ensure efficient, reliable and safe operations for our customers," said Syed Sajjadh Ali, MD – India, Electrical Sector, Eaton. Eaton's extended range of 93E UPSs is an ideal solution for facilitating a lower total cost of ownership through a combination of energy efficiency and high reliability in extensive manufacturing and other mission-critical operations. With a transformer-free design and sophisticated sensing and control circuitry, the 93E is capable of achieving an efficiency rating of up to a 98.5 percent, making it one of the most energy-efficient UPSs in its class and still providing maximum load protection. The 93E provides surge suppression for the load, detects the location of faults (utility or load) and takes appropriate action and switches to double-conversion operation in less than 4 milliseconds. The 93E's high system efficiency reduces utility cost, extends battery run time and ensures cooler operating conditions.The 93E enhances real compatibility by providing 0.99 input power factor and less than 5 percent total harmonic distortion, thus eliminating interference with other critical equipment in the same network. UPS also ensures flexible installation options, which can result in quicker deployment. The aesthetically designed accessories enable coordinated solutions that enhance both safety and reliability while reducing installation time and total cost. Eaton is positioned through its global solutions to answer today's most critical electrical power management challenges.

US anti-dumping duty may boost capacity utilization rates of Taiwan solar firms - TrendForce

On August 19, US Department of Commerce announced it had revised the preliminary anti-dumping duty on solar products produced by Motech Industries in Taiwan, causing Motech's tariff rate to drop from 44.18%, the highest among Taiwanese producers, to 20.86%, the lowest. For other Taiwanese photovoltaic (PV) producers, the average duty rate has fallen to 24.23%. "Given the revised duties imposed on Taiwanese makers and the high quality of Taiwan's products, Taiwan may still get US orders indirectly if Taiwanese vendors are willing to sacrifice some gross margins," said Corrine Lin, an analyst at EnergyTrend, a subsidiary of Taiwan-based market intelligence firm TrendForce. The US's previous higher anti-dumping duty caused Taiwanese PV cell prices to fall significantly. They have dropped more than $0.06/watt in Taiwan and PV cell products on the island now retail for about the same price as first-tier Chinese company. Although PV cell prices will remain low in the short run, first-tier cell manufacturers' capacity utilization rates have generally improved, Lin said. "Chinese demand has also finally begun to increase and China will temporarily close the loophole of polysilicon importing through export processing zones (EPZs) in order to avoid tariff rates." Lin added. Consequently, additional import duties will be imposed on foreign polysilicon products in the Chinese market, Lin said, adding that as polysilicon imports decline, Chinese upstream polysilicon and wafer makers may be the first to raise prices. At the same time, demand is picking up in Europe and Japan, leading to more orders of products of better quality than competitors but similarly priced. With orders from Europe and Japan on the rise and Chinese demand increasing, utilization rates for both Taiwanese and Chinese producers are unlikely to be problematic. Additionally, while the market has cheered Motech's revised duty rates, lowering prices is usually the only way for Taiwan producers to stand out from their competitors. Finally, the most pressing issue for Taiwan's PV cell producers at this point is the lack of a dedicated port to export their products. Chinese producers have become more active and prices have moved accordingly. Polysilicon prices dropped 0.73% to US$20.251/kg. High-efficiency multi-si wafer prices reached US$0.921/piece, down 0.43%, while normal-grade declined 0.88% to US$0.899/piece. Mono-si wafer prices fluctuated and declined 0.26% to US$1.163/piece. For cells, overall market demand remained weak. Pressured by the high level of inventory and weak demand from China and overseas, some producers' prices dropped to US$0.313/watt. In addition, module prices dropped 0.87% to US$0.571/watt in line with falling prices in Japan.

L&T contracts for 225 MW Sikalbaha Gas based Power Plant in Bangladesh

LARSEN & TOUBRO

Bangladesh Power Development Board (BPDB) and Larsen & Toubro (L&T) signed a contract to set up a 225 megawatt, gas-based power plant in Sikalbaha, Chittagong in Bangladesh. The contract, which is valued at about $200 million, was secured by L&T in May 2014. The contract was signed at an event held in Dhaka on August 24. Four development partners of Government of Bangladesh from the Middle-East (Saudi Arabia, Kuwait, UAE and OPEC Fund) will finance the project with a fund of approximately $167 million. L&T's scope includes design, detailed engineering, supply, installation and commissioning of the power plant on a turnkey basis. L&T-Sargent and Lundy, a subsidiary of L&T, will carry out the plant integration and detailed engineering. Speaking at the event, Bangladesh State Minister, Nasrul Hamid said several countries and a number of international companies, including Indian companies, have shown their readiness to invest in Bangladesh due to prevailing congenial political and economic atmosphere. This is the second gas-based power project secured by L&T in Bangladesh. L&T had recently been awarded a $280-million order for setting up the 360 MW Bheramara combined cycle power plant. Highlighting L&T's capabilities, Shailendra Roy said the Company has contributed enormously in building India's infrastructure by implementing landmark projects with international quality and environment, health and safety standards. L&T will carry the same spirit to Bangladesh.

SolarReserve contracts to Supply Solar Power in Central America

SOLARRESERVE

SolarReserve, a leading global developer of utility-scale solar power projects and advanced thermal energy storage technology, signed a supply contract for its 20 MW Acajutla photovoltaic (PV) solar power project in El Salvador as part of a highly competitive tender solicitation by the local electric distribution companies. The tender, the country's first for utility-scale solar power, was administered by Distribuidora de Electricidad del Sur (DELSUR), one of the seven electricity distribution companies in El Salvador, and was overseen by El Salvador's Electricity and Telecommunications regulatory body Superintendencia General de Electricidad Telecomunicaciones (SIGET). The Acajutla project is the first of several in SolarReserve's pipeline of 800 MW of solar power projects in development in Latin America, which includes advanced solar thermal technology (CSP), photovoltaic (PV) technology, and hybrid (combined CSP and PV) solutions that can provide competitive 24 hour solar energy. "Many Latin American countries, including El Salvador, have experience with renewable energy such as geothermal or hydroelectric. As demand for electricity continues to grow, Latin America represents a great opportunity for solar power development," said Kevin Smith, SolarReserve's CEO.

New Gamesa milestone: installed capacity hits 30 GW

Gamesa, a global technology leader in wind energy, shored up as a world-leading player in terms of installed capacity, having hit 30 GW mark. This milestone was achieved with assembly of one of the eight G128-4.5 MW turbines being installed at the Tornio wind farm in Finland. Electricity generated by these 30 GW annually provides enough energy to supply more than 18 million European households and prevents the emission of 45 million tonnes of CO_2/year, equivalent to the annual emissions generated by 15 million cars or the carbon offset by 7.5 million hectares of trees in the same period. Since it installed the first G42/44-500kW turbine back in 1994, company installed 30,000 MW of its turbines in countries all over the world, including Kenya, the Philippines, Mauritania, Ecuador (Galápagos Islands) and Uruguay. In Spain Gamesa installed the most capacity (12,208 MW), followed by the US (3,941 MW) and China (3,512 MW). The company has gradually expanded its geographic footprint in recent years: MW sold outside Spain jumped from just 5% of the total in 2000 to almost 100% in 2013. Today, Latin America and India are the company's main growth engines, having accounted for almost 70% of first-quarter 2014 sales volumes. As for the best-selling platforms, of the 30 GW installed by Gamesa, its 2.0 MW platform tops the ranks (installed capacity: 17,460 MW), followed by the 850 kW range (8,690 MW).

South Africa, 10th solar power in world: contributes over 500 MW

South Africa harnessing energy from the sun, connected over half a gigawatt of utility-scale solar power, moving into the world top 10 of countries according to figures released by Wiki-Solar, the leading authority on the deployment of utility-scale solar power- PV power stations of 5 to 10 MW and above. The United States tops Wiki-Solar's list of the top 10 markets for utility-scale solar power, with 349 solar plants together generating 6 498 MW, followed by China (4607 MW), Germany (3428 MW), India (1897 MW), Spain (1680 MW), the UK (1523 MW), Italy (875 MW), Canada (714 MW), and France (677 MW). South Africa is in 10th spot, with 15 solar plants now contributing 503 MW to the country's electricity grid. Most of these plant were built under the first round of the government's renewable energy programme for private producers- and with several solar projects still under construction, and contracts for further projects having been signed, South Africa is likely to climb still further up Wiki-Solar's rankings. In November, the Department of Energy signed agreements with 17 new preferred bidders in the third round of the programme, following signing off of 47 projects in first and second rounds, bringing to 64 the total number of renewable energy projects since December 2011.

Alstom and PG&E to advance Synchrophasor Grid Monitoring

Alstom Grid, along with other solution providers, have partnered with Pacific Gas & Electric Company (PG&E) to continue collaboration into Phase II of PG&E's synchrophasor project, Synchrophasor Technology Realization. This collaboration, partially funded by US Department of Energy (US DOE), aims to advance situational awareness enhanced with stability monitoring, towards proactive grid stability management as data quality is improved and system-wide reliability indicators are strengthened. As such, systems can be restored faster and post-event analysis is improved. In 2013, Alstom Grid collaborated with PG&E project team to deliver enhanced e-terra integrated real-time synchrophasor and Energy Management Systems (EMS) applications for Phase I, Production Grade Synchrophasor Project. This enables PG&E to monitor power system behavior from a new class of GPS time-synchronized, high resolution Phasor Measurement Units (PMUs). These devices take grid measurements up to 120 times per second vs the traditional four to six second data rate generated by unsynchronized SCADA sensors used over the past several decades. Increased visibility allows PG&E to identify and analyze system vulnerabilities in real-time, assess available transfer margins across transmission corridors and provide corrective actions to prevent potential blackouts. Phase II will roll out Alstom's Grid Stability Package, recently released at CIGRE 2014, the biennial worldwide forum of the electrical power industry in France. This solution will help realize investments and the full aim of this project – integrate existing measurement-based PMU analytics, model-based EMS and dynamic stability analytics from Phase I to enable proactive management of grid stability. Alstom's solution will provide a more holistic and accurate view of current grid status, better intelligence to understand, predict and mitigate potential developing events, and unmatched historical data quality for better post-event analysis and power system control. "The smart grid technologies are here, the challenges are manageable and the benefits far outweigh the costs. To modernize legacy grid systems is a delicate balance of maintaining status quo while incorporating rapidly evolving technology, and managing security concerns and other core standards, all within the current economic climate," said Vahid Madani, Pacific Gas & Electric PG&E. "A crucial success factor in advanced technology deployment for mission critical functions is confidence in use of the tools. Through partnership with Alstom Grid and others, industry visions have become reality. For PG&E, objectives of our Phase I Synchrophasor Project have been accomplished with confident, trained end users at our utility."

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Fire Safe Coating for Power Cables

Fire retardant coating based on pentanediono complex of chromium, phosphates, amides, polyols, amino and acrylic binders have been developed for poly vinyl chloride insulated power cables. The fire performance of developed coating has been assessed by employing different national and international standard procedures. The cables coated with developed coating showed significant improvement in circuit failure time in power cable, fairly high Limiting Oxygen Index (LOI), reduced smoke generation and no surface spread of flame on exposure to test conditions. During fire, the coating swelled to form spongy, cellular insulating foam which acts as an effective barrier against the conduction of heat to the surface and to the core of electric cable specimen.

N K Saxena, Sunil K Sharma and Sushil Kumar

Electric cables are extensively used in all major industries. Modern production facilities demand long runs of power cables all over the plant area. Any fire incidence in the vicinity of a cable may result in the initiation of fire at the cable surface and flame spread along it. Other ignitions may be due to short circuit or overheating of the cable itself. In the majority of cases any fire incidence to the cables causes extensive damage to the occupancy when it spread along the electric cables and through these to other combustible material. A large amount of smoke and other combustion products are evolved when a cable is involved in fire thus resulting in considerable loss to life and property.

In order to check spread of fire through electric cables, all openings through which these cables pass should be segregated. It is essential that these are sub divided into smaller zones. This may be achieved by sealing all such openings with suitable fire resistant materials so as to provide fire barriers at different intervals. However, provision of such barriers may not be technically feasible for existing electric cable systems. Propagation of fire can also be checked by applying an effective fire retardant coating on power cables since such a treatment is possible even for the existing cable system.

Fire retardant coatings can safely be grouped under two categories, the non-intumescent and the intumescent coatings. While the fire retardant non-intumescent coatings comprise additives such as borax, boric acid, antimony oxide zinc oxide chlorinated compounds etc. that do not support combustion.

Such coating do not offer much protection under continuous exposure to fire as cracks are developed and they loose adhesion thus burn the substrate after certain period depending on the composition. However, fire retardant intumescent coatings resist for longer duration as these coating are swell up on heating due to evolved gases. The resulting expanded residual carbonaceous matter forms toughened insulating layer over the substrate, which provide insulation between flame and substrate. Several researchers have studied various fire retardant coating to retard burning characteristics of cellulosic material. Only some work has been reported on fire protection of power cables through coatings. However, sufficient attention has not been paid towards the use of suitable coatings for polyvinyl chloride sheathed electric cables.

Metal oxides and their chelate complexes have normally been used as smoke retardant in PVC. This article deals with studies on use of metal based organic complexes to improve the efficacy of intumescent coating for power cables.

Metal oxides & their chelate complexes have normally been used as smoke retardant in PVC. This article deals with studies on use of metal based organic complexes

Experimental

Preparation of coating

Fire retardant intumescent coating was prepared by mixing the following main ingredients:

- Dehydrating agent such as ammonium phosphate or polyphosphate
- Spumific agent such as melamine or cyan guanidine
- Carbonific agent such as 2-2 bishydroxymethyl, 1-3 propanediol or starches
- Metal complex such as Tris (2,4 pentanediono) Chromium (III).
- Plasticizer such as dioctyl phthalate or tricrecyl phosphate
- Thickening agent such as sodium salt of D-mannuronic acid
- Pigments like Rutile titanium dioxide or zinc oxide
- Binder such as acrylic emulsion and amino resin.

Coating was prepared by mixing above ingredients of 325-400 mesh size with 2-5 percent solution of thickener along with appropriate quantity of essential paint accessories like antisettling, wetting and anti-foaming agents. Requisite amount of water was also added in order to obtain brush consistency. It was stirred with heavy duty stirrer for one hour. The coating thus prepared was applied with brush on PVC insulated cables in different thicknesses. The effect of coating thickness on fire performance is studied.

Evaluation of coating

The fire retardant intumescent coating was applied on PVC insulated electric cables. The effect of coating thickness on fire performance was studied by employing different amount of coating to achieve different coating thickness. Standard procedures were followed for determination of physical properties such as colour, specific gravity, flexibility etc. of coatings which are given in Table 1 Fire performance of the coating was also studied by evaluating circuit failure time, flame propagation characteristic, smoke generation characteristics and limiting oxygen index using different standard procedures.

Colour	Off white
Odour	Faint
Consistency	Brushable
Specific Gravity	1.28 – 1.32
PH	6 – 8
Flexibility (As per IS:10810)	No Cracking observed
Volatile Content	30 -33%

Table 1: Physical Properties of Coatings

Circuit Failure Time of Cables

Three and a half core aluminum conductors PVC insulated armored cables specimens of length 1200 mm and having an outer diameter of 24 mm were used to determine the circuit failure time. The cables were coated with different amounts of coating to achieve 0.5 to 4.5 mm dry coating thickness. 100 mm sheath of outer covering of the cable was removed from each end of the specimens. At one end of the cable, the conductor wires were suitably connected for electrical connections and at the other end the exposed cores were spread apart to avoid contact with each other. The cable specimen was held horizontally by means of suitable clamps and all the metal part of the supporting apparatus was properly earthed. The cores of the cable under test were connected to separate phases for obtaining three sets of connections to the three phases. Adjacent conductors were connected to different phases. The test was carried out in a chamber provided with proper means for disposing of gases resulting from the burning cable. A Tubol type gas burner of 610 mm long was used to ignite the specimen. A thermocouple was fixed parallel to the burner and 75 mm above it to measure the temperature of the flame. The liquefied petroleum gas was used as a fuel. The air supply and flame height were so adjusted that a temperature of 750^{O}C was obtained throughout the test.

440 V, 3 – phase electric supply was connected to the cable specimen, through a 3 – ampere fuse in each phase and a 5 – ampere fuse in the neutral line which was earthed. The cable remained energized with rated voltage throughout the fire test. Flame temperature; 75 mm above the burner; was maintained at 750^{O}C. The flame and rated voltage were applied continuously till no failure of 3 – ampere fuse took place. A few specimens were exposed at 750^{O}C for 20 minutes and then the re-energized test using rated voltage (as above) was carried out 12 hours latter to check the continuity of the electric cable. Observations, made during the evaluation studies when different coating thicknesses were applied. The effect of coating thickness on fire performance and re-energize test was studied. The results are recorded in Table 2.

Flame Propagation characteristics of Cables

For certain locations it is important to use a cable which retards spread of flame in case of fire and self extinguishes fire when the source of heat is removed. In the above study, the flammability characteristics of a single cable were studied in horizontal position but it could not be assumed that the group of cables laid in a single layer and in vertical position would behave in a similar manner as the single cable. Consequently, the flame propagation

Cable Diameter (mm)	Coating Thickness (mm)	Circuit Failure Time (Min:Sec.)	Re-energize Test
24	Uncoated	04:07	-
24	0.5 - 0.6	05:08	-
24	1.0 - 1.2	07:17	-
24	1.5 - 1.6	11:38	-
24	2.0 - 2.2	19:14	-
24	2.5 - 2.6	22:40	Fail
24	3.0 - 3.2	25:45	Pass
24	3.5 - 3.7	29:10	Pass
24	4.0 - 4.2	30:42	Pass
24	4.5 - 4.6	31:30	Pass

Table 2: Effect of Coating Thickness (Results as per IEC-331)

characteristics of a number of cables laid in a single layer were evaluated employing the IEEE-383 method. Eight PVC insulated multistrand aluminum conductor cables of 19 mm outer diameter and approximately 2.5 m long were coated to an average thickness of 2.0 mm. These were arranged with a thin galvanized iron wire in the center position of the metallic tray 2500 mm long, 300 mm wide and 75 mm deep. The spacing between the cables was kept at approximately 8.0-9.0 mm.

The flame source used a 610 X 610 mm 2 piece of burlap with a weight unit area of 0.3 kg/m². The burlap was folded as described in the IEEE-383 standard to make a bundle 100 x 100 x 150 mm in size. It was wrapped with a fine copper wire to retain the shape of the bundle. The folded burlap was soaked for 15 min in super F multigrade 20, W40 engine oil and then drained for about 5 min. The burlap igniter was weighed before soaking and after draining. The fuel pick up by the folded burlap was 160-165g. For assessing the fire performance, a cable tray with coated cables was placed vertically in the naturally ventilated room. The igniter was held by a metal wire in the center and in the front of the cables 60 mm above the bottom of the cable tray. The burlap igniter was set on fire and allowed to burn out naturally. It gave an exposure of about 30-35 min. Observations made during the evaluations are recorded in Table 3.

Composition Number	Affected Charred Length (mm) of Different Cables							
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
1	NIL	14	204	298	308	302	30	NIL
2	NIL	21	184	266	290	286	27	NIL
3	NIL	24	197	270	296	292	33	NIL
Uncoated	185	305	714	960	998	884	418	194

Table 3: Fire Performance as per IEEE- 383

Smoke Generation

Experiments were conducted using the NBS (National Bureau of Standards) Smoke Density Chamber as described in ASTM E-662. A PVC sheet of size 76 x76 x 4 mm was used to determine the smoke generation characteristics of developed coatings. The PVC sheet was coated of about 03 mm dry thickness of coating. The specimen was mounted vertically so as to face the electrically heated radiant energy source, having an irradiance level of 2.5 w /cm² averaged over the central 38.1 mm diameter area of the specimen. A photometric system with a vertical light path was used to measure the varying light transmittance as smoke accumulated. The light transmittance measurement was used to calculate the specific optical density of smoke for twenty minutes. An uncoated specimen of PVC sheet of same size was also evaluated under similar conditions. The following parameters were determined:

D_m = maximum specific density

$T_{90\%}$ = time where 90% of Dm is reached (min)

D_{90s} = optical density at 90 sec.

SON = sum of specific optical density at 1 min., 2 min., 3 min., and 4 min. a measure for the rate of smoke development

V_{max} = maximum rate of smoke development estimated every 30 sec & expressed as Ds/min.

SOI, the smoke obscuration index SOI is calculated as:

$$SOI = \frac{D_m^2}{2000 t_{16}} \left\{ \frac{1}{t_{0.9} - t_{0.7}} + \frac{1}{t_{0.7} - t_{0.5}} + \frac{1}{t_{0.5} - t_{0.3}} + \frac{1}{t_{0.3} - t_{0.1}} \right\}$$

Where T_{16} = time to reach D_m 16

$T_{0.9}$, $T_{0.7}$.....$T_{0.1}$ = Time to reach 90%, 70%....10% of maximum Dm.

The results are reported in Table 4.

Limiting Oxygen Index

Limiting Oxygen Index (LOI) is the value of Oxygen Concentration; in the Oxygen- Air mixture; up to which the material supports flaming combustion. Higher the value of LOI better is the fire retardancy. The test reveals the intrinsic flammability of a material but tells very little about its role in propagating a fire from one place to another. The minimum concentration of oxygen in a mixture of oxygen and nitrogen flowing upward in a test column that will just support combustion is determined under equilibrium conditions of candle –like burning according to ASTMD -2863. The limiting oxygen index of a material is determined as:

$$LOI = 100X \frac{O_2}{O_2 + N_2}$$

Where O_2 and N_2 are the volume concentration of each gas in the air stream.

A Stanton Redcroft FTA flammability unit was used to determine the oxygen index of different compositions. The apparatus was

Specimen	Dm	T90%	D90s	SON	Vmax	SOI
Coated	33.2	18.12	1.76	10.2	3.4	1.05
Uncoated	614	3.06	112	1084	316	4524

Table 4: Smoke Generation Results as per ASTME-662
Lower value of Dm, D90s, SON, SOI, Vmax and higher value of $t_{90\%}$ indicate better performance of a material

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calibrated for 0% oxygen and 100% oxygen levels. A PVC sheet of size 52 x140 x 5mm was used to determine the limiting oxygen index. A coating of about 2.5 mm dry thickness was applied to the PVC sheet. The specimen was clamped in the specimen holder and mounted vertically in the center of the test column. A tentative initial oxygen concentration was selected to start the set of experiments. The entire top of the specimen was ignited with the help of propane gas. The ignition flame was then removed and the timer started to record the duration of the specimen burning. The uncoated specimens of the PVC sheet was also evaluated under the same conditions using the same set up.

The objective of the test was to determine the minimum oxygen concentration which just allowed the specimen to continue burning either for 3 minutes or at least 75 mm of the length of the material. If the concentration of oxygen was on the low side, it was raised if the burning of the specimens extinguished before meeting either of the criteria that is either burn for more than 3 min. or for a minimum burning length of 75 mm whichever of the two conditions was satisfied earlier.

The oxygen concentration may be on the higher side and needs to be reduced if the specimen continues to burn beyond 75 mm or 3 minutes. The optimum value of oxygen concentration in the gaseous mixture, flowing through the column, is termed the limiting oxygen concentration. The observations recorded with coated and uncoated are given in Table 5.

Specimen	% Oxygen
Coated	100
Uncoated	41.8

Table 5: Limiting Oxygen Index (as per ASTMD 2863)

Results and Discussion

The main constituents of fire retardant intumescent coatings under study are Spumific agents (amides), Carbonific agents (Polyol), dehydrating agents (phosphates) & propanediono complex of transition metals. The complex used in the present study was propanediono complex of chromium. When this combination is exposed to fire, the phosphate decomposes to produce phosphoric acid which acts as dehydrating agents. The Polyol is dehydrated by the acid forming a large amount of carbonaceous char that produces a noncombustible barrier to protect the substrate. Amide gives off non –flammable gases causing carbon to produce a honeycomb blanket resulting in a highly effective insulation. The binder on softening forms an expandable skin over the carbonaceous char to resist the escape of gases produced by amides. All these reaction take place within the coating, thereby protecting the material from heat.

It is evident from the fire test that coating composition under discussion is very effective in reducing the burning characteristics of electric cables. During exposure no flame spread was observed in coated specimens. The studies also revealed that the fire performance is also dependent on the thickness of the coating. It is observed that for 24 mm diameter cable a coating thickness of 3.0 mm is required to pass the re-energize test after 20 minutes exposure as per standard IEC – 331 (Table 2). The specimen was considered to have passed when no failure of any 3 ampere fuse occurred during the exposure and, after 12 hours in the re-energize test, the cable also withstood a 3 phase 440 V electric supply. Those specimens which could not meet the above criteria were considered to have failed. However, uncoated cable specimen resists only four minutes and seven seconds under similar exposure condition (Table 2).

The results of coated and uncoated 19 mm diameter cables evaluated following IEEE -383 standard method are given in Table 3. It is observed from data that coatings were found quite effective in preventing the propagation of fire when they were arranged in a single layer and exposed in vertical position. It is also noted that coated cables did not burn out to the total height (2440 mm) above the flame source. The maximum affected charred length was observed in the cables which were centrally located in the cable tray and were in direct contact with the heat source. Maximum charred length was recorded in cables; to the height of 308 mm which may be due to the direct contact of flame. This indicates that the coated cable specimens did not allow the flame to spread. It is also interesting to note that in the coated specimens no bare wires were seen after the total burning of the burlap igniter indicating that the insulation remained intact in-spite of the sever exposure conditions. Only exfoliation of the coating was observed in the coated cables. However, uncoated cables were found affected up to 998 mm height and the PVC insulation was also damaged.

Transition metals are mainly used by different workers in reducing smoke generation of PVC polymers. Essentially all of the effective metal based smoke suppressants appear to work in solid phase resulting in increased char formation and thus reduced flammability of the polymer. In the present study, Tris (2,4) pentanediono) chromium (III) metal based organo (MBO) complex was prepared and studied as fire and smoke retardant additives in coating. Efficacy of MBO complexes is superior to that of the transition metal alone. On the basis of earlier studies carried out it was established that best results in terms of flammability and smoke suppression were obtained when the Pentanediono complex of chromium (III) was used at a loading of 2 Phr (parts per hundred parts of resin) in case of plasticized PVC. As no studies have so far been conducted on the use of MBO in coatings this analogy was used and thus in the present studies only 2% of the Pentanediono complex of chromium is used in the coating combination. It has been found quite effective as fire and smoke retardants in coating. Further, the effect of change in the percentage of MBO in the coating composition will be reported in subsequent research publications.

The coating composition thus prepared shown the maximum optical density of smoke as 33 only. While it was noted as 614 in case of uncoated specimen. The value of $t_{90\%}$ was also increased from 3 minutes to 18 minutes in case of coated specimen. Thus, indicating that a smoke generation time was increased six folds when intumescent coating is used. The smoke obscuration index further strengthens our claim that the coated specimens perform better.

Further experimental results for the Limiting Oxygen Index, compiled in Table 5, show that the coating did not show any ignition even when the oxygen concentration was raised to 100% which is very high in comparison to the uncoated specimen.

Conclusion

Metal based organic complex of chromium was synthesized in the laboratory for use as flame and smoke retardant in coating. Fire retardant intumescent coating based on indigenously available chemicals was developed found quite effective in reducing the flammability of electric cables. Circuit Failure time is increased significantly in the coated cables. When rated voltage was applied to coated cables after exposing them to standard fire conditions, the cables were found to be in workable condition. The specimens with these coatings showed neither surface spread of flame nor any heat penetration. After exposure, the coating intumesizes and provides a spongy cellular insulating foam that acts as an effective barrier to the conduction of heat. The formulation was also found to be quite effective in reducing the production rate and amount of smoke.

Profile

Dr Sunil K Sharma

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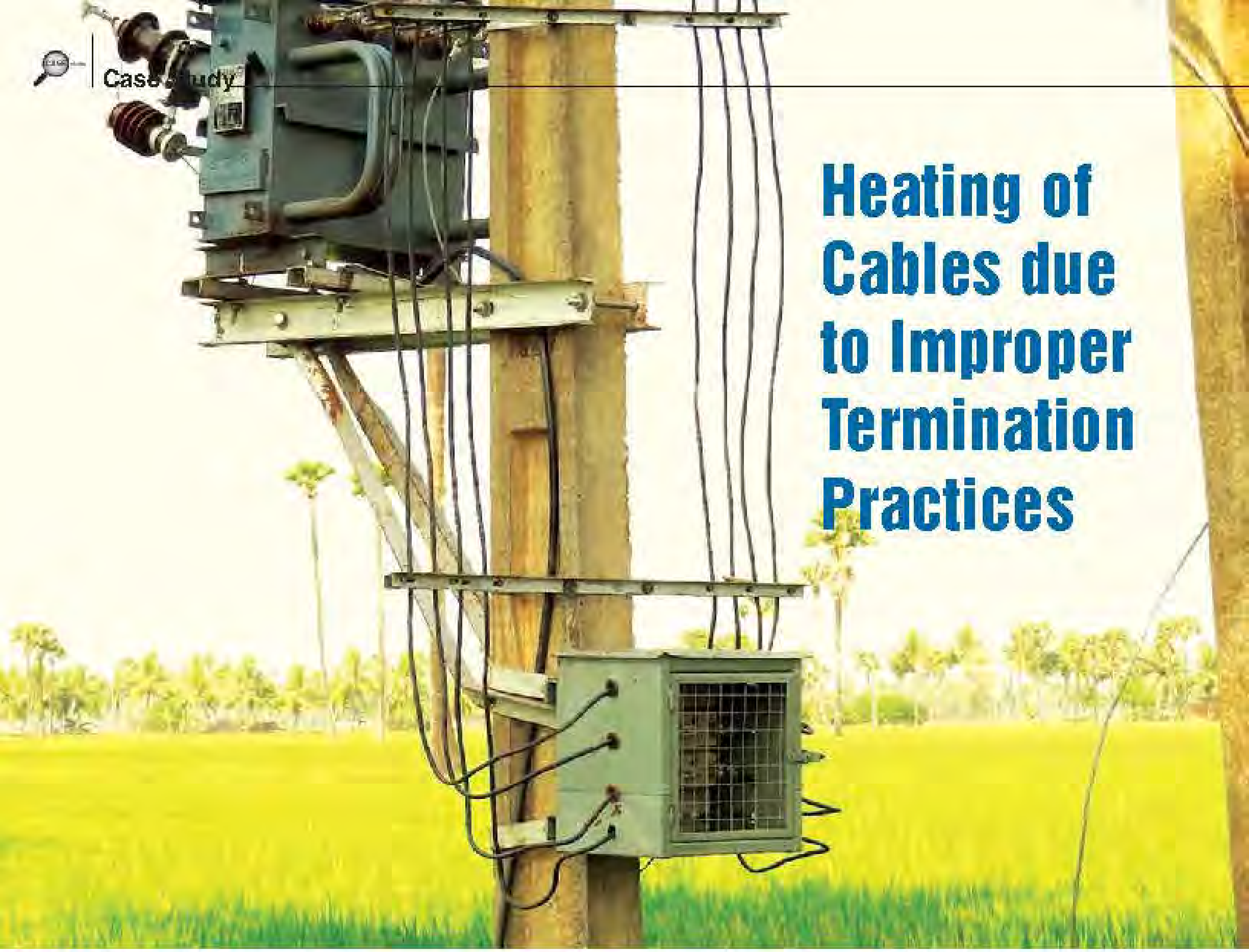


Heating of Cables due to Improper Termination Practices

Electric power is normally generated at 11-25kV in a power station. To transmit over long distances, it is then stepped-up to 400kV, 220kV or 132kV as necessary. Power is carried through a transmission network of high voltage lines. Usually, these lines run into hundreds of kilo meters and deliver the power into a common power pool called the grid. The grid is connected to load centers (cities) through a sub-transmission network of normally 33kV (or sometimes 66kV) lines. These lines terminate into a 33kV (or 66kV) substation, where the voltage is further stepped-down to 11kV for power distribution to load points through a distribution network of lines at 11kV and lower.

The power network, which generally concerns the common man, is the distribution network of 11kV lines or feeders downstream of the 33kV substation. Each 11kV feeder which emanates from the 33kV substation branches further into several subsidiary 11kV feeders to carry power close to the load points (localities, industrial areas, villages, etc.,). At these load points, a transformer further reduces the voltage from 11kV to 415V to provide connection through 415V feeders (also called as Low Tension (LT) feeders) to individual customers, either at 240V (as single-phase supply) or at 415V (as three-phase supply). See Fig. 1.

Electrical System at Consumer end

The integral key components of an Electrical Power Distribution system at the consumer end are:

- Transformer
- Cables / Cable Terminating components / Trenches / Cable Trays etc

- Switchgear with all Switching devices, protective devices, Metering devices, Relays, Safety Earthing systems etc.

> ***Common requirements of the various systems of distribution in a consumer's premises are an adequate standard of Safety from risk of Electrical shock or fire, adequate protection***

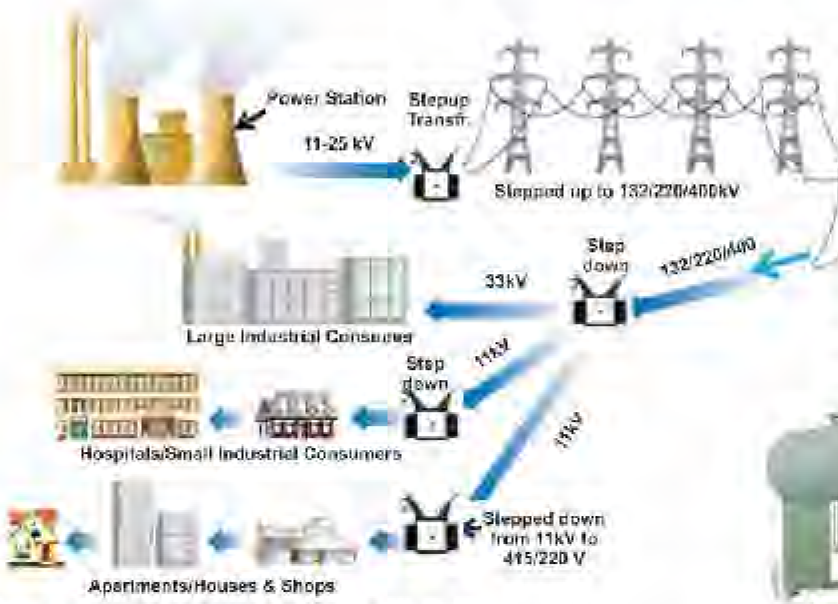


Fig. 1: Generation to Consumer Power Distribution

Role of Cables in Distribution System

Common requirements of the various systems of distribution in a consumer's premises are an adequate standard of Safety from risk of Electrical shock or fire, adequate protection against physical damage, economic life, efficient operation. Power Cables play a very important role in the transfer of Electrical power from the source to the consuming load. Proper sizing of the Cable, considering the max. ambient temperature of the environment is the fundamental requirement, since safe permissible current rating of the cable depends on the cross sectional area of the cable selected. Selection of suitable cables for inflammable or explosive environment is very essential. Despite selecting the best of the products ensuring due care, if the workmanship on these cables like cable termination or Cable jointing is poor, it can result in overheating & fire accidents. The object of this article is to bring out two such Case studies where failures had taken place due to improper cable termination.

Case Study 1

Termination of the L.T. cables on the Secondary side of a 1000KVA, 11kV/420V 3 phase, Power Transformer.

An Industrial project was being set up and for meeting the requirement of the electrical power for the project construction, the owners had planned to install a 1000 KVA, 11kV/420V, 3 ph. Power Transformer at the site. They had also procured, 1.1 KV grade PVC, armored, 4 core 185 sq.mm. copper cable as well as L.T distribution board with a 2000 Amp. Incoming Circuit breaker & a number of TPN out going feeders with MCCB's. The transformer with cable box on the Secondary side, was installed in an outdoor yard & the L.T. Switch board inside a room, about 10 meters away from the transformer. A contractor was asked to lay & terminate L.T.Cables from the transformer Secondary side to the Incomer circuit breaker of the L.T. Switch board. The cable was routed through a trench in which a cable tray was laid. The tray was provided with u-clamps for holding the L.T. Cables in position. The Contractor had laid four parallel runs of the above cable (See Fig. 2). The contractor completed the cable laying & termination at both ends and energized the transformer. Since the project was in the initial stages, the construction load consisted of a few welding machines, grinders etc.

Fig. 2

Distribution Transformer (1000 KVA Outdoor Type)

whose total Secondary side load on the transformer was less than about 100Amps, (as against the full load current of about 1350 Amps of the transformer). The outside of the cable started warming up including the U-clamps provided for the cables. As the load increased, the cables as well as the U-clamps got excessively heated up making it difficult to touch them with bear hands. There were four parallel runs of cables each with 185 sq.mm (Totalling 740 sq.mm) of Copper conductor per phase & the load was negligible for this size. The transformer was switched off to find out the reason for this unusual heating. When the transformer's secondary side cable box cover was removed and termination was inspected, the mistake done by the cable jointer was evident. It was found that he had connected all the four cores of the cable No 1 to phase R, all the four cores of the cable No 2 to phase Y & cables 3 & 4 similarly connected to phase B & Neutral terminals of the transformer respectively (See Fig. 3). The same termination mistake was done at the incoming circuit breaker end also. Since the cables used were provided with steel armoring & all

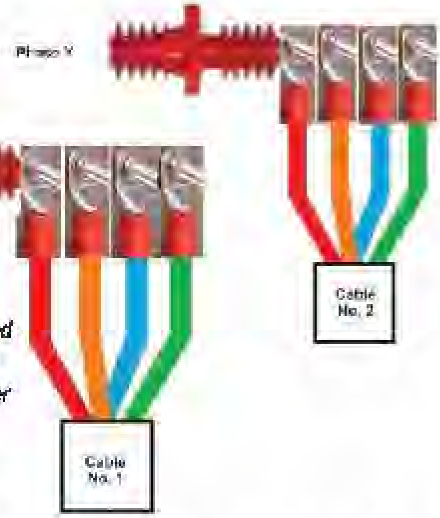


Fig. 3: All the four cores of a single aromred cable connected to one phase of the Transformer Secondary Bushing (Results in heating of armor)

the four cores of the cable carrying current in the same direction were in parallel, the armor is bound to heat up due to what is called 'eddy-current heating'. A single core cable carrying alternating current creates concentric magnetic fields radiating outward from the conductor, when this magnetic field encroaches on adjacent ferrous metal local heating is produced as a result of Eddy Currents.

When all the four cores of a single cable are connected to the four terminals of the Transformer secondary, assuming balanced loading of the phases, the magnetic fluxes produced by the currents in each core would cancel out and there would not be any residual flux. But, when we connect all the four cores to the same phase, only one phase flux would be there and there would not be any neutralizing flux from the other two phases. This entire phase flux would magnetically link with the armor and induce a voltage in the armor. And, when this armor is having a closed path the induced voltage would circulate currents in the armor which causes the heat and the temperature rise. If the value of the current is high then the temperature rise may even result in the damage of entire cable insulation.

After identifying this problem, the cable termination was re-done at both the ends, in such a way that all the four cores of each cable was connected to the 3 phases & Neutral terminals as shown in Fig. 4. Cable heating problem was thus solved.

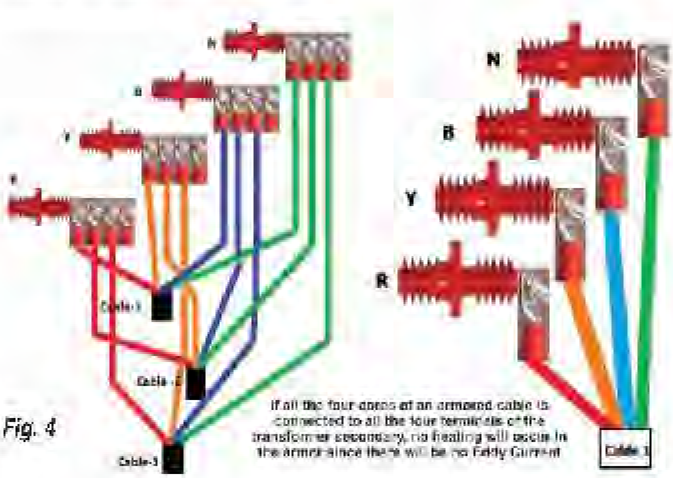


Fig. 4

Case study 2

Termination of the outgoing cables at the pole mounted sheet steel box, housing MCCB's for 250 KVA, 11kV/420V, 3 phase and Neutral, Transformer centers.

A reputed builder in Bangalore installed three Nos. pole mounted transformer stations of capacity 250 KVA each for supplying power to the newly constructed residential towers. Connected to each transformer on their Secondary side, was a M.S. sheet steel box containing two nos. each 400 Amps rated MCCB's. The sheet steel boxes were also pole mounted near the respective transformers. Two parallel runs of 1.1 kV grade, 3½ core, 240 sq.mm, aluminum, PVC insulated cables, one for each MCCB was connected & the other ends of the two cables were connected to the incoming circuit breakers of two separate L.T. Distribution switch boards located at the basement of each tower. In short, there were six cable runs for the three transformer centers feeding six LT switch boards. The contractor to whom the termination of these cables were entrusted, laid the cables from the pole mounted MS sheet steel boxes to the LT boards located at the basements. Since the space between the MCCB's and the bottom of the MS.Sheet steel box was insufficient to take the entire 3 ½ core cable inside the box & then separate the individual cores inside the box for termination, he drilled holes in the bottom steel plate of the box to take individual cores through each hole. Eight holes were drilled for eight cores. His workmanship was so poor that he did not even use proper cable glands for each core. (See Fig. 5).

Fig. 5: Pole Mountaed Sheet steel box showing Transformer Secondary side circuit breakers feeding two separate feeders

After some time of operation, standing at the bottom of each pole mounted Transformer structure, it was observed near the entry point of each core into the MS box, the PVC insulation around each of the cores had started cracking & peeling out exposing the bare aluminum conductors. This type of insulation damage was noticed on all the three pole mounted boxes at the transformer centers, involving all the 24 cores. The damages were so severe that on some cores the insulation had become brittle and fallen off exposing the bare conductor to a length of about 3" to 4" near the cable entry points. All the six cables (24 cores) from the three pole mounted MS sheet steel boxes were taken out for closer examination. It was observed that similar insulation damages had also occurred on these cores inside the box also closer to the drilled holes. See Fig. 6.

The reasons for these premature insulation damages on all the three

Fig. 6

Cutting the bottom MS Plate through which individual cores were taken through individual holes

Fig. 8

Fiberglass Reinforced Plastics (FRP) sheet with drilled holes for cables

transformer centers were analyzed as under: At this juncture it is necessary to explain the theory of Eddy current heating. See Fig. 7 for Eddy current heating.

- Since the space between bottom of MCCB's & the bottom of the sheet steel boxes were insufficient to take the entire 3 ½ core cable inside the box and split the cores for connection to MCCB's, the contractor decided to separate the cores about one meter below the MS box & took all the individual cores into the sheet steel box by drilling one hole for each core.
- During the above process he did not use proper cable glands, either of brass or other Non magnetic material, for taking the individual cores inside the box. The alternating current flowing through the individual core will set up an alternating magnetic field around the core, resulting in an eddy current effect heating up the Sheet steel plate around the core. If the load current in the core increases, the circulating current in the sheet also increases resulting in the increase of heating. Since these cores are continuously loaded round the clock the heating effect is also continuous resulting in the damage to the core insulation in the vicinity of the drilled hole.

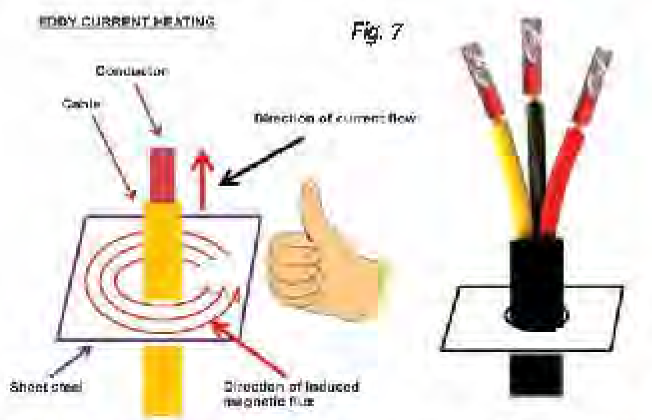


Fig. 7

Right hand thumb shows the direction of currents & the direction of fingers show the direction of induced magnetic flux. In the case of an alternating current in the conductor, the induced flux is also alternating & produces a circulating current in the sheet steel. Depending on the Resistance of the sheet, induced current produces heat in the plate.

In the case of a three phase cable carrying balanced current, the magnetic flux induced by each core oppose and gets nullified & hence no Eddy current or heating in the steel plate occur.

- Had the entire cable comprising of 3 ½ core been taken through a single hole in the sheet steel box using normal cable glands, the magnetic fluxes produced by the currents flowing in individual cores would have cancelled out & there would not have been any residual flux & hence no Eddy current heating would have occurred.
- Following corrective measures were taken to resolve the above issue in all the three transformer centers. Since all the 24 cores had suffered damages to outer insulation & since it was not possible to cut the damaged portion & re-do the termination of the cables (as length of the cables were in sufficient) the damaged cores were provided with Heat shrinkable sleeves up to the terminal of the MCCB, thus taking care of the repair of the damaged insulation. The rectangular bottom steel sheet of the box was cut and a Fiberglass Reinforced Plastic sheet (FRP) with pre-drilled holes for cable entry (See Fig. 8) was bolted to the bottom of the box and the repaired cores were taken through the FRP sheet for termination. Usage of FRP, which is electrically insulated has prevented the eddy current heating effect.

From above case studies it is clear that despite having selected the best of equipments, if the contractor selected for the execution of the job is inexperienced in cable termination, failures of cables are inevitable.

Profile

C V Govinda Raju

presently Consultant for Steel plants in India & abroad has taken up role of conducting training lecture sessions & is on the faculty of INSTRUCT, Bangalore. Formerly ED, Karnataka Vidyuth Karkhane Ltd; President, Ispat Group Company, he qualified in Electrical Engineering, from University Visveswaraya college of Engg. Bangalore, served Visveswaraya Iron & Steel works, Bhadravati in various capacities handling major Steel Plant projects. He was with ISPAT group & also associated with L.N.Mittal (Arcelor Mittal Steel). He retired as President of ISPAT Group Company.

Cable Fault Locator System in Underground Distribution Network

Underground cables/ wires find numerous applications in today's world in transmission, distribution and industrial/ commercial premises. Although underground system having more benefits, it creates many problems once fault occurs. This article includes discussion on current scenario of fault locating techniques.

Yogesh B Mandake & Prof Prasanna D Bharadwaj

Article presents new technique to detect open circuit and short circuit fault in underground cable/wire. Prototype developed and tested for practical readings. Conclusion drawn from obtained test results and also discussed suggestions for further work in the same area.

Introduction

Underground system having more popularity due to following advantages:

- Less damage due to storms or lightning
- Maintenance cost is low
- Chances of faults are less
- Voltage drop is small
- General appearance is better

Underground distribution system mainly suffers from open circuit, short circuit and earth fault. Detection of this type of faults accurately and quickly is very challenging job. Many scholars and researchers spent time to work in this area for obtaining ideal method of locating faults. Ideal method means one which will be economical, having use of portable instruments, less time consuming, accurate and user friendly.

General steps for locating underground cable faults are as follow:

- Fault classification: Identifying the type of fault
- Pre-location: Determining the distance to the fault.
- Route tracing: Determining the route of the cable at site.
- Pinpointing: Determining the exact position of the cable at the site.

This article reviews different cable fault locating techniques which are currently in use from literature survey. This article also presents design of new fault locating technique which removes drawback of current systems. Proposed system tested for different conditions in order to catch certain conclusions and discuss future work.

Current Fault Locating Techniques

In literature, different methods for estimating the underground cable faults are described and each method has its own merits and demerits. There is no single method which will be best among all methods. In general there are two categories of fault locating techniques in underground cables or wires as 1. Tracer 2. Terminal. Tracer method include fault location search by "walking" through the cable circuits. A faulted segment can be determined from audible or electromagnetic signals and also requires some members at outage area. Second method (Terminal method) determines fault location of a distribution cable network from one or both ends without tracing.

Two popular and conventional methods for locating faults in underground cables are (i) Murray loop test and (ii) Varley loop test. These simple tests can be used to locate the earth fault or short circuit fault in underground cables. Principle of Whetstones Bridge is mainly employed by both these methods for fault location. Direct current is used to measure the resistance, which helps to calculate distance of fault in percentage of total line length. Wavelet based scheme tested to find incipient fault's in underground cables. Wavelet analysis mainly includes the function of analyzing electromagnetic transients in power systems. Time Domain Reflectometer (TDR) instrument used to detect permanent faults in

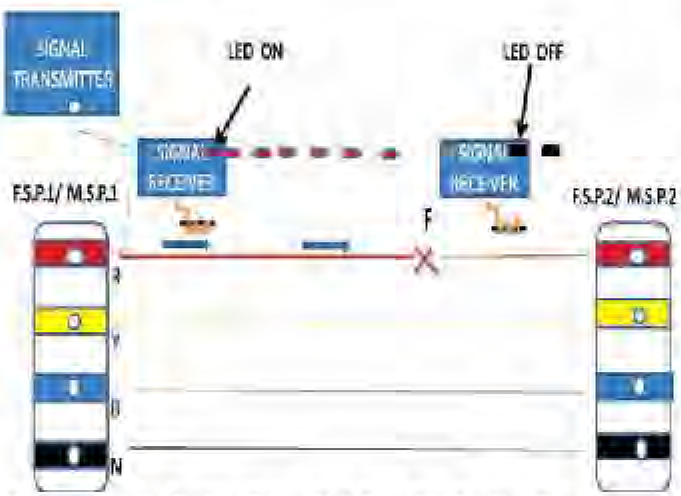
LT underground cables. Permanent fault includes open circuit and short circuit type of faults. Impedance based method used to locate single phase faults in underground cables. Method uses the values of fundamental frequency voltage and currents measured at the origin terminal of line. Travelling wave approach also used to detect underground cable fault, which include injection of pulse signal into defective cable. Reflected wave forms produced due to this are used to detect a fault. In single phase configuration, fault generated waves are also used to both real time and after the fault location for residential cable distribution systems. Thumper machine is mostly used to locate underground LT cable faults, in which high voltage surge generator is used to used to supply a reasonably high voltage to faulty core of an underground cable to generate high current-arc resulting in loud noise. This sound is audible above the ground.

Proposed System

In proposed system, we develop fault locating kit for locating open circuit and short circuit fault in underground cables or wires.

Fault Locating Principles

For open circuit fault:



F.S.P. = Feeder Section Pillar; M.S.P. = Mini Section Pillar
Fig. 1: Open circuit fault locating principle

Open circuit fault occurs when any core get open. i.e. R phase in fig. In this case we transmit high frequency signal through faulty core by using F.M. transmitter. This signal detected with signal receiver kit (consisting of inductor coil and LED) by walking along cable route. In short LED glow until we are on right path as well as signal also present. As we cross faulty point, LED will be off due to absence of signal. Thus technique is helpful for both tracing route of laid cable and locating approximate open circuit fault point.

Short circuit fault locating principle:

In case of short circuit, we are using the concept of incremental internal cable / wire resistance with increase in length (distance). We measure the resistance at any two end of cable (i.e. R and Y in Fig. 2) with other end is in open condition(i.e. A and B in Fig. 2). It is possible to measure the distance of fault of cable by calculating voltage drop.

Fig. 2: Short circuit fault locating principle

Let,

Vs- Supply end voltage

Vr-Receiving end voltage

Voltage drop

= (Vs - Vr) (Volts)

Resistance of short circuited length (Rsc)

= (Voltage drop) / (Supply current) (Ω)

Short circuited length

= (Rsc / Resistance in /Km) 1000 (Mtr)

Length of short circuit fault point

= [(Short circuited length) / 2] - (Mtr)

The system is integrated with computer (MATLAB software) using RS232 serial port wherein GUI is provided to input required data for calculations and show result thereby avoiding manual errors.

Prototype Design

- Signal transmitter kit: To transmit signal through faulty core during open circuit fault
- Signal detector kit: To detect signal along route of cable for route tracing & finding open circuit fault location
- Main control circuit: To control all hardware and corresponding calculations
- Computer with MALAB GUI files: To provide user display for giving input data and reading output results.

Fig. 2.1: Main parts of practically developed kit

Testing Data

Open circuit fault:

Reading for 1.5 sq. mm flexible wire:

Fault created at distance of 4M.

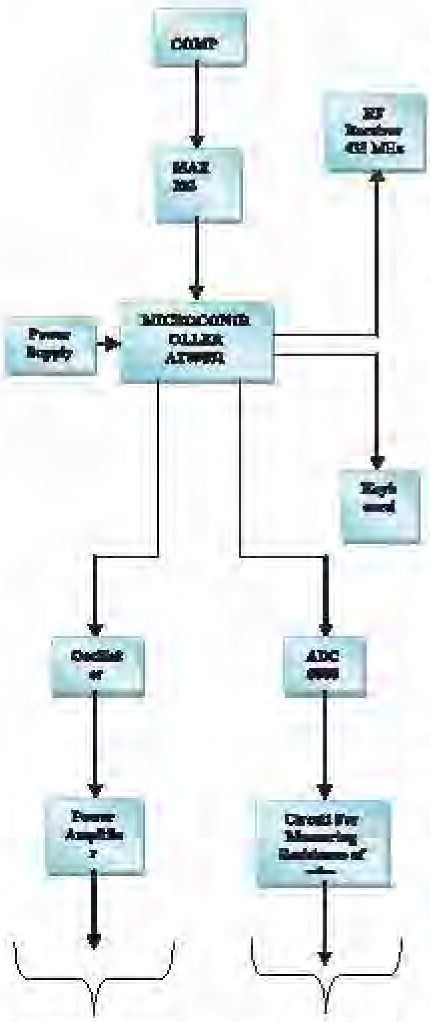
Fault distance observed: 4.1M*

Reading for 25 sq. mm 1.1 KV underground cable:

Fault created at distance of 10M.

Fault distance observed: 10.2M*

* (From practical readings it is observed that, signal indicating LED gets off at an average distance of 0.6M beyond the open circuit fault due to prorogation of signal. Above readings are neglecting that distance).



For Open Circuit Fault *for Short Circuit Fault*

Fig. 2.2: Block diagram of fault locating kit

Sheets referred: Cable resistance is in ohm/km which get referred from technical sheets provided by Polycab wires private Ltd.

Short circuit fault

Reading for 1.5 sq. mm flexible wire:

Fault created at distance of 10M.

Fault distance observed: 10.05M

Reading for 25 sq. mm, 1.1 KV underground cable:

Fault created at distance of 10M.

Fault distance observed: 10.2M

*Above readings are observed for both overhead cable/wire and underground cable/ wire buried at 1 feet deep trench.

Applications

- Used for locating faults in underground cables
- Model can be used for locating and tracing wires laid out in the structures of buildings as well as other types of metallic lines and ducts.
- It can be used for locating faults in telecommunication lines.

Result and Discussion

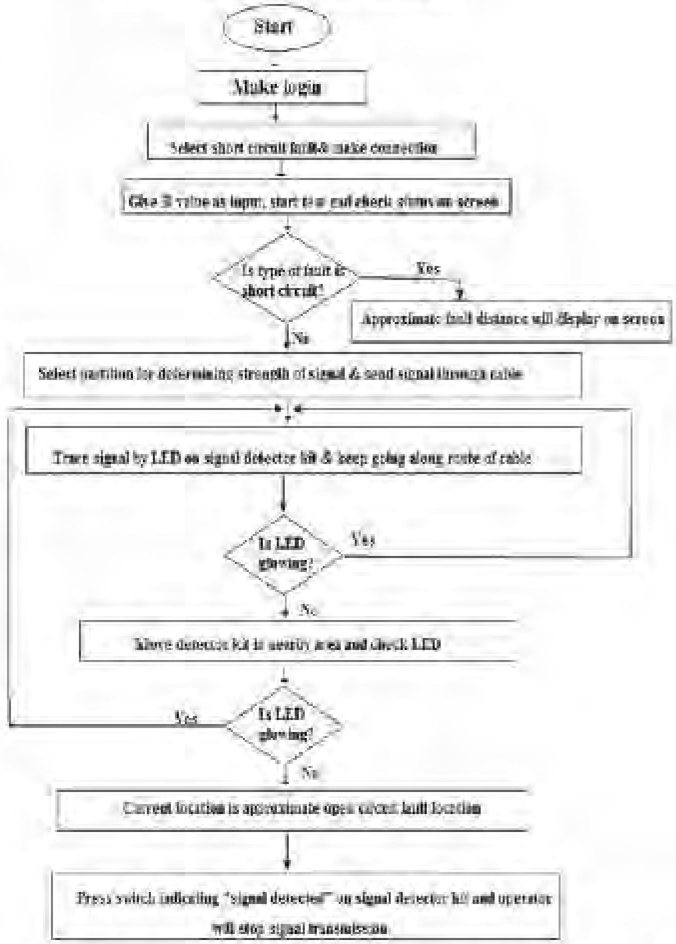
Proposed system

Proposed system gives more accurate results for both overhead and underground system cables and wires. While taking practical readings, it is observed that LED gets off at a higher distance as compared to actual fault due to propagation of signal. In case of short circuit fault, readings are more accurate for large distances. Design is very user-friendly and portable.

Conclusion

Different techniques for locating underground cable faults are discussed. Signal transmission technique and voltage drop principles are useful for locating open circuit and short circuit fault detection as well as for cable route tracing purpose. Proposed technique having potential for commercial use with field application and can lead to portable fault locator equipment. There is requirement of greater value of supply voltage and higher signal strength for commercial application of proposed system.

Flow chart for fault locating technique



Profile

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PD Testing and Monitoring of HV XLPE Cable Systems

The correct design and the quality of production of XLPE cable and its accessories, terminations and joints, is checked by various routine tests at the manufacturer's plant according to relevant standards.

However, installation work on site poses a possible risk of introducing faults, which could negatively impact reliable operation over time. Small particles, dust, and moisture might lead to defects in electrically critical locations of the accessories. Dielectric tests performed on siteare therefore highly recommended. These supplementary testsare aimed at checking the dielectric integrity of the fully assembled cable line in order to eliminate defects caused by damages during transportation and lay-out or incorrect assembly of the accessories.

The preferred voltage for on-site tests is ac voltage of industrial frequency, although voltage testing only delivers binary results (withstand or breakdown). Therefore, it is recommended to combine ac voltage testing with sensitive on-site partial discharge (PD) measurements.

Why PD? A major part of all in-service failures in HV XLPE cables can be attributed to the insulation system of accessories, joints and terminations. These failures will normally develop over time. In order to detect these changes at an early stage, detailed information about the actual insulation condition is necessary. With suitable sensors, this information can be derived by monitoring PD activity during the operating life of the equipment.

This article describes the best practice for performing after installation testing & continuous PD monitoring to assess the quality and extend the life of the HV XLPE cable system.

PD Measurements During After-Installation Testing

High-voltage (HV) tests are executed on site for all extruded HV cables. On-site test procedures usually have to be negotiated between the manufacturer and the user on the basis of international and national standards.

Two IEC standards cover after installation tests of extruded cable systems: IEC 60840:2004 for cables of rated voltages from 30 kV (Um = 36 kV) up to 150 kV (Um =170 kV) and IEC 62067:2001 for rated voltages above 150 kV up to 500 kV (Um = 550 kV). High test power, especially required for long cable lines testing, can only be effeciently generated by mobile resonant test systems, where the weight-to-power ratio and feeding power demand is relatively low and the transport volume is acceptable (See Figure 1).

The whole dielectric test should be performed as a step test. PD measurements should be taken at every voltage level. By increasing the test voltage in steps of e.g. 20% of the maximum test voltage, critical defects are usually identified before breakdown.

Because HV cables must be tested at the manufacturing facility prior to shipping at installation site, the on-site PD measurements focus on the field-installed accessories. For this purpose, each accessory has to be equipped with special sensors, such as high frequency current transformers (HFCTs) to pick up the PD signal with high efficiency (See Figure 2).

A major part of all in-service failures in HV XLPE cables can be attributed to the insulation system of accessories, joints and terminations. These failures will normally develop over time.

Fig. 1: Resonance test set connected to the cable termination

As an example, during a particular after installation testing of a 220 kV XLPE cable line, fifteen HFCTs were used to pick up the PD signal. They were equipped with an air gap in the core to prevent magnetic saturation.

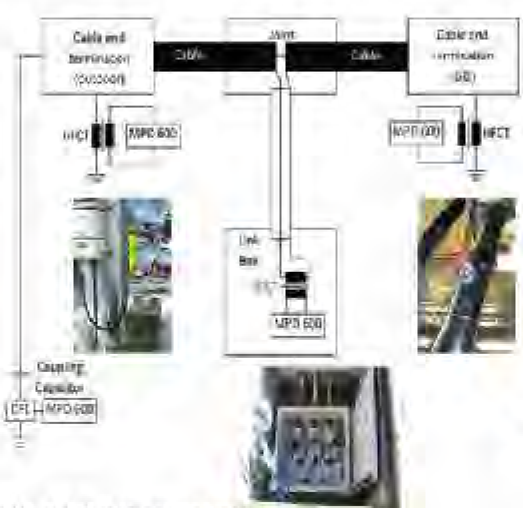

Fig. 2: PD test arrangement

One MPD600 unit from OMICRON was connected to the coupling capacitor and calibration was performed according to the IEC 60270 & IEC 60885 standards. A performance check was performed on the other fifteen PD acquisition units, which were mounted into the link boxes close to the terminations and connected in a daisy chain with fiber optics. (See Figure 3). A real calibration is not possible here because impulses cannot be injected directly into the closed and buried joint.

Fig. 3: Performance checks of HFCT sensors

The resonance test set used IGBT's as switching semiconductors. They produce strong impulses that cause high interference impulses on the MPD600 instruments, especially to those units which are rather close to the resonance test set. To eliminate this effect, PD signal gating was performed by one extra MPD600 unit which was installed close to the IGBT circuit to receive the switching impulses. During the time of the switching impulses, the signals of all other units were blocked by the MPD600 software. Due to the fact that this is done by software, such gating can be deactivated also for the replay of all recorded streams later on. The result of gating is shown in Figure 4.

The dielectric withstand test was performed at 180 kV and the corresponding voltage frequency andcurrent were 26 Hz and 68 A respectively. The measurement center frequency for all MPD600 units was set between 2 MHz and 3 MHz. The selection of lower frequency was not possible due to the high interference.

The PD results at 180 kV at all MPD600 units are shown in Figure 5. No

Fig. 4: PD measurements at joint without gating (left) and with gating (right)

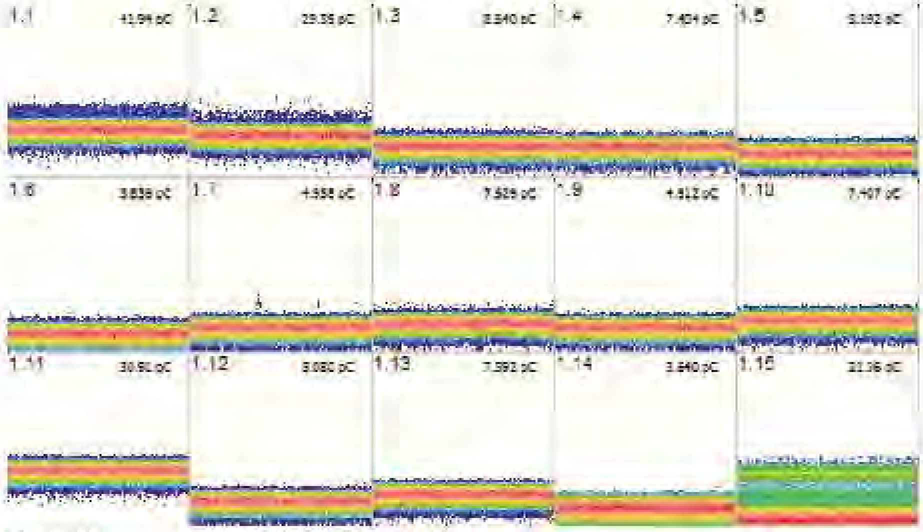

Fig. 5: PD measurement at 180kV with 15 MPD units

PD activity was detected and the tests were successfully finished within 3 ½ days.

1.1 = coupling capacitor, 1.3 = joint 1-2, 1.4 = joint 2-3, 1.5 = joint 3-4, 1.6 = joint 4-5, 1.7 = joint 5-6, 1.8 = joint 6-7, 1.9 = joint 7-8, 1.10 = joint 8-9, 1.11 = joint 9-10, 1.12 = joint 10-11, 1.13 = joint 11-12, 1.14=joint 12-13, 1.15=end terminal of GIS.

Monitoring of 420 kV XLPE Cable System in an Underground Tunnel

Continuous Monitoring System Concept

An underground tunnelhaving a length of 10 km and a 3-meter inner diameter connects the substations at Beddington and Rowdown in London. The tunnel houses a new 400 kV, 2500 mm2 XLPE cable circuit. The longest cable sections are approximately 1176 m in length, which is currently the recordfor this type of voltage in the UK.

A continuous monitoring system was applied to the cable system. Partial discharges (PD) are continuously monitored at all joints and terminations, and at the same time the system performs measurement of oil pressure in terminations and checks the condition of all sheath voltage limiters (SVLs) located in the joint bays (See Figure 6).

The concept of an applied continuous monitoring system is presented in Figure 7. The signals from different sensors measuring partial discharges, distributed temperature, oil pressure in terminations and sheath voltage limiters are acquired by multi-channel data acquisition units.

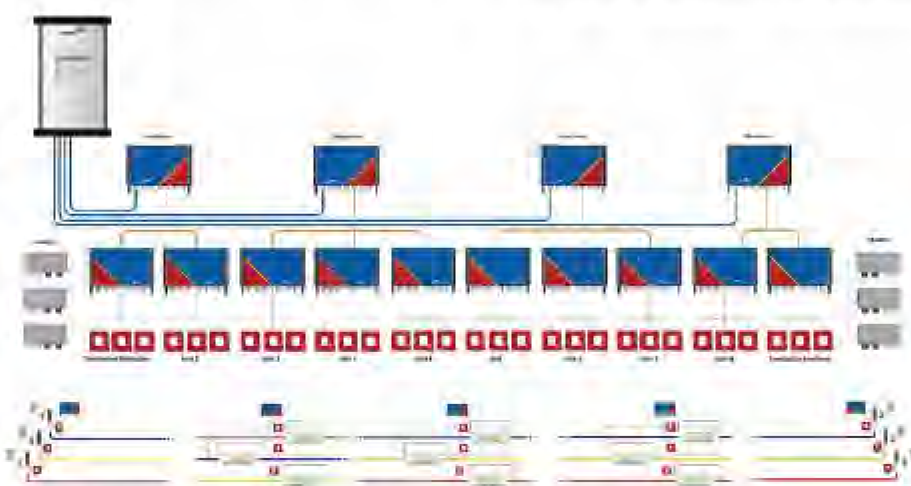

Fig. 6: Schematic diagram of monitoring system

In case of PD signals, the acquisition unit performs advanced pre-processing of the raw data. The disturbances are removed and main characteristics of the PD signal are determined. The output of the data pre-processing is transferred to a server, which enables long-term data storage. Advanced intelligent pre-processing reduces the amount of data to adequate levels for transmission over a communication network.

The separation of PD sources and the effective suppression of external noise is achieved by the application of synchronous multi-channel (3PARD) evaluation techniques. The 3PARD diagram visualizes the relation among amplitudes of a single PD pulse in one phase and its crosstalk generated signals in the other two phases.

PD Acquisition System and Inductive Power Supply

Inductive high frequency current transformer (HFCT) sensors are mounted on cross-bonding (CB) links and are used to detect PD directly at the accessories. The PD monitoring system consists of one four-channel, high-precision and modular acquisition unit for each accessory. The acquisition unit is connected to a data concentrator. One data concentrator collects monitoring data from two or three acquisition units via fiber optic cables, and it routes the data to a server. Pre-processing functions, such as band pass integration, gating, denoising and multi-source separation, are already performed in the data concentrator.

The active components of the monitoring


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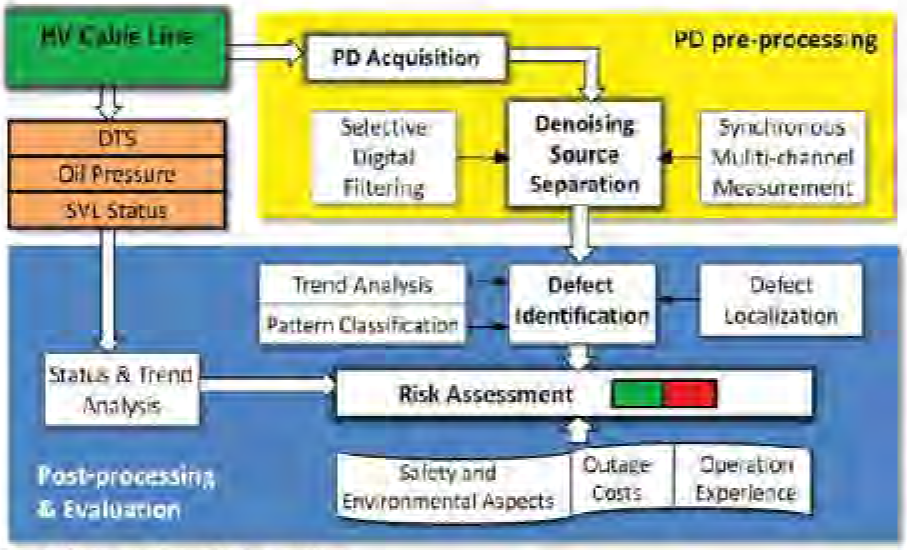


Fig. 7: Concept of monitoring system

system require electrical power for several processes. In addition to the computer and communications devices, pre-amplifiers or signal converters (for example electrical to optical) located close to the sensors also have to be supplied with power.

The Inductive Power Supply (IPS) provides the necessary electronics to supervise and manage the dc current delivered at its output, depending on the various HV cable current load situations (See Figure 8). The PCBs and electronics elements are filtered and optimized to avoid any disturbances of the PD measurements close by.

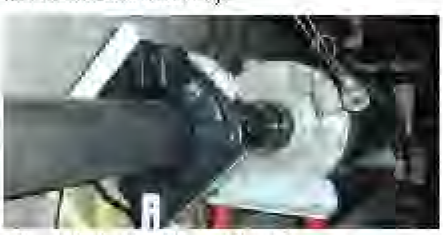


Fig. 8: Inductive Power Supply

Sheath Voltage Limiters Monitoring

Sheath Voltage Limiters (SVL) minimize the transient voltage across the screen separation of cross-bonding joints during switching or lightning transients and they reduce the risk of damage. The access to the SVLs is limited, so there is a requirement to continuously monitor their status, such as:

- Normal operation (below inception voltage);
- SVL is short circuited when the conductive flashover trace is generated through the SVL varistors;

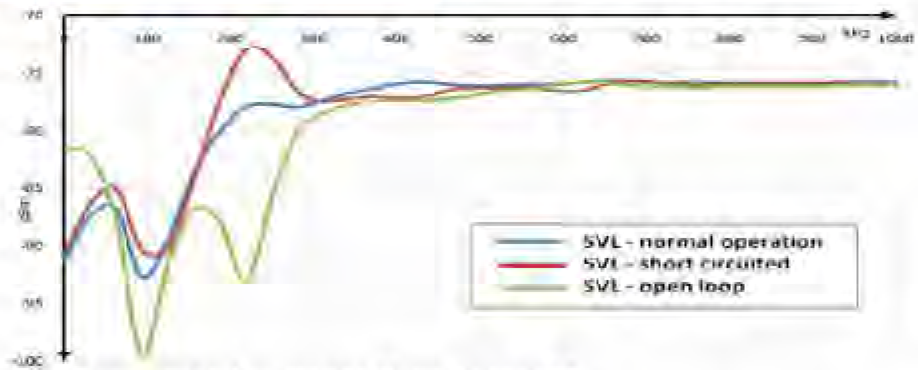


Fig. 9: Frequency signal response for different status of SVL

- SVL is in open loop – totally damaged (active elements destroyed-exploded).

An SVL is a non-linear resistor and, together with the parallel cable screen at a cross-bonding link, creates characteristic loop impedance. This impedance will change according to the status of the SVL, and the operation of the SVL monitoring system is based on these changes. In the monitoring system, the PD acquisition units located at the joint bay periodically "inject" signal pulses using their internal test generators. These signals propagate through the HFCT sensors to the SVL impedance loop and are collected by the acquisition unit. The Fourier transforms of injected and returned signals are calculated, averaged and compared. No special sensors are required for the scope and a major part of evaluation of SVL monitoring data is performed within the monitoring server. Differences can be easily analyzed and distinguished by a spectral processing algorithm implemented in the monitoring server software (See Figure 9).

	Mode	
Value	Permanent	Periodic
Partial Discharge	every 2-3 sec	for 1 every 1 h
Oil pressure at terminations	every 2- 3 sec	once every 1 h
SVL status	–	once every 8 h

Table 1: Default time scheduling for different measured values

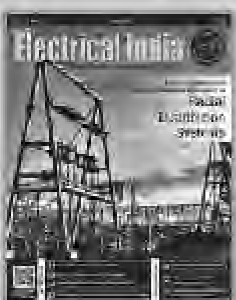
Server and Software Architecture

The monitoring server receives data for analysis, display, and storage. The acquisition units are configured and remote-controlled by the monitoring system software. The software supports remote access over TCP/IP. This allows operators to quickly react to detected problems and access the stored data from any remote location. The software is a highly modular, scalable distributed system. Its system architecture consists of the Windows-based core part and the web-based control part. The core part of the monitoring software is realized as windows services and runs continuously without any direct user interactions. The core system implements: Collection and persistence of measurement;data post-processing and analysis; security tasks for data access and system operations;and external interfaces for data exchange over Ethernet or field bus.

Trend Analysis

The monitoring system provides data from each of the acquisition units and oil pressure sensors in permanent & periodic time intervals (See Table 1).

During the permanent mode, the data is acquired every 2-3 seconds, compared with threshold values and displayed in real-time in the graphical user interface. If this data is within



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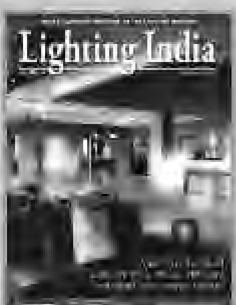

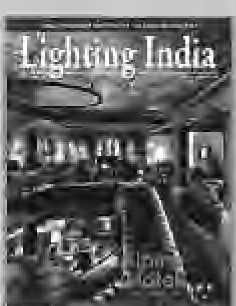

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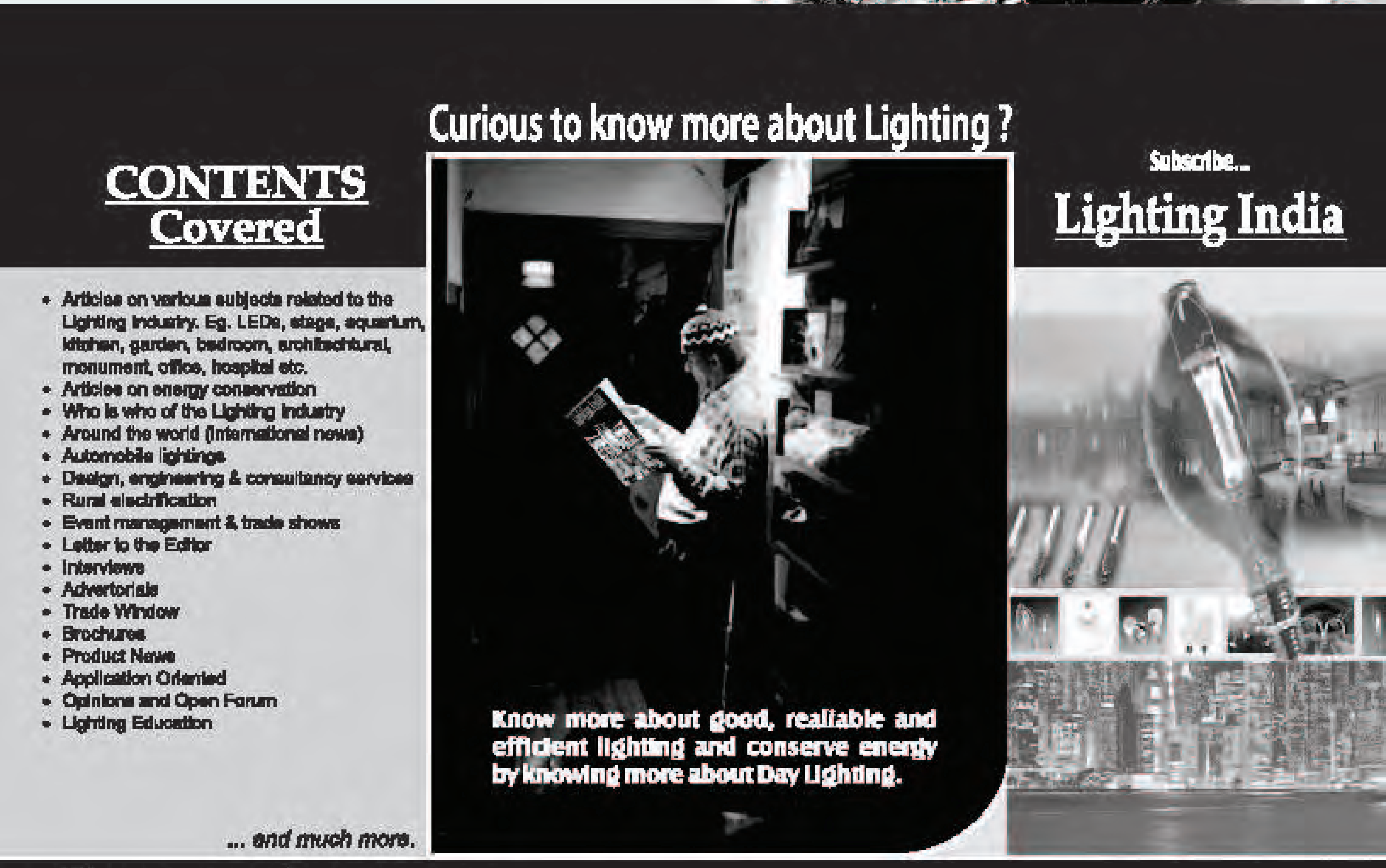

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normal margins, it will be colored in green. If the values exceed thresholds for 'warning' or 'alarm', they are colored in yellow or red accordingly.

Periodic measurements are initiated in equidistant time spans, such as every hour. The duration of the periodic measurement is normally 1 minute. During this time span, all mentioned scalar values are calculated and PRPD (phase resolved PD) and 3PARD diagrams are acquired. This data is saved for later post-processing and trend visualization. Unscheduled periodic measurements are triggered in case one or more measured quantities exceed the threshold level.

Fig. 10: Graphic user interface

PD activity is displayed as PRPD for each phase/sensor and for each separated PD source, respectively. Trend diagrams of statistical parameters such as PD magnitude, frequency of occurrence of PD pulses, etc. are available. Suitable filter options enable the user to select the data display according to his specific interest. The user can set limits that cause warning or alarm messages to be generated when exceeded. The measured values are continuously compared with signal levels (See Figure 10).

The measured quantities are color-codedbased on their value related to pre-set warning or alarm threshold levels. For example, if the detected PD level on any channel on one asset exceeds a configurable threshold, the corresponding value will be drawn in red.

The SVL status is verified within the Server Software by FFT-based spectral analysis of the signal injected to the XB link loop impedance from PD acquisition unit. A statistical model of "normal" SVL behavior is used for reference.

Fig. 11: Installation of the system on site

The model is constructed based on the SVL data collected during starting limited time period of cable system operation with different load conditions. SVL status analysis is based on statistical comparison parameters between the model and current SVL measurements which clearly distinguish normal operation of SVL from short circuited and open loop SVL.

Acceptance of the Monitoring System on site

The monitoring system was routinely tested in the factory and later installed on-site (See Figure11).

The site check of monitoring system performance was performed according to the following steps:

- Step 1: Verification of the functional readiness of the measuring system and of the monitoring server
- Step 2: Verification of the synchronous behaviour of the PD measuring system
- Step 3: Determination of PD impulse attenuation, damping and dispersion along the cable system.

The following parameters were determined: PD impulse attenuation; damping and dispersion along the cable; velocity of the calibration signal in the cable; best frequency ranges for PD measurements at all PD units (with highest signal to noise ratio); and PD detection path division factor for every chosen frequency range.

Maintenance of the system and customer support

The monitoring systemservice and maintenance scheme is presented in Table II. The installed system elements, such as sensors, acquisition units, power supplies, batteries and fiber optic data transmission network elements are periodically inspected and checked. These visual inspections and functional checks include adjustments, repair or minor maintenance activities. Such visual inspections are planned once every three years in coordination with the scheduled maintenance activity of the cable system. This requires access to the system installations, including the cable tunnel, manhole, shafts and other related substation facilities. It may also necessitate an eventual outage of the cable system, which requires respective scheduling efforts. Software updates include periodic modifications, bug fixes, and enhancements with new features. If requested by the system owner, regular checks and evaluation of data values as well as trending of the acquired partial discharges stored in the monitoring system database can be performed on a per cable system accessory basis. In the case of repeatedly reported trending alerts or alarms, or specific PD events detected by the monitoring system, outside PD expert consultancy and support can be requested by the system owner.

System element	Maintenance scheme		
Hardare	Activity to be performed	Periodicity	Responsibility
	visual check	yearly	owner
	functionality check	every 3 years	owner & system provider
Sofware	updates	every 3 years	system provider
	data evaluation	periodic reports	system provider
	expert consultancy	in case of PD event	system provider

Table 2: Maintenance scheme of a monitoring system

Conclusions

- The combination of resonance AC voltage testing and distributed, synchronous PD measurements at all cable accessories has proven highly effecive for after installation testing of HV XLPE cable systems.
- A continuous PD monitoring system provides actionable data to support maintenance on a condition-based rather than time-based plan to extend the life of the HV asset.
- Separation of PD sources and suppression of external noise is effectively performed by the multi-channel evaluation techniques of the monitoring system.
- The Inductive Power Supply provides the necessary power to the monitoring equipment to supervise the 400 kV cable system. The dc current delivered is depending on the HV cable load situations, but even at very low load the power is sufficient to run the monitoring system.
- To verify the status of SVL, the system can utilize the CB link loop impedance.
- A modular, distributed monitoring software system allows reliable long term storage of monitoring data and provides access via web interface.
- The monitoring system provider supports the asset owner in all stages of the monitoring project, from system design, installation and periodic mainenance, to traning and data evaluation support.

Profile

Dr. Wojciech Koltunowicz

M.S., PhD and Dr. hab. degrees in electrical engineering from Warsaw University of Technology. He was with Institute of Power in Poland, as a research scientist in High Voltage Department. He was with CESI, Italy, involved in HV testing and diagnostics of HV equipment. At OMICRON, he was involved in monitoring of HV equipment. He is Secretary of CIGRE Advisory Group "Insulating Gases", WG D1.25 and Member of AG D1.02 "High Voltage and High Current Test and Measuring Technique and Diagnostic". He is also member of IEC TC42 WG14 & author of many international reports.

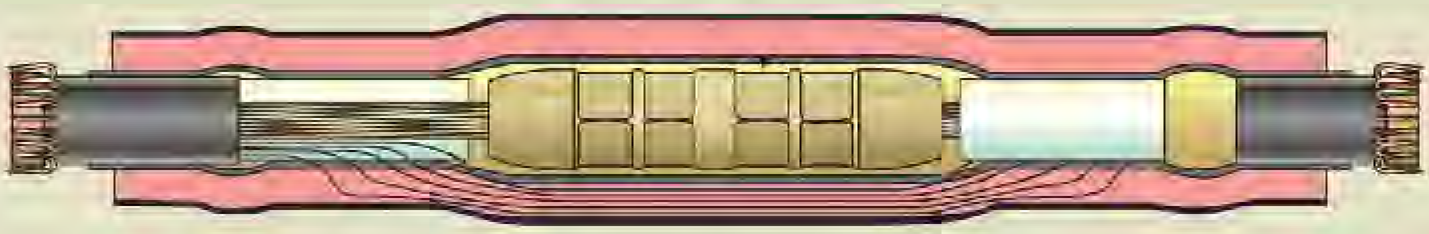
Profile

Dr. Michael Krüger

is head of engineering services with OMICRON electronics GmbH, Austria. He studied electrical engineering at the University of Aachen (RWTH) and the University of Kaiserslautern (Germany) and graduated in 1976 (Dipl.-Ing.). In 1990 he received the Dr. techn. from the University of Vienna. Michael Krüger has more than 25 years of experience in high voltage engineering and insulation diagnosis. He is member of VDE & IEEE.

Joints & Terminations of Cables

The art & science



A great care is taken in the manufacturing process of cables. There are a number of checks and quality factors to ensure that the best product is in the hand of users. Even all raw materials, which go into the making of a cable are checked and sometime tested. All these are done so that the cable, which is the carrier of energy, signals and data as the case may be, is a reliable carrier. They are certified for their quality by recognized institutes like BIS, popularly known as ISI.

- *P S Shah*

The data cable and signal cables are normally low voltage low current cables hence their reliability is more if laid and terminated properly. The chances of failures of such cables are usually very less. But this is not the case with high voltage and high current carrying cables. This article tries to explain this usually neglected aspect of cable termination.

Many of us might have seen a red spot (Hot Spot) in the night on electrical distribution companies' installations near the transformer centers, from where we get our electrical power supply. This usually is more visible in rural areas and overhead lines. This is due to lose connections or bad termination. Over a period of time due to high temperature leading to incandescence, the oxidation of the metal takes place and the conductor gets cut and may even fall on ground. The exposure of bare conductor to environment leads to its deterioration. The number of factors can affect the conductor and armor, as the insulation is most of the time impervious to attack by such factors. Some of such factors are humidity, chemical gases and heat. All these lead to gradual damage to the metallic portion of the cable. In one of the acid manufacturing companies, not only power cables but even the winding wires of motors were getting affected due to harsh environment and the failure rates of motors was pretty high.

In yet another case, where in high horse power low tension motors of 400 HP were deployed, there were frequent flash overs in the motor terminal box. The cost of such unpredictable breakdowns was colossal for a continuous process plant. So the matter was investigated and it was found that the motor terminal box was not large enough to accommodate the aluminum power cable, and as a result the termination was not good enough, beside the electrolytic corrosion due to dissimilar metals of aluminum and copper, the problem was getting accentuated. So an additional big junction box with tin plated copper bus bars was erected near motor and from this junction box proper size copper cables were connected to the motor. Also bimetallic washers with corrosion inhibiting compound were used to make joints as sound as possible. This arrangement resulted in remarkable improvement. Later on with the advent of infrared thermometer even the temperature of such joints were measured periodically as part of monitoring. It was observed that the fasteners used were of iron so the joints were getting hot. To overcome this problem, the special fasteners of high conductor metal brass with tin plating improved the reliability.

A great care has to be exercised with high current termination. We all know that the heat is proportional to the square of the current and directly proportional to the value of resistance.

The failure of high ampere cables is due to heat generation, but the failure of a high voltage cable is due to partial discharge or popularly known as tracking

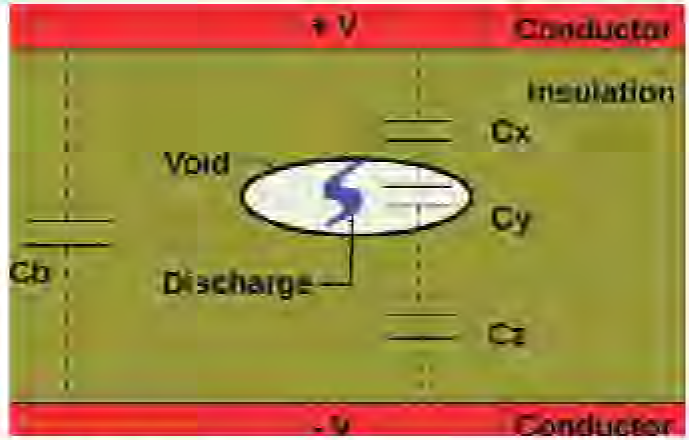
To elucidate, I will take the case of above 400HP low tension motor. The normal current was 400 Amperes. So if there is a resistance of 0.005 ohms or 5 milliohm, the amount of power dissipated in this joint could be (400*400*0.005=800 watt) about 800 watts. Due to lack of ventilations, the amount of heat produced could be so high, that it can charred the cable insulation and hasten the oxidation of metals in contact. With the help of good milliohm meter we may measure the resistance of joints and decide about the soundness of joints. The best thing is to avoid the numbers of joints in power distribution system, but this is not always possible. Each joint reduces the reliability of total system as a seamless connectivity is not possible. Beside there is change of interphase when there is joint. A joint, as such is an evil necessity. The major cause of most of the fires is usually attributed to electricity. Some simple check points mentioned below, if taken care of, may lead to good joint or termination of cables.

- Use proper type of lug. (Size, type and material)
- Ensure that the conductor is not damaged while cutting insulation.
- Use proper type of fastener (Material & size)
- Ensure proper butting of surfaces
- Use bimetallic washer if required when copper and aluminum is to be joined
- Use corrosion inhibiting compound while terminating or jointing
- Use double crimp if possible on lug barrel
- Ensure proper tightening of fasteners.

The failure of high ampere cables is due to heat generation, but the failure of a high voltage cable is due to partial discharge or popularly known as tracking. In any high voltage cable the armor is supposed to be at zero potential and the conductor is at high voltage so there are various voltage gradients across the cable. If the potential gradient is higher than the dielectric strength of the media, the arc or spark takes place in such media which is known as tracking, which leads to flash overs and thus creating short circuits. Partial discharges within an insulating material are usually initiated within gas-filled voids within the dielectric. Because the dielectric constant of the void is considerably less than the surrounding dielectric, the electric field across the void is significantly higher than that across an equivalent distance of dielectric. If the voltage stress across the void is increased above the corona inception voltage (CIV) for the gas within the void, Partial Discharge activity will start within the void.

A partial discharge within a solid insulation like that of a HV cable may be explained as under. When a spark jumps the gap within the gas-filled void, a small current flows in the conductors, attenuated by the voltage divider network Cx, Cy, Cz in parallel with the bulk capacitance Cb. So, great care has to be taken for the termination of HT cables to avoid such tracking. In case of high voltage cables, the care of insulation is more critical unlike LT high power cables where care of conductor is critical.

High-voltage cables of differing types have a variety of applications in Radiology, ignition systems and AC and DC power transmission. In all applications, the insulation of the cable must not deteriorate due to the high-voltage stress, ozone produced by electric discharges in air, or tracking. The cable system must prevent contact of the high-voltage



conductor with other objects or persons, and must contain and control leakage current. Cable joints and terminals must be designed to control the high-voltage stress to prevent breakdown of the insulation. Often a high-voltage cable will have a metallic shield layer over the insulation, connected to earth ground and designed to equalize the dielectric stress on the insulation layer. The bends of the cables must not be very sharp as it leads higher voltage gradient in insulation and may lead to its failure.

Diagnostic field testing of cables is now possible with commercially available Tan Delta and Partial Discharge measuring devices. These tests are performed off-line, providing the most information possible. Test procedures and test specifications are within IEEE and other Standard. The most basic use of the Very Low Frequency (VLF) is to perform a go/no-go withstand test to expose defects that cannot hold the test voltage. If a cable can't hold 1.5 – 3 times normal voltage, depending on cable class, find out the cause or reason now. Let failure occur during downtime, make the repair, and then do not worry about that cable for many years. It is very useful following installation, repair, or to ensure critical cables are sound. In situations where the user can tolerate a failure during the test, it is the simplest and most certain way to test a cable. Any defect severe enough to be driven to partial discharge is allowed to fail. Lesser defects and good insulation are unaffected. It is the ultimate diagnostic test.

When a non destructive diagnostic test is preferred over a withstand test, there are proven options. The first technique and the most common is a Tan Delta test. This is a "global" test of the cable, providing the condition from end to end. Using a VLF as the voltage source and a separate divider to make the measurements, the voltage is raised while measuring the Tan Delta of the cable. If a cable is perfect, it behaves like a capacitor, where there is a phase shift of 90 between the voltage and current. The more degraded the insulation and accessories are, the more this angle becomes less than 90, as resistive leakage current is added. This change in the angle is easily measured and assumptions can be made about the degree of degradation. The absolute TD number is not important, but more indicative is the curve trend if it is sharply upward as the voltage is raised, the cable is highly degraded. Test many cables and rate them as highly or moderately degraded, or good. This data is used to help prioritize cable replacement, injection, and /or to determine what other tests may be of value. TD testing is easily performed and interpreted.

Partial Discharge testing is fairly new using VLF, yet proven and accepted. The obvious advantage to using VLF rather than power frequency systems is the smaller size, lower weight, far less power consumed, and price. PD testing attempts to locate defects and their severity along the cable path. While TD testing provides the overall health of the cable, PD testing finds individual locations of electrical discharge. The operator then makes a determination whether the level of PD is worrisome or acceptable. Any PD in the insulation at levels near or slightly above operating voltage is unacceptable, whereas accessories can survive with rather high levels of PD. This is where the interpretive nature of PD testing comes in. With no real guide as to what is and isn't acceptable PD and at what voltage level, particularly in accessories, interpretation can be difficult. Also measured are the Partial Discharge Inception Voltage (PDIV) and the PD Extinction Voltage (PDEV).

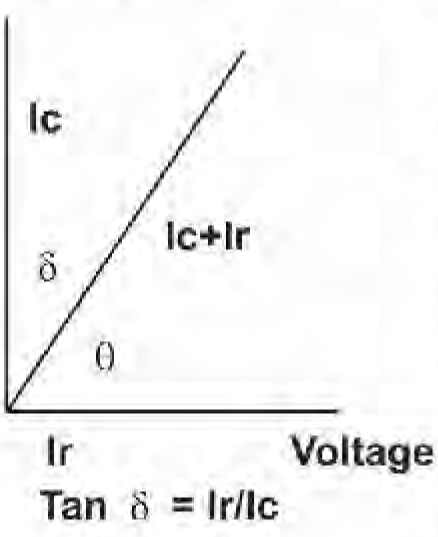
Knowing where PD begins relative to applied voltage compared to normal operating voltage, and where the PD extinguishes when voltage is lowered, provides valuable data used in the interpretation. PD testing is of great value, although the most expensive Tan Delta is a diagnostic test conducted on the insulation of cables and windings. It is used to measure the deterioration in the cable. It also gives an idea of the aging process in the cable and enables us to predict the remaining life of the cable.

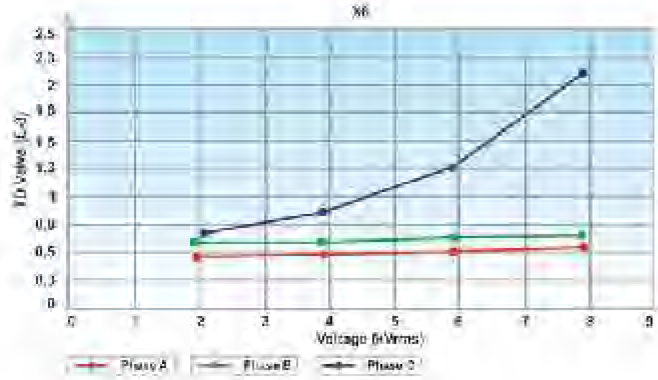
Principle

It is alternatively known as the loss angle test or the dissipation factor test.

The Tan Delta test works on the principle that any insulation in its pure state acts as a capacitor. The test involves applying a very low frequency AC voltage. The voltage is generally double the rated voltage of the cable or winding. A low frequency causes a higher value of capacitive reactance which leads to lesser power requirement during the test.

Besides, the currents will be limited enabling easier measurement. In a pure capacitor; the current is leading the voltage by 90 degrees. The insulation, in a pure condition, will behave similarly. However, if the insulation has deteriorated due to the entry of dirt and moisture, the current which flows through the insulation will also have a resistive component. This will cause the angle of the current to be less than 90 degrees. This difference in the angle is known as the loss angle. The tangent of the angle which is Ir/Ic (opposite/adjacent) gives us an indication of the condition of the insulation. A higher value for the loss angle indicates a high degree of contamination of the insulation.





Method of testing

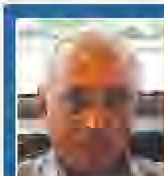
The cable or winding whose insulation is to be tested is first disconnected and isolated. The test voltage is applied from the Very Low Frequency power source and the Tan delta controller takes the measurements. The test voltage is increased in steps up to the rated voltage of the cable. The readings are plotted in a graph against the applied voltage and the trend is studied. A healthy insulation would produce a straight line.

The test should be continued only if the graph is a straight line. A rising trend would indicate weak insulation which may fail if the test voltage is increased beyond the rated voltage of the cable.

Summary

The termination of cable is usually most neglected part of installation. But for the reliability of system as a whole, it is one of the most critical factors. The termination of HV cable needs great care and is a highly skilled and special job, must be left to the specialist. The cable termination is art and science both as is combination of skill & engineering.

Profile



PS Shah

Presently working in Surat Special Economic Zone as Deputy General Manager is BE (Elect) has experience of more than three decades in Projects and Maintenance mainly in Electrical Engineering. He also worked as Chief Engineer and received three Certificates of Merit and One Letter of Appreciation for good work from ASP-SAIL, Two Letters of Appreciation from Bombay Dyeing Group and Two Letters of Appreciation from Steelco Gujarat Ltd. So far six articles in Electrical India, Three articles in Lighting India and one article in Cooling India written are published.

Interview

Operating as the most ethical Power Exchange

M G Raoot, MD & CEO
Power Exchange India Limited

Power Exchange India Limited (PXIL) is India's first institutionally promoted Power Exchange that provides innovative and credible solutions to transform the Indian Power Markets. PXIL provide users with the best in class IT solutions. PXIL trading solutions are secure and can operate on any telecommunication media. PXIL is India's first and only Quality Management System ISO 9001:2008 certified Power Exchange in the country. In an exclusive interview to **Electrical India, M G Raoot** states, becoming more customer friendly, introducing new products are our immediate goals.

➢ As CEO Could you brief us on your journey especially when you had been in control at National Power Exchange as its founding MD & CEO power sector?

My role at NPEX was to create a state of art power exchange for the Indian Power Market. Along with my team, we conceptualized and implemented foundational activities at NPEX which was promoted by some of the biggest names in the power and IT space like NPTC, NHPC, PFC, & TCS. Unfortunately the exchange could not come up due to reasons beyond the control of management.

➢ Could you detail us about the changes that you have brought in at PXIL? Till date how far PXIL has been successful in transforming the Indian Power Market?

Power Exchange India Limited is the result of amalgamation of some of the most respected exchanges in the country, i.e. National Stock Exchange of India Limited and National Commodities & Derivatives Exchange and leading players in the Indian Power Sector namely PFC, WBSEDCL, GUVNL, MPPTCL, TPTCL, GMR Energy, JSW Energy. PXIL is an organization founded with a purpose of transforming the Indian Power Sector into a vibrant competitive market place.

In context to PXIL's contribution in transforming the power market we have been unique in a way to offer indigenously developed solutions for the Indian Power Market. Right from choosing to offer an indigenously developed product, internet based trading platform, 15 minute blocks, congestion management, weekly product etc all the initiatives have been for the Indian context.

During the last one year, the Hon'ble CERC in its wisdom has come up with two amendments to ensure competitive neutrality in the market space. The exchange neutral NOCs and development of a methodology to levy

NLDC charges are a testimony to this. In terms of performance FY 13-14 has been a year of revelation for PXIL. From being a loss making -cash starved entity, we have managed to turn around things. We are proud to say that PXIL now is not only self sustaining but a cash profit making entity. Our financial results which will be released shortly after completion of financial year will reflect the efforts of our team under new management. To point out few achievements we successfully integrated latest MILP based mathematical matching engine which is much advanced than our competition. We become the first and only power exchange in India to achieve ISO 9001:2008 quality certification. We are market leader in the REC segment; we have more than doubled our market share from 23% in FY 2012013 to nearly about 55% in FY 2013-14 till Feb-14. Our average trading volumes have grown from 2 MUs per day to near 5 MUs per day. We managed to reduce our expenses and have emerged as a leaner & fitter group of motivated individuals. But this is not where we stop; PXIL is determined to improve many folds in coming years and prove its worth as an organization to all its stakeholders.

- **What would you comment on the failures such as black outs, load shedding, power cuts that have been severe in the country? What would you suggest to improve the caliber / efficiency of the power market?**

Timely completion of projects and exploiting renewable energy potential in the power generation space, supporting generation with adequate transmission capacity and arresting T&D losses. Practicing utility scale DSM projects in distribution sector will be key in addressing the gap in demand and supply which ultimately result in load shedding, power cuts. Black out are not common these days as the Indian grid is far more secure and reliable as compared to earlier years.

To improve the reach and efficacy of the power market, implementation of Open Access provisions in true spirit, and provision of adequate transmission infrastructure, introduction of exchange traded longer tenure contracts are few aspects which require immediate attention to improve trading volumes on power exchanges. There have been positive developments like tightening of UI Band with introduction of Deviation Settlement Mechanism and provision of allowing ancillary services markets through Exchanges, but still the issues mentioned above are most important and crucial for development of Exchanges in India.

- **What training do you provide to different companies by PMCOE, could you detail us its features?**

PXIL established a Power Market Centre of Excellence (PMCoE) back in 2009 to enhance the knowledge about power markets in the power sector. We conducted our first training program in Feb 2010 in association with IIM Ahmedabad. Since then PMCoE has conducted more than 20 capacity building programs training over 600+ professionals from the power sector at national and international level with some of the most respected organizations like IIM Ahmedabad IIT Bombay, ASCI, NPTI, Korea Power Exchange, Elexon Balancing (London, UK).

Our programs have covered various topics of general interest in generation, transmission, distribution and trading areas. We are all set to conduct another program at IIM Ahmedabad in month of October 2014 on power transmission. The registration for this program are open now.

- **Detail us on the latest technologies that you have introduced for power trading along with benefits available to traders?**

We understand that, as Power Market grows, the complexities in terms of products, network utilization also will increase. Heuristics based models are good and have served the purpose of Market till now however they lack in the areas like, optimizing network utilization India is not a transmission network surplus market. We therefore made a strategic decision to revamp our matching engine and trading platform. We wanted to introduce to the Indian Power Market, a technology that is efficient & effective today and also after 5-10 years from now.

We can certainly say today that our matching engine 'PIOUS-22' (PXIL IIT Bombay Optimized Ultra Solution-22) based on Mixed Integer Linear Programming (MILP) model is far ahead of others who still use heuristics based matching engine. Now we plan to upgrade the balance of software to offer a trading experience at par with international electricity exchanges. We will soon offer state-of-art Trading Engine - 'P-NEST', which stands for "PXIL NSPOT Efficient Smart & Secure Trading System".

P-NEST platform offers several advantages over its predecessor 'EnTRiM' in terms of access, ease of usage and information dissemination, enhancing overall functionalities and better risk management. It offers technological upgrade as we move from "Thick Client based solution" to "Complete Web Based Solution." A 'Continuous Matching' feature will be available in 'P-NEST.' Next is its flexible and modular Risk Management and Margining system. 'P-NEST' offers stage-wise margining and Risk Management systems at various stages of product cycle which allows participants to place bids with an opportunity to fulfil their requirements. Technologically, 'P-NEST' trading platform offers a robust database. This means that PXIL would be migrating from its present MS SQL database to Oracle database which is the industry standard and well known for variety in features and enhancements. Overall, it would be a customer delight on the new trading platform. We are sure that this step of ours will soon translate into better market position for PXIL in near future.

➢ Where does PXIL stands in comparison to other power exchanges in the country?

In the physical segment our volumes are steadily growing as compared to the last few years. We are now trading 3-5 MUs per day as compared to 1-2 MUs in FY 12-13. Though are volumes are less in compared to the overall market size, we are confident that with the implementation of new trading platform 'P-NEST', we would be able to increase our volumes many folds in a quick time.

In the REC segment we have established market leadership in FY 13-14 with a market share of 52% and we are holding to that position in FY 14-15 with YTD market share of over 66%.

➢ Can you highlight the services and solutions that PXIL offers to improve efficiency of power markets?

Currently PXIL offers 5 different types of contracts in physical segment, the Day Ahead Spot contract which is essentially a collective transaction contract, Day Ahead Contingency contract which is a bilateral contract promising day ahead delivery. Intra-day contract, again a bilateral contract for same day delivery. In the term ahead market PXIL provides Weekly and Any Day products, both Bilateral contracts promising delivery upto 11 days.

As discussed above we are determined to offer innovative technology driven solutions to the market participants. We have already offered 'PIOUS-22' (PXIL IIT Bombay Optimized Ultra Solution-22) based on Mixed Integer Linear Programming (MILP) model and are on the verge of introducing new state-of-art Trading Engine - 'P-NEST', which stands for "PXIL NSPOT Efficient Smart & Secure Trading System". With these technical competencies PXIL would be able to quickly introduce new types of products and services to the power market. For example we will be shortly introducing flexi bids options for the first time in the Indian power market. We would be able to offer more such innovative solutions to the power market participants in future.

➢ What are your future plans in next two years?

Becoming more customer friendly, introducing new products are our immediate goals. We would push the matter with appropriate authority on boosting the REC trade on Exchanges and put our best efforts ensuring that Energy Efficiency Certificates, Longer Tenure product & Ancillary services come strictly on Exchange platform. Even launching of evening market would help the sector.

In long run we strive to remain operating as the most ethical power exchange in the country.

Packaged Substation

A Solution Towards Safe & Smart Applications in Handling of Electrical Power

With the ever-increasing demand of power and to fulfil the requirements of present scenario of the industries, it has become very necessary to enhance the capacity by installing of new generating station, thereby developing the infrastructure for transmission and distribution of power. India, like all fast growing countries, where space is a premium concern, it has become a necessity to go for compact size of equipments. The substation having a number of equipment, large space for installation, safety for inhabitants and huge amount of money for its operation and maintenance placed many obstacles for the new upcoming projects. In such situation it has become mandatory to go for maintenance free, safe and compact installation which can save space, money and environment.

Leena H Roy, S Bhattacharyya, B V Raghavaiah and Yugal Agrawal

A substation is a part of an electrical generation, transmission and distribution system. Among several other important functions, substations transform voltage from high to low and vice versa. Between the generating station and consumer, electric power may flow through several substations at different voltages levels. Substation may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer. Generally substations are unattended, relying on SCADA for remote supervision and control.

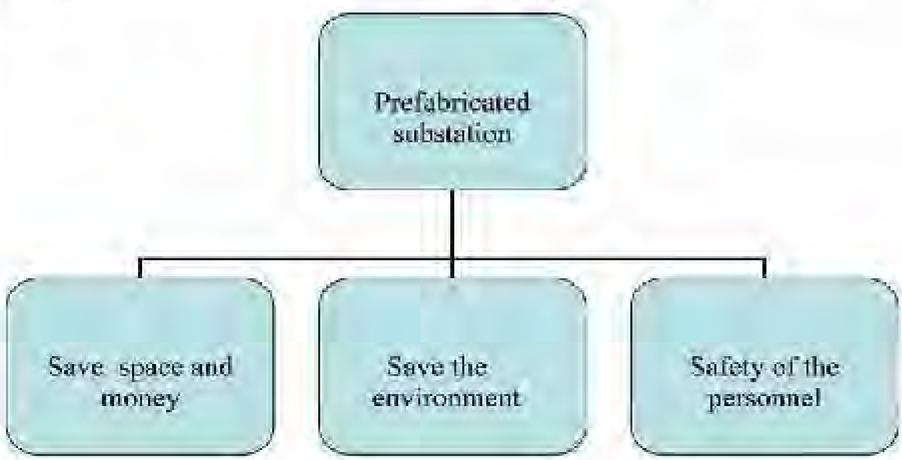
A substation essentially includes transformers to change voltage level between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages. The word "substation" comes from the earlier days when the distribution system was yet to become a grid. As central generation station became larger, smaller generating plants were converted to distribution station, receiving energy supply from a larger plant instead of using their own generators. The first substations were connected to only one power station where, the generators were housed, and were called the subsidiaries of that power station.

Now-a-days, the packaged substation including, all the required electrical components within a single enclosure are installed with different configuration. Packaged substations are tailored to individual customer requirement using products from the comprehensive range; providing a convenient, single source packaged substation by reducing time and cost. Flexibility is provided through tailored configuration from the wide choice of products available.

As central generation station became larger, smaller generating plants were converted to distribution station, receiving energy supply from a larger plant

Prefabricated substations are operated at rated voltage above 1kV and up to 52kV on the HV side. They can be situated at ground level, or partially, or completely below ground level. The prefabricated / packaged substation is a complete set of power distribution equipment; which combines the transformer, HV switchgear and control devices, LV switchgear and control devices, power measurement devices, interior connection and auxiliary equipments. The high voltage power input, step down transformer and low voltage power distribution are effectively combined together to be especially applicable to the construction and reconstruction of the power network. The prefabricated substation offers a complete set of features which include; small volume, being able to be transported to the load centers, reliable power supply, low loss, short power transmission period, user friendly, easy installation and maintenance, safe and reliable service, little investment, quick taking effect etc.

The pre-fabricated substation comes as a module combining the benefits on 3 counts as follows:



Less space and money

- Optimal use of raw material
- Minimal occupation of surface
- Minimal civil work
- Equipment durability reducing its cost .
- High mechanical and electrical endurances
- Easier installation, it only requires to connect the incoming and outgoing cables at the site. It is also easy to move the transformer at any time.

The protection of environment impact is reduced by

- By reduction of the volume of dielectric liquid.
- Reduction in the losses in the transformer.
- Electromagnetic compatibility can be provided using special type of shielding on the enclosure
- Fireproof insulation
- Reduced environmental, visual and acoustic impact
- Excellent resistance to pollution and other environment factors
- Easy to transport due to its reduced dimensions
- Simple installation.

Safety of the operating personnel

- Against internal arcs, accidental direct contact, touch and step voltage
- Equipotential work surface
- No access to live parts
- Sufficient air intake and outlet, especially in the transformer area are implemented in ventilation systems. The ventilation systems generally have a degree of protection IP23 according to IEC 60529

- Cable entry: incoming and outgoing cables are routed properly through cable glands.
- The PSS has air tight design, grounding enclosure and no conductive parts on surface mean any need of dielectric clearance, which can reliably ensure personal safety.

The design and operating characteristics of PSS are verified in the standard IEC 62271-202. This standard gives an IAC classification to substation that passes the internal arc. As established in the local regulations, keeping their effectiveness to provide protection in case of any internal fault with respect to the safety aspects it is essential to install an earthing circuit that channelises the fault current, protecting persons and property.

With the introduction of packaged substations in the electrical market the safe and smooth operation of the PSS is to be ensured. The product standard IEC 62271-202 gives the details of the tests and the aspects to be worked upon in case of failures.

The electrical and mechanical tests to be performed as per standard are:

- Dielectric tests
- Temperature rise tests
- Short-time & peak withstand current tests on main & earthing circuits.
- Functional tests
- Verification of the degree of protection
- Calculations and mechanical tests.
- Internal arcing test
- Electromagnetic compatibility test.

The packaged substations are widely used in the European markets and nowadays the installation of PSS is also being started in some areas of India. The constant increase in the technological and functional complexity of electrical installations makes it essential for every component to offer highest levels of continuity of service and reliability combined with minimum maintenance requirement.

The PSS are mostly used in multiplexes, Cineplex and densely populated areas. Therefore the oil-filled transformers are to be replaced by resin cast transformers as the oil-filled transformers are prone to high risk of fire. The cast resin transformers have many advantages over oil-filled transformers such as-

- They do not propagate fire and are self-extinguishing.
- No risk of leakages of inflammable or contaminating substances such as oil or silicon.
- They are maintenance free.
- They have a long working life.
- Installation costs are substantially reduced.
- Compact dimensions are much reduced compared with liquid filled equivalents.
- High specification & superior performance characteristics.
- Ability to boost output by upto 40% for short period by the addition of forced draught fan cooling.
- The risk of internal arcing faults is further reduced by enclosing both main and distribution busbars and risers in segregated sheet steel chambers thus preventing intrusion by foreign bodies.

Internal arcs can occur inside the substation in a number of locations and can cause various physical phenomena. The internal arc tests are intended to verify the effectiveness of the design in protecting persons in case of an internal arc. It does not cover all the effects that may constitute a hazard, such as the presence of gases with potential toxic characteristics that can be present after the fault. The hazard of the propagation of fire after an internal arc to combustible materials or equipment placed in the proximity of the substation is not covered by this test. The significance and criteria of the internal arc test is described herein.

Testing of prefabricated substation under conditions of arcing due to an internal fault

The internal arc heats directly the surrounding insulation gas and a part of the electrical energy will be transferred via convection and heat conduction in thermal energy, which results in an overpressure in the switchgear compartment.

After exceeding a predetermined pressure limit, the hot gases expand over pressure relief devices into the substation or switchgear building. The hot gases and the transient pressure waves may endanger persons in the switchgear room and may seriously damage the electrical equipment and the building.

One of the main effects of internal arcs is the dynamic pressure stress on mechanical parts of the switchgear and on the walls of the building. To avoid the destruction of the substation or the switchgear building it is necessary to integrate overpressure relief systems in form of ventilation openings, vent outlets etc.

Central Power Research Institute has the facilities for all the tests on PSS like Internal arc test ,Impulse and Power-frequency tests and Heat-run test, of which the most severe one is the internal arc test, which is described here in a little details.

Internal arc classification

- Prefabricated substations classified IAC-A: These substations meet the prescribed criteria for protection of the operators when they are performing normal operations inside or in the front of the substation.
- Prefabricated substations classified IAC-B: These substations meet the prescribed criteria for the protection of the general public in the vicinity of the substation.
- Prefabricated substations classified IAC-AB: These substations meet the prescribed criteria for the protection of both the operators and the general public.

Test arrangements

- The substation shall be fully equipped. Mock-ups of internal components are permitted provided they have the same volume and external material as the original components.
- Prefabricated substations are designed for outdoor installation. Therefore, no room simulation around the substation is required for internal arc tests aimed at verifying the degree of protection provided outside the substation. However, where the ground around the substation is suspected to contribute to the performance of the substation simulation to the ground surface might be required.
- Indicators shall be fitted vertically at all accessible sides of the prefabricated substation, facing all points where gas is likely to be emitted (for example, joints, inspection windows, doors) up to 2 m above the ground level in a checker-board pattern.
- The tests covering the case of a fault in

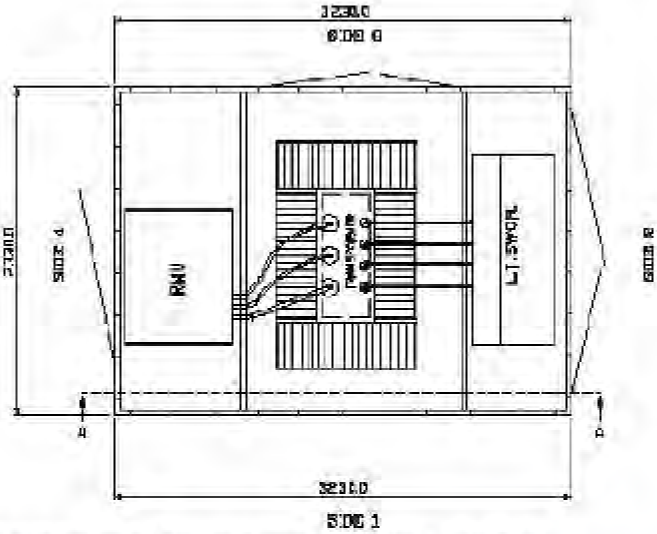
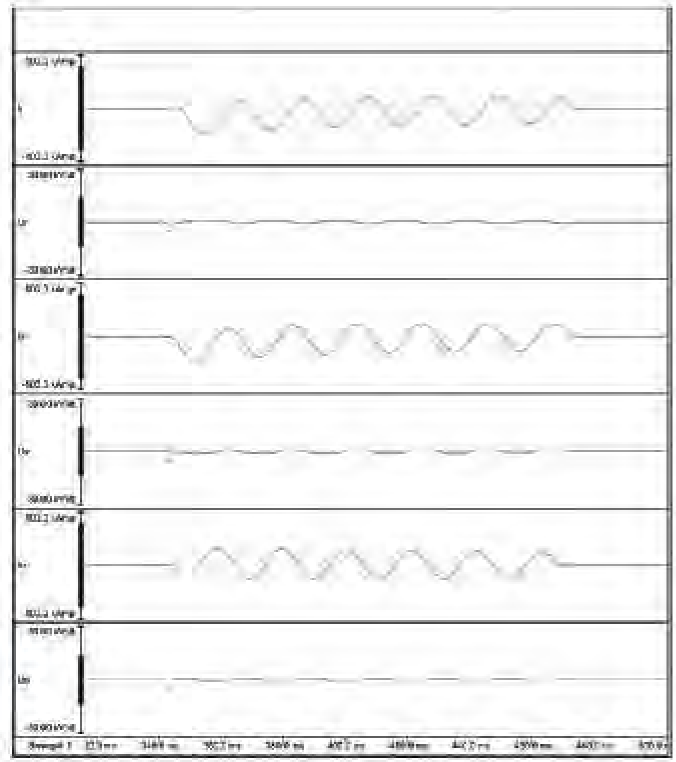


Figure shows the test conducted on Transformer chamber (Shorting point is at HV terminals of transformer)

Photograph of Package substation before test

Photograph of Package substation after test

the HV interconnection (generally test on transformer compartment) shall be performed. The point of initiation shall be located at the furthest accessible point from the supply. The feeding direction shall be in accordance with the normal expected flow of the energy in service.



Oscillogram (Current & voltage waveforms) of internal arc test

Acceptance criteria

- Criterion No. 1: Correctly secured doors and covers of the substation do not open. Deformations are accepted, provided that no part comes as far as the position of the indicators in every side. The substation needs not to comply with its IP code after the test.
- Criterion No. 2: No fragmentation of the enclosure occurs within the time specified for the test. Projections of small parts, up to an individual mass of 60 g, are accepted.
- Criterion No. 3: Arcing does not cause holes in the roof and in the accessible sides up to a height of 2 m.
- Criterion No. 4: Indicators do not ignite due to the effect of hot gases. Should they start to burn during the test, the assessment criterion may be regarded as having been met, if proof is established of the fact that glowing particles rather than hot gases caused the ignition. Pictures taken by high-speed cameras, video or any other suitable means can be used by the test laboratory to establish evidence. Indicators ignited as a result of paint or stickers burning are also excluded.
- Criterion No. 5: The enclosure remains connected to its earthing point. Visual inspection is generally sufficient to assess compliance. In case of doubt, the continuity of the earthing connection shall be checked.

Conclusion

The conventional substations have substantially over-engineered the logical approach for installation where the safety and reliability is highly demanded. The compact design of packaged substations has brought the opportunity and means of being more cost effective vis-à-vis conventional substations, apart from being flexible, interchangeable, mobile and easier to operate. It can be looked as a piece of equipment with its own set of testing and operating procedure, like other big components of the substation. But the advantage lies in getting rid of the hassles of operating of number of equipments separately. This inherently results in increased reliability and safety.

The value added engineering of packaged substation always reduces the time and cost and the innovative design reduces the need for large infrastructure, possibly less land to be purchased. The modular design eliminates movements during operation. With the goal of boosting the safety and efficiency of substation, the concept of packaged substation is moving fast towards greater acceptability day by day.

Profile

Leena H Roy

MTech in digital communication from MANIT, Bhopal has 13 years working as a test engineer in High Voltage Laboratory in STDS, Bhopal.

S Bhattacharyya

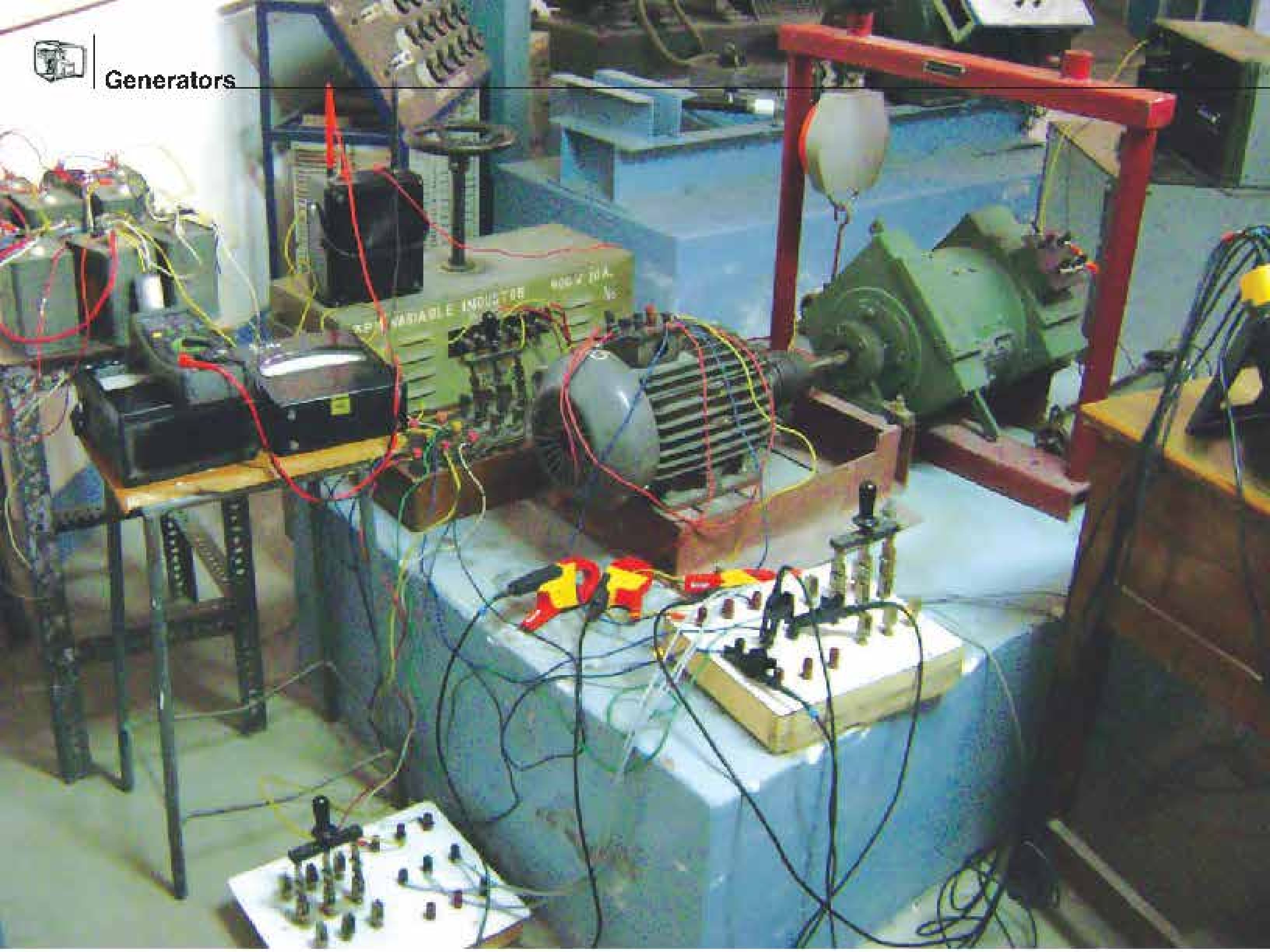
Mtech (Power Systems) from IIT, Kharagpur, completed MBA (Finance) from JU, Kolkata. Started career in the manufacturing units of Areva T&D India (the then M/s GEC of India Ltd). He joined CPRI as Engineering Officer and was involved in SC and other testing activities of the Institute. Currently working in the Bhopal unit of CPRI as Joint Director, heading the HV and other Supplementary Test Laboratories.

B V Raghavaiah

Presently Additional Director & Unit Head of CPRI, Bhopal is post graduate from JNTU, Hyderabad. He presented several technical papers. He is a member of BIS, CIGRE, Development Council for Heavy Electrical & Allied Industries, GOI, Ministry of Heavy Industries & Public Enterprises, Department of Power and MPERC. He also visited ABB Switzerland, CESI Italy, represented CPRI at Malaysia for Global bids for TNB, Malaysia; visited Japan as international inspector of STL.

Yugal Agrawal

Presently Engineering Officer-4 in STDS, CPRI Bhopal is ME and presented several technical papers in conferences & Lectures.He visited South Korea as International inspector of Short Circuit testing Liaison (STL) & Malaysia to deliver training to TNB Engineers. He is member of Institution of Engineers, India & Member of Peer Group for review of course content of training themes for capacity building under R-APDRP for PFC, Delhi.



Steady State Analysis Doubly Fed Induction Generator for MPPT & Minimum Loss Criterion

In this article, suitable model of the doubly-fed induction machine (DFIM) for steady-state calculations are presented. Further, an analytical approach is developed to determine proper rotor current commands I^*_{dr} & I^*_{qr} which give maximum mechanical power tracking (MPPT) and minimum loss (active and reactive) based on the measured generator speed.

Dheeraj Joshi and Reshmi P R

Steady-state equivalent circuit of induction machine is shown in Fig 1. This equivalent circuit is valid for one equivalent Y-phase and for steady-state calculations. In the case that it is Δ-connected the machine can still be represented by this equivalent Y representation. In the equivalent circuit Vs is the applied phase stator voltage to the induction machine, Is is the stator current, Ir is the rotor current, r_S is the stator resistance, r_r is the rotor resistance, L_{lS} is the stator leakage inductance, L_{lr} is the rotor leakage inductance, R_C represents the magnetizing losses, L_m is the magnetizing inductance and s is the slip.

To get maximum output power from a Doubly fed Induction Generator is to extract maximum mechanical power from the wind turbine and to minimize generator losses.

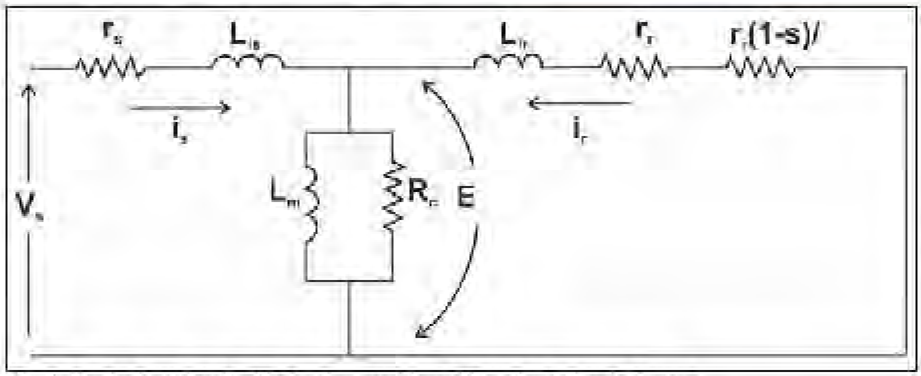


Fig. 1: Equivalent circuit of induction machine with a short-circuited rotor

In order to take the wound rotor with slip rings into consideration the equivalent circuit is extended with the applied phase rotor voltage, Vr. The equivalent circuit with the inclusion of an external rotor voltage can be seen in Fig. 2.

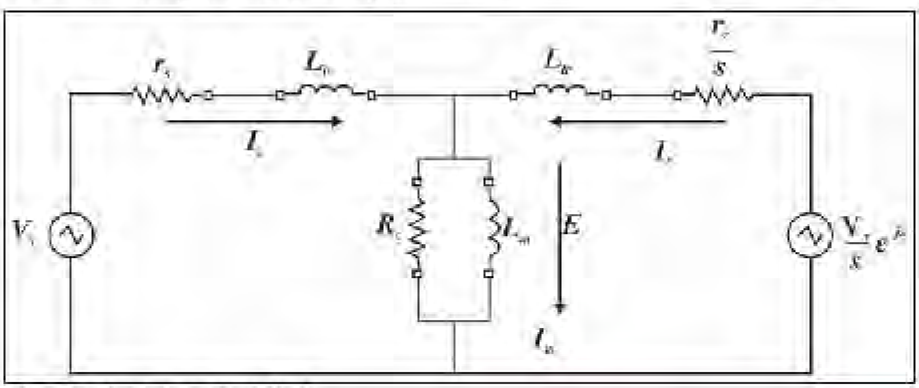


Fig. 2: Equivalent circuit of DFIG

According to the equivalent circuit of Fig. 2, obtained from the d, q stator and rotor equations, the equations describing the model of the DFIG are functions of three independent variables. These are as follows.

- The speed of the generator which is introduced through the slip,
- The magnitude of the rotor excitation voltage 'V'_r' and
- The angle 'α' between the stator applied voltage Vs and the rotor excitation voltage V_r refereed to the stator.

Modeling of DFIG considering the condition of Maximum Power Tracking and Minimum Loss and Minimum Reactive Power Criteria

The main objective to get maximum output power from a Doubly fed Induction Generator is to extract maximum mechanical power from the wind turbine and to minimize generator losses. An analytical approach is proposed to determine proper rotor current commands I^*_{dr} and I^*_{qr} which give the desired objectives. The core loss component, which was usually neglected in previous model, is included in the DFIG model in order to have more accurate results.

In order to operate the machine in maximum power mode it is assumed that the maximum mechanical power is related to generator speed by the expression:

$$P^*_m = K_{opt}\,\omega_r^3 \qquad (1)$$

When the direct-axis (d-axis) is aligned to stator flux linkage, the rotor voltage V_r, rotor current I_r, stator voltage V_S, and stator current I_s can be transformed from a b c coordinates to their d q components. Then, the rotor voltage V_r can be controlled by the rotor-side converter using the vector control. It has been shown that the mechanical power extracted from the wind turbine is controlled mainly by the q-axis rotor current Iqr, while the copper loss is mainly affected by the d-axis rotor current Idr. The equivalent circuit is given in Fig. 3.

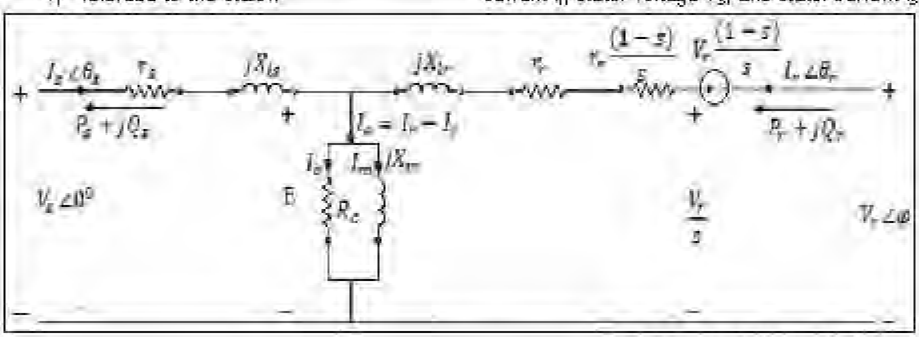


Fig. 3: Equivalent circuit diagram

The analysis in the absence of core loss is analyzed by assuming R_c=1e8.

Derivation for the modeling of DFIG considering the condition of MPPT and minimum loss

According to Fig. 3, stator voltage can be written as follows;

$$V_s = Z_m I_r - (r_s + jX_{ls}) I_s \qquad (2)$$

$$Z_m = \frac{R_c X_m}{R_c^2 + X_m^2}(X_m + jR_c) = \frac{A}{B}(X_m + jR_c) \qquad (3)$$

Where $A = R_c X_m$ and $B = R_c^2 + X_m^2$

$$I_m = I_s - I_r \quad (4)$$

Where $I_m = I_m^r + jI_m^i,\ I_r = I_r^r + jI_r^i$ (5)

Substituting (4) in (2) we have

$$V_s = Z_m(I_s - I_r) - (r_s + jX_{ls})(I_s^r + jI_s^i) \quad (6)$$

$$= \frac{A}{B}(X_m + jR_c)(I_r^r - I_s^r + j(I_r^i - I_s^i)$$

$$- (r_s + jX_{ls})(I_s^r + jI_s^i)$$

$$= [\frac{A}{B}(X_m)(I_r^r - I_s^r) - \frac{A}{B}R_c(I_r^i - I_s^i)$$

$$- r_s I_s^r + X_{ls} I_s^i] + [\frac{A}{B}(X_m)(I_r^r - I_s^r)$$

$$+ \frac{A}{B}R_c(I_r^i - I_s^i) - r_s I_s^i - X_{ls} I_s^r]$$

Equating real and imaginary part

$$\frac{A}{B}(X_m)I_r^r - \frac{A}{B}R_c I_r^i + \left(-\frac{A}{B}(X_m) - r_s\right)I_s^r$$

$$+ \left(\frac{A}{B}R_c + X_{ls}\right)I_s^i = V_s \quad (7)$$

$$\frac{A}{B}(X_m)I_r^i + \frac{A}{B}R_c I_r^r + \left(-\frac{A}{B}(X_m) - r_s\right)I_s^i$$

$$+ \left(\frac{A}{B}R_c + X_{ls}\right)I_s^r = 0 \quad (8)$$

Solving (7) and (8)

$$I_s^r = \frac{1}{c}(DI_r^r - EI_r^i + F) \quad (9)$$

$$I_s^i = \frac{1}{c}(EI_r^r + DI_r^i + G) \quad (10)$$

Where

$C = (Br_s + AX_m)^2 + (BX_{ls} + AR_c)^2$

$D = AB(A + R_c X_{ls} + r_s X_m)$

$E = AB(R_c r_s - X_m X_{ls})$

$F = -BV_s(Br_s + AX_m)$

$G = BV_s(BX_{ls} + AR_c)$

$$P_s = 3\mathrm{Re}(V_s I_s^*) \quad (11)$$

$$P_s + jQ_s = 3V_s(I_s^r - jI_s^i)$$

$$P_s + jQ_s = 3V_s[\frac{1}{c}(DI_r^r - EI_r^i + F)$$

$$- j\frac{1}{c}(EI_r^r + DI_r^i + G)] \quad (12)$$

Therefore from (12) we have,

$$P_s = 3\frac{V_s}{c}(DI_r^r - EI_r^i + F)$$

$$Q_s = 3\frac{V_s}{c}(EI_r^r + DI_r^i + G)$$

To derive the formula for rotor power, first the rotor voltage has to be derived,

$$\frac{V_r}{s} = V_s + (r_s + jX_{ls})I_s + (\frac{r_r}{s} + jX_{lr})I_r \quad (13)$$

Substituting (5) in (13) we have

$$\frac{V_r}{s} = V_s + (r_s + jX_{ls})(I_s^r + jI_s^i)$$

$$+ \left(\frac{r_r}{s} + jX_{lr}\right)(I_r^r + jI_r^i) \quad (14)$$

Substituting (9) in (13) we have

$$\frac{V_r}{s} = V_s + (r_s + jX_{ls})(\frac{1}{c}(DI_r^r + EI_r^i + F) +$$

$$j\frac{1}{c}(EI_r^r + DI_r^i + G)) + \left(\frac{r_r}{s} + jX_{lr}\right)(I_r^r + jI_r^i) \quad (15)$$

Expressing V_r in terms of real & imaginary terms we have,

$$V_r = \{[\frac{SAB}{C}(r_s A + X_m(r_s^2 + X_{ls}^2) + \frac{r_r}{s}]$$

$$I_r^r - I_r^i[\frac{SAB}{C}(X_{ls}A + R_c(r_s^2 + X_{ls}^2)) + sX_{lr}] +$$

$$\frac{sV_s}{C}[AB(A + R_c X_{ls} + r_s X_m)]\} +$$

$$j\{[\frac{SAB}{C}(X_{ls}A + R_c(r_s^2 + X_{ls}^2)) + sX_{lr}]$$

$$I_r^r + [\frac{SAB}{C}(r_s A + X_m(r_s^2 + X_{ls}^2)) + \frac{r_r}{s}]$$

$$I_r^i + \frac{s}{c}[ABV_s[R_c r_s - X_m X_{ls}]\}$$

$$V_r = [\left(\frac{s}{c}H + r_r\right)I_r^r - \left(\frac{s}{c}I + sX_{lr}\right)I_r^i + \frac{sV_s}{c}D]$$

$$+ j[\left(\frac{s}{c}I + sX_{lr}\right)I_r^r + \left(\frac{s}{c}H + r_r\right)I_r^i + \frac{sk}{c}] \quad (16)$$

Then the rotor powers can be expressed has;

$$P_r = 3Re(V_r I_r^*) \quad (17)$$

$$= 3\{[\left(\frac{s}{c}H + r_r\right)I_r^r - \left(\frac{s}{c}I + sX_{lr}\right)I_r^i + \frac{sV_s}{c}D]$$

$$I_r^r[\left(\frac{s}{c}I + sX_{lr}\right)I_r^r\left(\frac{s}{c}H + r_r\right)I_r^i + \frac{sk}{c}]I_r^i \quad (18)$$

$$= 3\left\{L[I_r^{r2} + I_r^{i2}] + \frac{D}{C}sV_s I_r^r + \frac{s}{c}KI_r^i\right\} \quad (19)$$

where

$L = \frac{s}{c}H + r_r$

$H = AB[Ar_s + X_m(r_s^2 + X_{ls}^2)]$

$I = AB[AX_{ls} + R_c(r_s^2 + X_{ls}^2)]$

$K = ABV_s[R_c r_s - X_m X_{ls}]$

$$Q_r = 3Im(V_r I_r^*) \quad (20)$$

$$= 3[\left(\frac{s}{c}H + r_r\right)I_r^r - \left(\frac{s}{c}I + sX_{lr}\right)I_r^i + \frac{D}{c}sV_s]$$

$$I_r^i - 3[\left(\frac{s}{c}I + sX_{lr}\right)I_r^r + \left(\frac{s}{c}H + r_r\right)I_r^i + \frac{s}{c}K]I_r^r \quad (21)$$

The copper loss P_cu can be expressed as;

$$P_{cu} = 3[I_s^{r2} + I_s^{i2}]r_s + 3[I_r^{r2} + I_r^{i2}]r_r \quad (22)$$

Substituting (9) and (10) into (22)

$$P_{cu} = 3[\frac{1}{c}(DI_r^r - EI_r^i + F)^2 +$$

$$\frac{1}{c}(EI_r^r + DI_r^i + G)^2]r_s + 3[I_r^{r2} + I_r^{i2}]r_r \quad (23)$$

$$P_{cu} = \frac{3}{c^2}\{((D^2 + E^2)r_s + C^2 r_r)(I_r^{r2} + I_r^{i2}) +$$

$$2(EG + DF)r_s I_r^r + 2(DG - EF)r_s I_r^i (F^2 + G^2)r_s\} \quad (24)$$

$$P_{cu} = \frac{3}{c^2}\{M[I_r^{r2} + I_r^{i2}] + NI_r^r + PI_r^i + Q\} \quad (25)$$

Core loss can be found out by first deriving the I_c core loss current;

$$I_c = I_c^r + jI_c^i \quad (26)$$

$$= \frac{V_s + (R_s + jX_{ls})I_s}{R_c} \quad (27)$$

Then the core loss can be computed as;

$$P_{core} = \frac{3}{r_s C^2}\{R(D^2 + E^2)$$

$$[I_r^{r2} + I_r^{i2}] + TI_r^r + UI_r^i + V\} \quad (28)$$

Where,

$R = r_s^2 + X_{ls}^2$

$T = \frac{N}{r_s}R + 2CV_s(Dr_s - EX_{ls})$

$U = \frac{P}{r_s}R - 2CV_s(Er_s + DX_{ls})$

$V = \frac{Q}{r_s}R + 2CV_s(Fr_s - GX_{ls}) + C^2V_s^2$

To derive the first formula for solving I_r^r & I_r^i, based on extracted mechanical power.

$$P_m^* = P_s - P_r + P_{cu} + P_{core} \quad (29)$$

$$P_m^* = 3\frac{V_s}{c}(DI_r^r - EI_r^i + F) -$$

$$3\left\{L[I_r^{r2} + I_r^{i2}] + \frac{D}{c}sV_s I_r^r + \frac{s}{c}KI_r^i\right\} +$$

$$\frac{3}{c^2}\{M[I_r^{r2} + I_r^{i2}] + NI_r^r + PI_r^i + Q\} +$$

$$\frac{3}{r_s C^2}\{R(D^2 + E^2)[I_r^{r2} + I_r^{i2}] + TI_r^r + UI_r^i + V\} \quad (30)$$

$$P_m^* = W[I_r^{r2} + I_r^{i2}] + XI_r^r + YI_r^i + Z \quad (31)$$

Where,

$W = \frac{3}{c^2}[-C^2L + M + \frac{R(D^2 + E^2)}{R_c}$

$X = \frac{3}{c^2}[CDV_s(1 - s) + N + \frac{T}{R_c}]$

$Y = \frac{3}{c^2}(-CEV_s - CKs + P + \frac{U}{R_c})$

$Z = \frac{3}{c^2}(CFV_s + Q + \frac{V}{R_c})$

Derivation for solving I_r^r & I_r^i, based on loss minimization

As active power losses are minimized, following equation is written

$$\frac{\partial(P_{cu} + P_{core})}{\partial I_r^r} = 0 \quad (32)$$

$$\partial(\frac{3}{c^2}\{M[I_r^{r2} + I_r^{i2}] + NI_r^r + PI_r^i + Q\} +$$

$$\frac{\frac{3}{r_s c^2}\{R(D^2 + E^2)[I_r^{r2} + I_r^{i2}] + TI_r^r + UI_r^i + V\})}{\partial I_r^r} = 0 \quad (33)$$

Since P_{cu} and P_{core}. Are functions of I_r^r and I_r^i, we need $\frac{\partial I_r^i}{\partial I_r^r}$ in order to solve (29).

This can be got by partial derivative of (31) w r t I_r^r and get the desired $\frac{\partial I_r^i}{\partial I_r^r}$ as follows:

$$\frac{dP_m^*}{dI_r^r} = \frac{dW[I_r^{r2} + I_r^{i2}] + XI_r^r + YI_r^i + Z}{dI_r^r}$$

$$\frac{\partial I_r^i}{\partial I_r^r} = \frac{2WI_r^r + X}{2WI_r^i + Y} \quad (34)$$

Substituting (34) in (33) we get,

$$A'I_r^r + B'I_r^i + C' = 0 \quad (35)$$

Where

$A' = 2Y[MR_c + R((D^2 + E^2] - 2W(PR_c + U)$

$B' = -2X[MR_c + R((D^2 + E^2))] + 2W(NR_c + T)$

$C' = Y(NR_c + T) - X(PR_c + U)$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From (35), we obtain the second formula for I_r^r & I_r^i

$$I_r^i = -\frac{A'I_r^r + C'}{B'} \quad (36)$$

Substituting (36) into (31) & solving we get;

$$D'I_r^r + E'I_r^r + F' = 0 \quad (37)$$

Where,

$$D' = W + W\frac{A'^2}{B'^2}$$

$$E' = W\frac{2A'C'}{B'^2} + X - Y\frac{A'}{B'}$$

$$F' = W\frac{C'^2}{B'^2} - Y\frac{C'}{B'} + X - P_a^*$$

Solving 36 we have;

$$I_r^r = \frac{-E' \pm \sqrt{E'^2 - 4D'F'}}{2D'} \quad (38)$$

I_r^i Can then be solved using (36). The pair of solution I_r^r and I_r^i in (36) & (38) with less loss are the desired rotor current components in real and imaginary axes.

Derivation for solving I_r^r & I_r^i, based on loss minimization & minimum reactive power

As active as well as reactive losses are to be minimized following equation is written;

$$\frac{\partial(P_{cu} + P_{core})}{\partial I_r^r} = 0; \frac{\partial(Q_s + Q_r)}{\partial I_r^r} = 0 \quad (39)$$

$$\frac{\begin{array}{c}\partial(\{\frac{3}{c^2}\{M[I_r^{r2} + I_r^{i2}] + NI_r^r + PI_r^i + Q\} + \\ \frac{3}{r_c c^2}\{R(D^2 + E^2)[I_r^{r2} + I_r^{i2}] + TI_r^r + UI_r^i + V\} - \\ \{3\frac{V_s}{c}(EI_r^r + DI_r^i + G) + \\ 3\left[\left(\frac{s}{c}H + r_r\right)I_r^r - \left(\frac{s}{c}I + sX_{lr}\right)I_r^i + \frac{D}{C}sV_s\right]I_r^r\} - \\ \{3\left[\left(\frac{s}{c}I + sX_{lr}\right)I_r^r + \left(\frac{s}{c}H + r_r\right)I_r^i + \frac{s}{c}K\right]I_r^i\}\end{array}}{\partial I_r^r} = 0 \quad (40)$$

Solving (40) we have,

$$2(ah - ec)I_r^r + 2(eb - ag)I_r^i + (bh - gc) = 0 \quad (41)$$

$$Am'I_r^r + Bm'I_r^i + Cm' = 0 \quad (42)$$

Where

$$Am' = 2(ah - ec)\ Bm' = 2(eb - ag)\ Cm' = (bh - gc)$$

$$a = \left(\frac{s}{c}I + sX_{lr}\right)b = \frac{sK}{c} + \frac{EV_s}{c}\ c = \frac{DV_s}{c} - \frac{sDV_s}{c}$$

$$e = MR_c + R(D^2 + E^2)\ g = NR_c + T\ h = PR_c + U$$

From (42) ,we obtain the second formula for I_r^r and I_r^i

$$I_r^i = -\frac{Am'I_r^r + mc'}{Bm'} \quad (43)$$

Substituting (43) into (31) & solving we get;

$$Dm'I_r^r + Em'I_r^r + Fm' = 0 \quad (44)$$

Where,

$$Dm' = W + W\frac{Am'^2}{Bm'^2}$$

$$Em' = W\frac{2Am'Cm'}{Bm'^2} + X - Y\frac{Am'}{Bm'}$$

$$Fm' = W\frac{Cm'^2}{Bm'^2} - Y\frac{Cm'}{Bm'} + X - P_a^*$$

Solving (36) we have;

$$I_r^r = \frac{-Em' \pm \sqrt{Em'^2 - 4Dm'Fm'}}{2Dm'} \quad (45)$$

I_r^i Can then be solved using (43). The pair of solution I_r^r and I_r^i in (45) and (43) with less loss are the desired rotor current components in real and imaginary axes.

Fig. 4 shows the various steps adopted to find out the various stator and rotor currents.

Fig. 5 gives the flow chart for the calculation for the control signal.

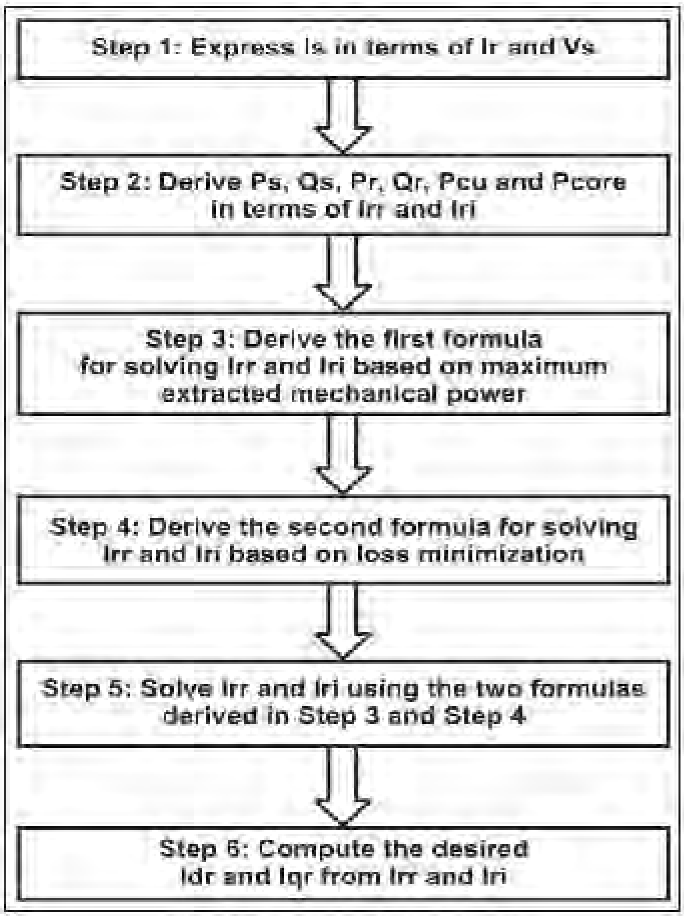

Fig. 4: Flow chart for the optimization

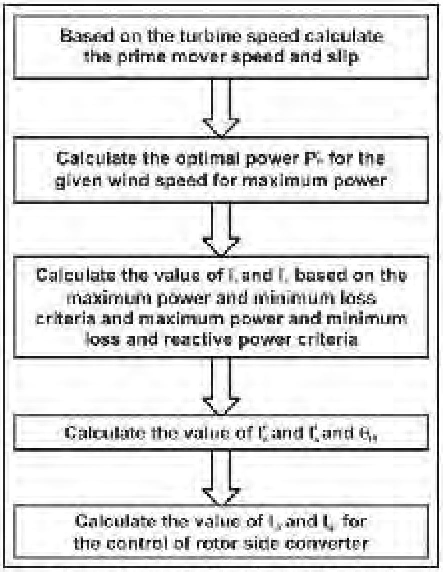

Fig. 5: Computation of control signal

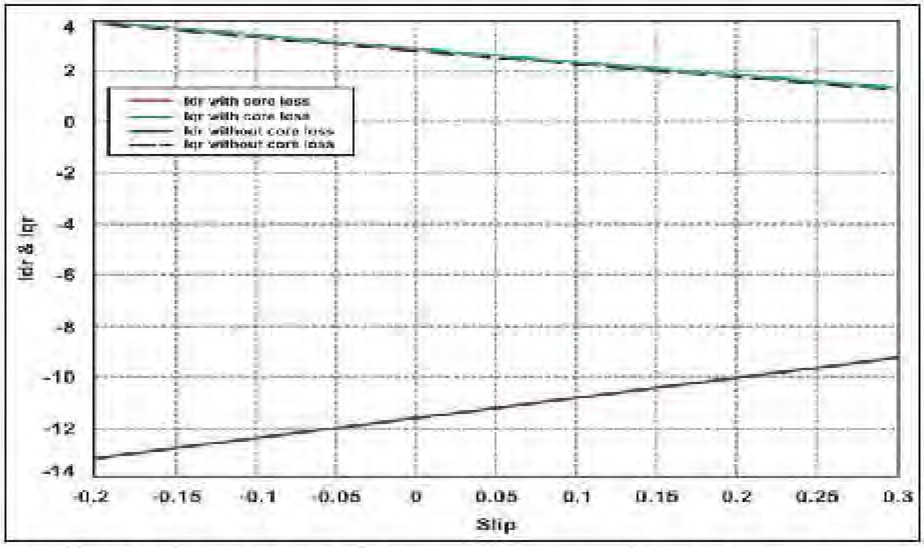

Fig. 6: Variation in I_{dr} and I_{qr} w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

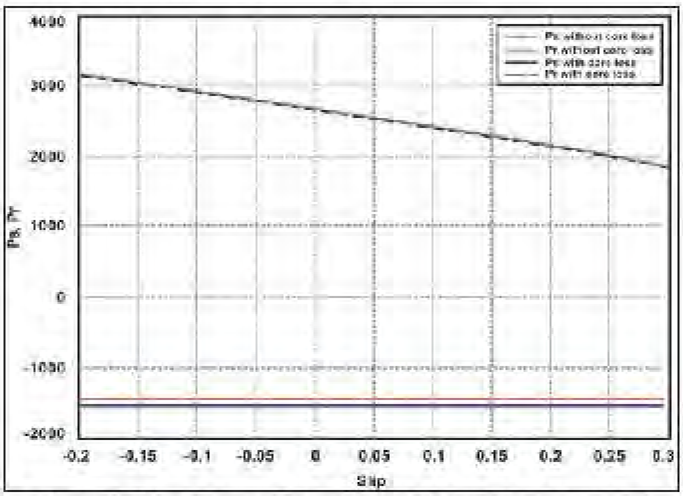

Fig. 7: Variation in P_s and P_r w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

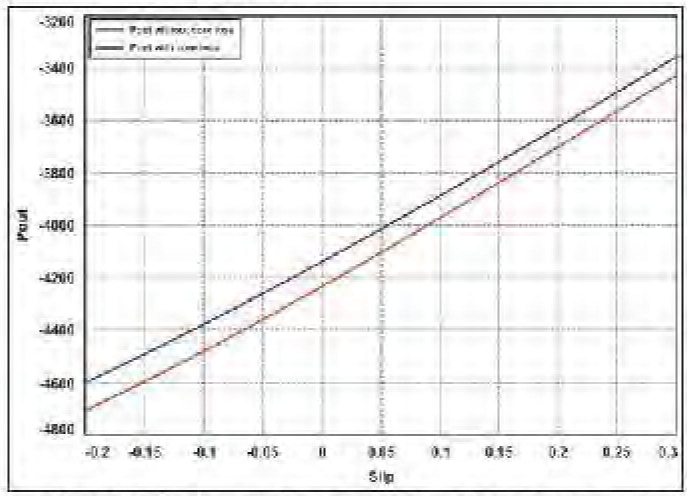

Fig. 8: Variation in output power w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

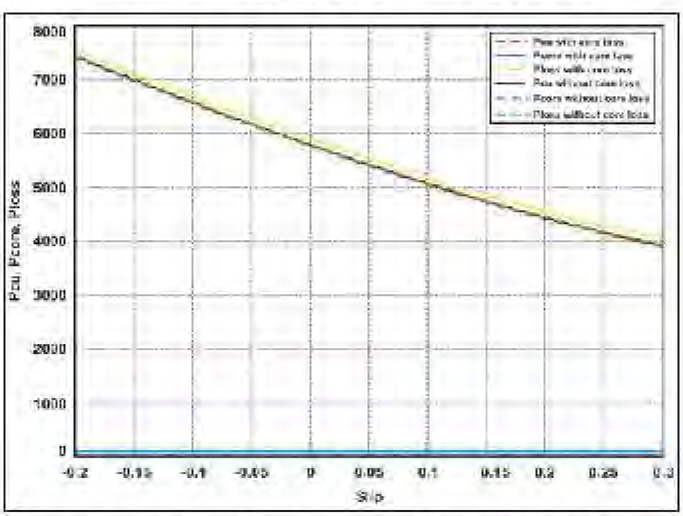

Fig. 9: Variation in P_{cu}, P_{core}, P_{loss}, w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

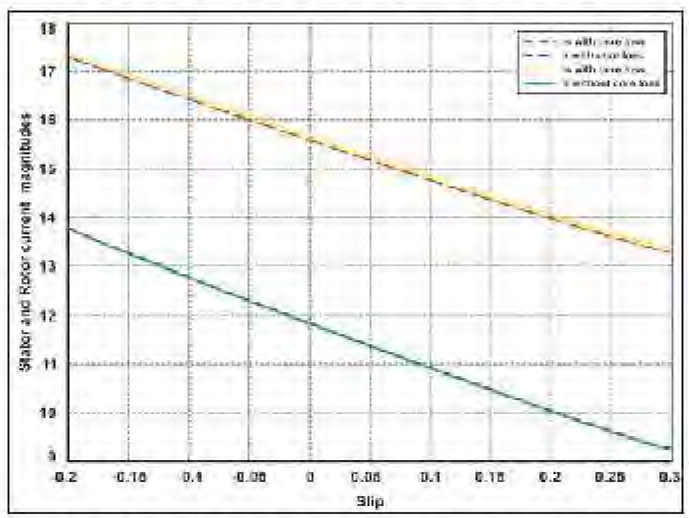

Fig. 10: Variation in I_s, I_r w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

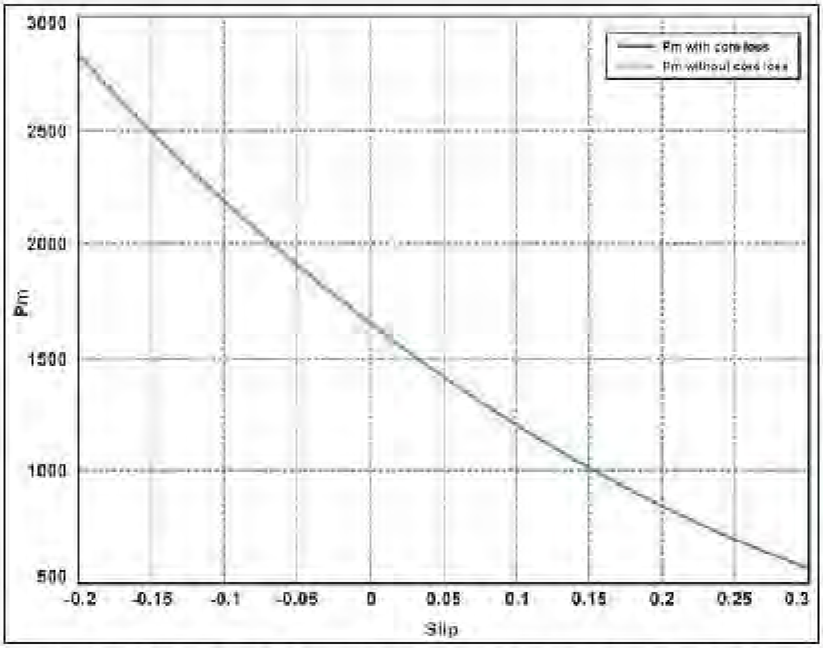

Fig. 11: Variation in P_m w.r.t slip under maximum power and minimum reactive power and minimum loss criteria

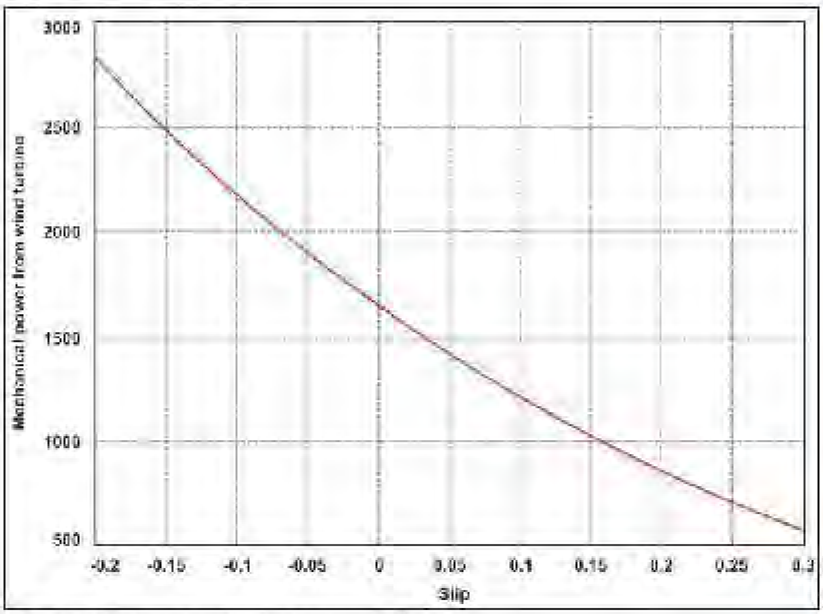

Fig. 12: Maximum mechanical power P_m^* w.r.t Slip

Results and Discussions

This part consists of the simulation results showing the variation of various parameters w.r.t slip when operated under maximum power and minimum loss and reactive power criteria considering the effect of core loss and in the absence of core loss.

When the core loss component was neglected the optimal d-axis and q-axis rotor current components I_{dr} and I_{qr} with maximum extracted mechanical power & minimum losses were computed as functions of slip. The optimization criterion is extended to maximum mechanical power and minimum losses and minimum reactive power.

Considering the condition of maximum mechanical power the DFIG is operated to provide a total power output depending on the speed of the generator.

It is seen from Fig. 7 that variation in Pr is more as compared to Ps and core loss will effect the Ps.

Fig. 8 and Fig. 9 shows that Pout is less if core loss is neglected for a given slip.

Fig. 10 shows that variation in stator and rotor current is almost same but effect of core loss is seen in stator current magnitude.

It can be observed from Fig. 11 and Fig. 12 that there is not much variation in mechanical power considering core loss & neglecting core loss. Further is also observed that irrespective of the optimization criteria the real powers of DFIG are almost of the same value.

Conclusion

In this article the effect of core loss and in the absence of core loss, analytical formulas have been derived for DFIG satisfying the condition of maximum output power tracking (MPPT) and minimum active and reactive losses condition. It is found the stator power, stator current and output power are affected by core loss.

Profile

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Understanding of ARC Flash Hazard in Power Systems

The consideration of arc flash hazards is a relatively new concern for power system design. However, it is a concern that is rapidly gaining momentum due to increasingly strict worker safety standards and system reliability requirements that demand work on live electrical equipment. Recently enacted guidelines and regulations regarding arc flash hazards have focused industry attention on quantifying the dangers of arc flash events in energized low and medium voltage electrical equipment. The arc flash hazard analysis is mandatory and more popular in European Countries and US to ensure safety of the personnel working under live conditions. However, it is becoming popular in India as well, so as to ensure system reliability.

Mrugen Sheth and Amrita Tandon

Since incident energy from an arcing fault is directly proportional to the arc clearing time, reducing the arcing time is very beneficial. It results in reducing the PPE level requirements and limiting direct damage to equipment. This article provides an overview of arc flash hazards, arc flash calculations, and suggests a means of reducing the arc flash hazard level through faster detection and clearing of arc flash electrical faults.

An arcing fault is the flow of current through the air between phase conductors or between phase conductors & neutral ground. Arc flash is the ball of fire and molten metal as well as a pressure force or blast that explodes from an electrical short circuit. Electrical arcs form, when a medium that is normally an insulator, such as air, is subjected to an electric field strong enough to cause it to become ionized. This ionization causes the medium to become a conductor which can carry current. An arcing fault can release tremendous amounts of concentrated radiant energy at the point of the arcing in a small fraction of a second, resulting in extremely high temperatures, a tremendous pressure blast, and shrapnel hurling at high velocity.

Fig. 1: Arc Flash in a Panel

Arc flash temperatures can easily reach 14,000 to 16, 000°F (7760°C to 8871°C). These temperatures can be reached by a fault in several seconds if not several cycles. The heat generated by the high current flow may melt or vaporize the material and create an arc. This arc-flash creates a brilliant flash, intense heat, and a fast moving pressure wave that propels the arcing products.

Some of the effects of an arcing fault include:

- Extreme Heat, Pressure Waves, and Sound Waves
- Molten Metal, Shrapnel and Vapour
- Intense Light.

An arcing fault can release tremendous amounts of concentrated radiant energy at the point of the arcing in a small fraction of a second

Arc flash is related to the available fault current and total clearing time of the over current protective device during a fault. It is not necessarily linear, as lower fault currents can sometimes result in a breaker or fuse taking longer to clear, thus extending the arc duration and thereby raising the arc flash energy. To perform an accurate arc-flash hazard analysis a realistic value for the three-phase bolted fault and the total clearing time for the affected overcurrent protective device must be known. Arc Flash Hazard Analysis and Study is required to be carried out in the installations where the worker is operating under live conditions.

Arc flash is measured in thermal energy units of cal/cm² and for arc flash analysis is referred to as the Incident Energy of the circuit. 1.2 cal/cm² of thermal energy on a person's skin for a short period of time generally produces a second degree burn. A second degree burn, although painful, is considered curable. Second degree burns occur if the temperature of human skin is raised to 175 F(79.4°C) for 0.1 seconds. Depending on the material, clothing may ignite when temperatures reach between 700-1400°F (371-760°C). If clothing and equipment are worn to limit the exposure of the worker to limits below those identified above, the worker should walk away from an accident, with minimal injury.

The intent of an arc flash hazard analysis is first to determine the amount of personal protective equipment (PPE) required by the worker to limit any burn to a second degree burn and second, to determine the safe distance away from energized equipment for unprotected persons.

Type of Faults

A bolted short circuit occurs when the normal circuit current by-pass the load through a very low impedance path resulting in current flow that can be hundreds or thousands of times the normal load current. All equipment needs to have adequate interrupting ratings to safely contain and clear the high fault currents associated with bolted faults.

In contrast, an arcing fault is the flow of current through a higher impedance medium, typically the air, between phase conductors or between phase conductors and neutral or ground. Arcing fault currents can be extremely high in current magnitude approaching the bolted short-circuit current but are typically

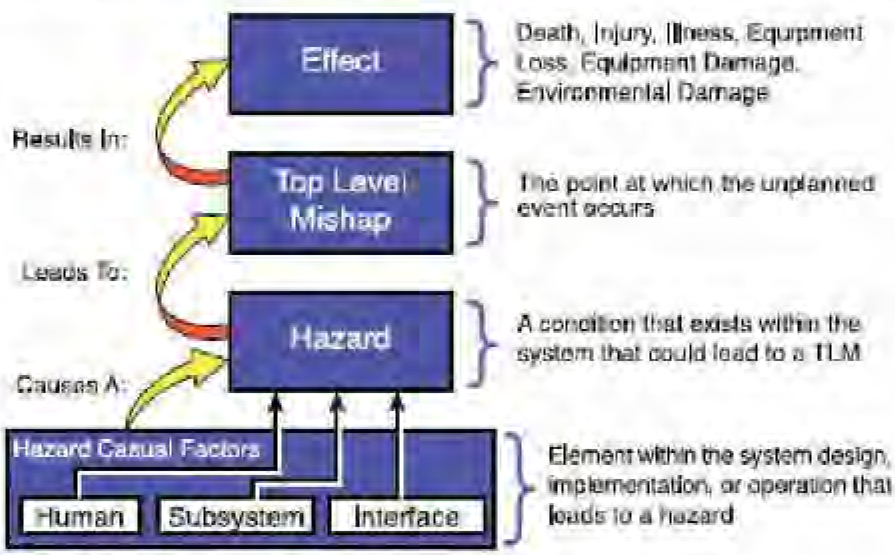

Fig. 2: Arc Flash Hazards and Effect

between 38% and 89% of the bolted fault. The inverse characteristics of typical over-current protective devices generally results in substantially longer clearing times for an arcing fault due to the lower fault values.

The amount of energy released during an arcing fault depends upon the voltage, the current, and the duration of the arc. The arc duration is dependent on the arcing fault current magnitude and the protective device settings. Due to its nature, the magnitude of an arcing fault is subject to many variables and therefore is difficult to perfectly predict.

Causes of Electric Arcs

Arcs can be initiated by the following:

- Accidental touching – Accidental contact with live exposed parts can initiate arc faults
- Dropping of tools - Accidental dropping of tools may cause momentary short circuit, produce sparks and initiate arcs.
- Failure of insulating materials
- Improperly designed or utilized equipment
- Improper work procedures
- Spark Discharge
- Over voltages across narrow gaps – When air gap between conductors of different phases is very narrow, arcs may strike across during over-voltages.
- Dust and Impurities – Dust and impurities on insulating surfaces can provide a path for current, allowing it to flashover and create arc discharge across the surface. Fumes or vapour of chemicals can reduce the breakdown voltage of air and cause arc flash.
- Corrosion – Corrosion of equipment parts can provide impurities on the insulating surfaces. Corrosion also weakens the contacts between terminals, increasing the contact resistance through oxidation or other corrosive contamination. Heat is generated on the contacts and sparks may be produced, this can lead to arcing faults with nearby exposed conductors of different phase or ground.
- Condensation of vapour and water dripping can cause tracking on the surface of insulating materials. This can create a flashover to ground and potential rise to phase to phase arcing.

Fig. 3: Arc Flash Hazard

Reasons to Address Arc Flash

The following are the reasons to address the arc flash.

- Protect the workers from potential harm and prevent loss of life
- Comply with Occupational Safety and Health Administration (OSHA) codes with National Fire Protection Association (NFPA) standards on employee safety, NFPA-70E
- Prevent loss to organisations through loss of skilled manpower, litigation fees, higher insurance costs
- Increases production uptime by reducing accidents.

NFPA 70E & Arc Flash Hazard

Arc flash analysis defines the safety equipment that the maintenance personal will wear and the safe distance to be maintained while working with energized switchgear.

NFPA has defined four various protection boundaries for classification of the arc flash hazard analysis. They are as under:

- Flash Protection Boundary
- Limited Approach Boundary
- Restricted Approach Boundary
- Prohibited Approach Boundary.

Flash Protection Boundary

The Flash Protection Boundary is the distance from the arc source at which the potential incident heat energy from the arcing fault falling on the surface of the skin is 1.2 cal/ cm^2. An exposure to 1.2cal/cm^2 would normally result in curable second degree burn. Within this boundary workers are required to wear protective clothing like fire resistant shirts and pants, and other equipment to cover the various parts of the body.

Limited Approach Boundary

An approach limit at a distance from an exposed live part within which a shock hazard exists. For a person to cross the Limited Approach Boundary and enter the limited space, he or she must be qualified to perform the job/task.

Restricted Approach Boundary

An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to the electrical arc over combined with inadvertent movement, for personnel working in close proximity to the live part.

Prohibited Approach Boundary

An approach limit at a distance from an

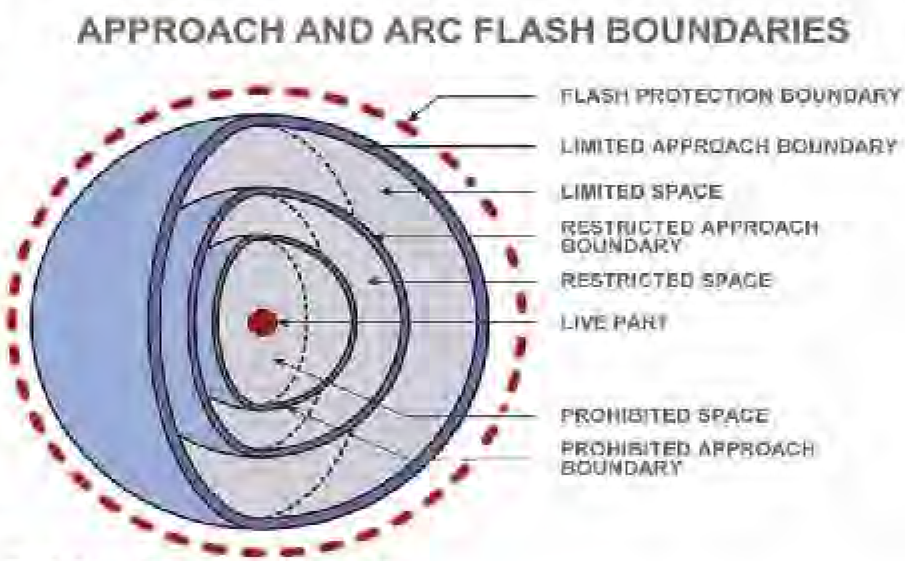

Fig. 4: Approach and Arc Flash Boundaries

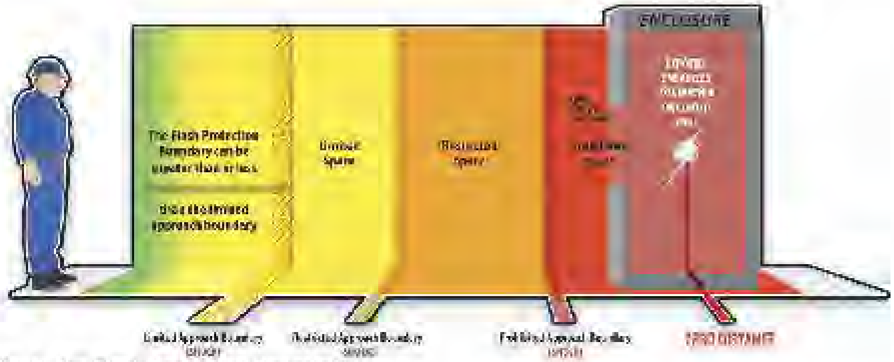

Fig. 5: Arc Flash Protection Boundaries

exposed live part within which, work is considered to be the same as making contact with the live part. Crossing the Prohibited Approach Boundary and entering the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts.

Classification of Hazard Risk Category

NFPA 70E defines 5 levels of risk category for arc flash hazard based upon the calculated incident energy at the working distance (Refer Table 1). As per the risk category, different Personal Protective Equipment (PPE) are required to be worn by the person working near the live equipment.

Practical Steps to Arc Flash Calculations

The following steps are involved in detailed arc flash study. Prior to beginning the data collection, it should be determined and agreed upon which method of calculation will be used.

- Identify all locations/equipments for Arc Flash Hazard Assessment
- Data Collection (Equipment data for short circuit analysis, protective device characteristics, Equipment data for arc flash study, gaps between conductors, type of enclosure, etc)
- Prepare a single line diagram of the system (The SLD can be prepared on any software such as ETAP, PTW, CYME)
- Short Circuit Study to calculate the bolted three phase fault current (The short circuit fault current can be obtained manually using equations or through a software tool)
- Calculate estimated arc current
- Estimate arcing time from the protective device characteristics and the contributing arc current passing through this device for every branch that contributes to the arc fault
- Estimate the incident energy for the equipment at the given working distances
- Determine hazard risk category for the estimated incident energy level
- Estimate the arc flash boundary for the equipment
- Document the assessment in the reports and one line diagrams
- Obtain the warning labels for all protective devices and bus-bars
- Sticking of warning labels at respective panels.

Limiting Arc Exposure

Exposure to arc flash can be limited in three ways.

- Avoiding arc flash incidents
- Reducing level of arc energy released
- Proper use of personal protective equipment (PPE).

Arc flash accidents can be reduced by following: use of proper tools, good preventive maintenance, planning and co-ordination of work, as well as skill development and practical experience. Also, dropping of tools and accidental touching, etc should be avoided. Taking care of the causes of the arc flash is the principal strategy for avoiding exposure.

Accidents may occur despite precautions taken to avoid them. In such cases, it is always better if the incident energy is low and the worker is prepared for the worst by using appropriate PPE.

Category	Energy Level	PPE Requirement	Remarks
0	NA	Non-melting, flammable materials	The Hazard Risk Category (HRC) Levels should be restricted up to Category 2 as the PPE required to be worn are easy to work with.
1	5 cal/ cm^2	Hard hat Safety glasses or safety goggles Hearing protection (ear canal inserts) Heavy duty leather gloves Leather work shoes (All arc rated clothing - minimum arc rating of 5 cal/ cm^2)	
2	8 cal/ cm^2	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Heavy duty leather gloves Leather work shoes (All arc rated clothing - minimum arc rating of 8 cal/ cm^2)	
3	25 cal/ cm^2	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather work shoes (All arc rated clothing - minimum arc rating of 25 cal/ cm^2)	Hazard Risk Category (HRC) of Category 3 and Category 4 shall not be recommended as the PPE used will be bulky.
4	40 cal/ cm^2	Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) Leather work shoes (All arc rated clothing - minimum arc rating of 40 cal/ cm^2)	

Table 1: Incident Energy vs PPE to be worn

Fig. 6: Warning Labels

Selection of PPE

PPE should be selected according to the needs of the worker and nature of work. Some of the factors to be considered while selecting the PPE are: Comfort, Fit, Layers, Materials and Abrasion Resistance.

Reducing Incident Energy on Worker

The incident energy exposure can be reduced by system design or operating procedures. Given below are the several ways to reduce the energy on an existing system.

- Reducing fault level
- Reduce the exposure time
- Remote operation
- Remote racking.

The fault level can be reduced by changing the system configuration, using current limiting fuses/breakers and current limiting reactors.The arcing time can be reduced by reducing safety margin for relay and breaker operation with improved solid state devices, bus differential protection with instantaneous protection, temporary instantaneous trip setting during work, and protective device co-ordination study. New microprocessor based relays can be programmed to supervise manually the closing of a breaker using a "punch" and "run" time that allows the operator 3 to 10 seconds after initiating a "close" to evacuate the vicinity before the breaker is actually closed.

Benefits of Performing Arc Flash Study

Below are some of the benefits of performing an accurate arc-flash hazard analysis:

- Enhance System Reliability - Proper protective device coordination study to ensure closest device to fault opens in the least amount of time - assuming proper periodic maintenance and testing of protective devices per manufacturer's recommendation.
- Equipment Evaluation Analysis is very important - if available fault current is higher than equipment rating severe arc-flash and arc-blast will most likely result.
- Since the system is modelled on software it will be easy to make future changes or upgrade with minimal expense or effort.
- Through the use of proper work procedures, arc flash hazard can be avoided and thus increased productivity is achieved.
- Drastically lessen your chances of having to make a very unpleasant visit to survivors.
- Provide the best possible PPE for electrical workers and technicians.
- Possibly lower insurance premiums.
- Brings electrical system up to date by providing current one-line diagram.

Conclusion

The article presents the basic understanding of an arc flash hazard in power system. One of the easiest and most cost effective means of limiting arc flash hazards is accomplished by limiting the arcing time. For calculating incident energy levels in the power system, one can refer IEEE 1584 standard which is based on empirical equations developed from statistical analysis from numerous laboratory tests.

Profile

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BE Electrical from MS University, Vadodara is currently working with L&T Technology Services, Vadodara as a Manager. He has experience of 17 years and has executed various projects for FMCG and Chemical Industries in India and US. He also has hands on experience in commissioning activities.

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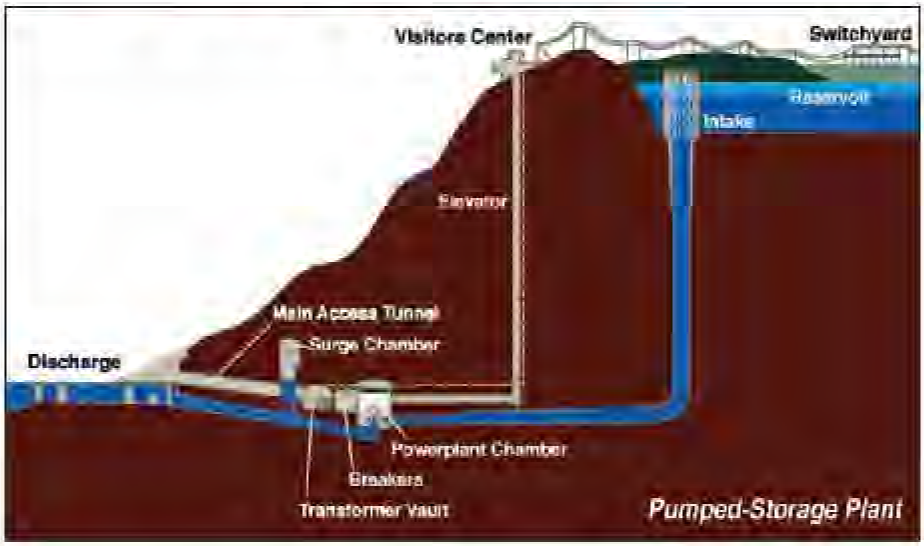
Energy Storage at Generation and Transmission levels



Recent developments in energy storage technologies have provided new opportunities, to operate the electric grid more efficiently, using energy storage systems. The emerging deployment trend of renewable sources and the trade in liberalized markets make higher demands upon the transmission network. This creates excellent opportunities for energy storage. Traditionally, electric energy was converted indirectly to another energy source such as batteries and flywheels for storage. The relatively new technologies of super conducting magnetic energy storage (SMES) and super capacitors can now store electric energy directly, even though the electric energy was so far considered economically non-storable. An idea of a global hydrogen economy energy storing system has assumed importance recently. A review of various energy storage technologies is presented in this article.

C S Indulkar and K Ramalingam

Since the electric grid has no substantial storage capacity, there has to be an instantaneous balance between generated electric power and stochastic demand. This balancing is difficult. The modern grid has thousands of power plants and millions of consumers and has to be rebalanced every few seconds. Electrical energy storage relieves this stringent balancing requirement. Recent developments in Supercapacitors and Superconducting Magnetic Energy Storage (SMES) systems have provided new possibilities for electrical energy storage in the future. Smart grid networks and energy storage technologies are gaining importance with larger-scale deployments plans in energy sector in the near future. Numerous nationwide smart grid deployment projects and advancements in energy storage markets are expected in the next few years. The success of these developments will certainly influence the respective technology's development. An application of energy storage is in vehicles (hybrid cars), and also at distribution and consumer levels (UPS, distributed energy storage)., Small-scale energy storage is needed for these distribution level applications. The application of large-scale energy storage is at generation and transmission level. However, energy storage is not restricted to single levels only, but is required at all levels from consumer to generation.

In view of the new opportunities and applications of energy storage systems, a review of various energy storage technologies, such as pumped hydro, compressed air energy storage, battery storage, flywheels, supercapacitors, superconducting magnetic energy storage, and hydrogen, are discussed below.

Energy storage at generation level

The production of electrical energy at any time equals the demand, including transmission losses and consumption. In a liberalized market, grid users try to balance their portfolios and the grid operator balances the system in real time. Both face a difficult balancing task, because of the following problems:

Unpredictability of supply

This is especially important for the emerging renewable energy sources, e.g. wind and solar power, which are neither controllable

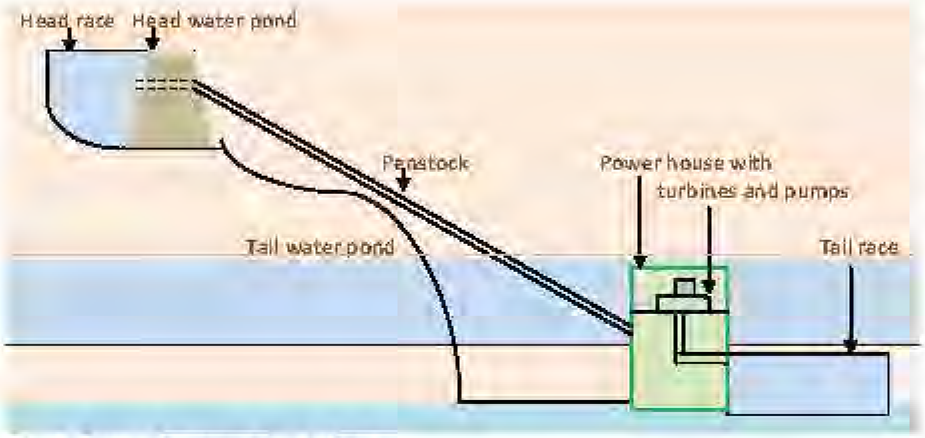


Fig. 1: Pumped storage power plant

nor reliable. A storage facility (operating reserve) can store energy in off-peak hours and inject energy during peak demands. This practice of load levelling allows for lower capacity and less expensive peaking generators, thus lowering the overall production cost. An additional advantage of using less peaking generators is the reduction of greenhouse gas emissions.

Variable demand for electrical energy

A flattening of the demand curve (load levelling) is advantageous, because less production capacity is needed for the same electrical energy consumption, and the generating units can operate at a higher efficiency. The methods to reduce the difference between peak and off-peak demand are referred to as 'load management', which is one of the aspects of demand side management (DSM). Examples of load management are: using different tariffs for day and night hours, and using high charges for high peak demands. This in turn creates an incentive for the customers to take measures such as peak-shaving and load shifting.

Stochastic nature and limited predictability of the variable demand

The load demand is unpredictable and stochastic in nature. In order to react on fast deviations from the expected demand, enough reserve capacity is needed. The more the uncertainty, the more is the need for reserve capacity. It is thus advantageous to reduce the uncertainty of the demand curve. This problem is alleviated by using energy storage.

The most important application of energy storage is balancing of supply and demand. Some energy storage facilities also have black-start capability, rendering them extremely useful for restoring power after a blackout. Energy storage can also be used as long term reserve, standby reserve or spinning reserve. Energy storage technologies are broadly classified as indirect storage that includes Batteries, Flywheels, Pumped Hydro, Compressed Air technologies and Hydrogen storage technologies. Direct storage technologies include Superconducting Magnetic Energy Storage system and electrically storing energy system with Super capacitors.

Energy storage at transmission level

In the transmission grid, energy storage can be used to improve power quality by correcting voltage sags, flicker and surges. It can also provide transmission line stability and power oscillation damping (POD). At the transmission level, the dynamic behaviour of the energy storage facilities is more important than at the generation level. Table 1 gives an overview of some common utility-side energy storage applications and the technical characteristics that are required at the generation and transmission levels.

Pumped Hydro

Electrical energy is used to pump water from a low reservoir to a high reservoir. The energy is stored as potential energy. Water from the high reservoir flows to the lower one through a turbine which drives an alternator. Worldwide, pumped hydro facilities can produce about 130 gigawatts. The operating cost of pumped hydro is low; it is reliable and has a long lifetime. This storage method can have large power ratings and a fairly fast response time for its size; typically the time to go from full load pumping to full load generation is in the order of minutes. The efficiency is approximately 75%.

The front image in this article shows the pumped hydro storage power plant. During off-peak hours, some of the surplus electric energy is generated by the base load plant. This is utilized to pump water from the tail water pond into the head water plant. During times of peak load, this energy is released by allowing the water to flow from the head water pond to the turbine.

In older plants, there were separate motor-driven pumps and turbine driven generators. Nowadays, the pump and turbine are provided on the same shaft with the electrical machine acting as either motor or generator. The latest design is to use a Francis turbine, which works as a centrifugal pump in the reverse direction of rotation with the help of a motor.

A serious disadvantage of pumped hydro is the dependence of the design on specific

	Operating reserve	Load leveling	Black-start	Power quality	Transmission line stability	Power oscillation damping
	Generation			Transmission		
Power [MW]	100	100	100	< 1	100	<1
Back up time	hours	hours	hours	minutes	seconds	seconds
Cycles/year	20-50	250	seldom	< 100	100	100
Response time	Seconds to 10 mins.	mins.	< 1min	cycles	cycles	cycles

Table 1: Technical requirements of storage applications

geological formations. Mostly, these geological constraints cause difficulty in construction. The investment cost of a pumped hydro installation is high. There are furthermore environmental concerns: large pumped hydro installations can be disruptive to the ecosystem, e. g changed river flows can affect the water quality and threaten species protection.

Moreover, the development of new, high-head pumps increases the number of usable geological formations. However, if the reservoirs are higher, they can be smaller in size, thereby reducing environmental impact. Apart from the smaller size reservoirs, the use of variable speed drives improves the efficiency and dynamic behaviour. A new concept, wind-pumped hydro storage, uses excess wind energy to fill a reservoir.

There is rising public opposition to pumped hydro because of environmental damage. Partially due to this opposition, and partly due to geological constraints, there is limited prospect for new projects. Other storage technologies, notably compressed air energy storage (CAES), have been developed that are less taxing to the environment, less dependent on geological formations and that can compete with pumped hydro with respect to storage capacity and cost. Table 2 gives the technical characteristics of pumped hydro and all other energy storage elements.

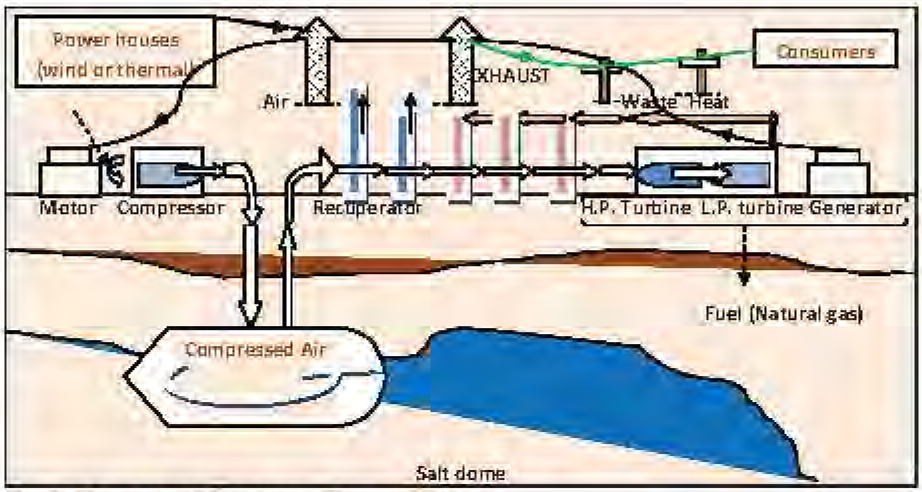


Fig. 1: Compressed Air Energy Storage Plant

Energy storage elements	Power	Back-up time	Response time	Efficiency	Lifetime
Pumped hydro	200MW- 2GW	hours	~ 12 mins.	~ 75%	~ 50 yrs.
Compressed air energy	25MW-2.7GW	hours	~12 mins.	~ 70%	< 50 yrs.
Battery energy	kWs – 50MW	hours	seconds	~ 80%	< 10 yrs.
Mechanical energy (Flywheel)	5kW-3 MW	mins.	~ 12 mins.	< 95%	~ 20 yrs.
SMES	10kW – 3 MW	secs.	millisecs.	~ 95%	~ 30 yrs.
Supercapacitors	< 150 MW	secs.	millisecs.	< 95%	> 10 yrs.

Table 2: Technical characteristics of various energy storage elements

Compressed Air Energy Storage (CAES)

An alternative to pumped hydro storage is CAES. A compressor train compresses air, which is then stored in an underground cavern. When electric energy is needed, the air runs through an expander train, which drives an electric generator. A conventional CAES facility uses fossil fuel before expansion. Therefore, CAES storage is regarded as a production plant (gas turbine) instead of a storage facility.

Compressed air is also used as a storage medium, a strategy that yields just a few hundred megawatts in total, about as much as battery-based energy–storage facilities can now produce. Compressed air energy storage facilities are very well suited to applications, which require high power and energy ratings. The storing losses are very small; energy can be stored for more than a year. The start-up time is approximately 12 minutes, comparable to pumped hydro and faster than conventional generation plants.

The main drawback of CAES plant is the need for suitable geological structures, such as mined salt caverns or natural rock caverns. Compared to pumped hydro, however, there are less geographical restrictions. Although it is possible to construct artificial caverns, this is not recommended because of the high cost. Fig. 1 shows a compressed air energy storage plant. Advanced adiabatic compressed air energy storage (AA-CAES) is a further development of conventional, adiabatic CAES with higher cycle efficiency. During compression, a conventional CAES facility loses heat, which must be regenerated, using fossil fuel, before expansion. AA-CAES plants have a separate thermal energy store that is used during expansion, eliminating the use of fuel. An advantage of AA-CAES is zero emissions. The costs of fuel are likely to rise with time. Conventional CAES requires natural gas or distillate oil to operate. In the long term, these fuels will become less attractive for electricity generation. Table 2 shows the technical characteristics of CAES.

Battery Energy Storage (BES)

A Battery Energy Storage system stores energy by using electrochemical reaction. Batteries can be found in many sizes and power ratings. Many different types have been developed, but the main principle behind all batteries is the same. Battery technology has advanced enormously in the past decade due to investments made by the consumer-electronics and electric-vehicle industries. The research applied to those industries is now being applied to batteries for the grid. Figure 2 shows a grid-tied and photovoltaic array -tied battery system.

The use of BES systems for load levelling alone is not cost effective. However, batteries

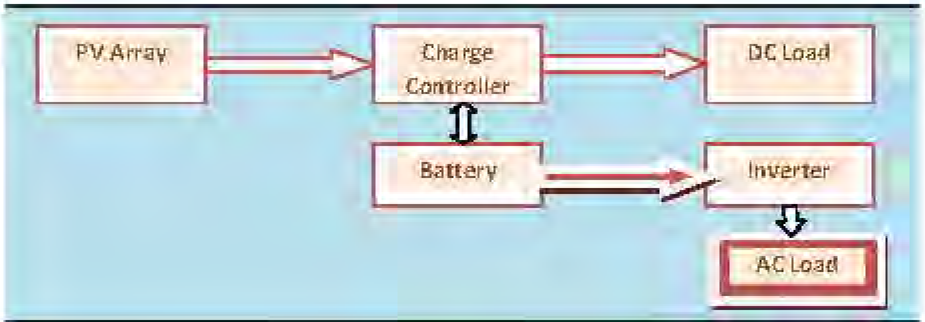


Fig. 2: Battery Energy Storage System

cover an extremely wide range, making them suitable for almost all energy storage applications. Therefore, one installation can be used for multiple applications, which can render its use cost effective. An example is the BES system in Puerto Rico (20 MW, 14 MWh), providing spinning reserve as well as voltage and frequency control. Batteries have a fast response time. While a gas turbine needs up to 30 minutes to start, a BES system needs only a few seconds. The standby losses are low and both energy efficiency and density are high.

However, BES systems have a limited lifetime, since batteries have to be replaced periodically. Also, maintenance requirements are generally higher than with competing technologies. The energy storage capacities of pumped hydro and CAES can currently not be attained by using BES systems, and the storage capacity in terms of hours of storage is less as well. Batteries are very sensitive to heat, and the service life can be reduced considerably, if operated above the rated temperature. New types of batteries do not suffer from these drawbacks as much, since they are more robust and not that sensitive to heat or charge variations. The investment cost is, however, higher.

Large scale distributed generation and the connection of renewable to the grid will create the need for additional energy storage systems. Fig. 3 shows the schematic of grid-connected battery storage and PV array systems.

BES is an interesting option. A new evolution in battery technology is the flow-battery. The principle of energy storage in the flow battery is different from the one in classical batteries. Electrical energy is stored or released by a reversible, ion exchanging, electrochemical reaction between two salt solutions-the electrolytes that are pumped through two separate circuits.

Flow batteries have numerous advantages over their conventional counterparts: high discharge depth, high cycle life, high capacity and reduced maintenance requirements. Energy density and efficiency, however, are lower.

There is concern about possible ecological damage caused by batteries. Batteries contain toxic materials which are injurious to the environment. Special care has to be taken when disposing of waste batteries. Table 2 shows the technical characteristics of battery energy storage.

- Considering low power permanent applications, lithium-ion batteries are the most successful technology.
- In small electrical systems, up to a few kWh, located in isolated areas such as renewable resources, lead-acid battery can be considered the most appropriate technology on electrical performance and cost.
- For electrical systems up to a few hundred kWh, lead acid battery is still the best, better than lithium-ion battery, because of the cost. Other storage technologies can be small compressed air and flow batteries, but they are less efficient or more costly.
- In electrical systems of many MWh, high energy storage technologies are required, such as large compressed air and flow batteries.

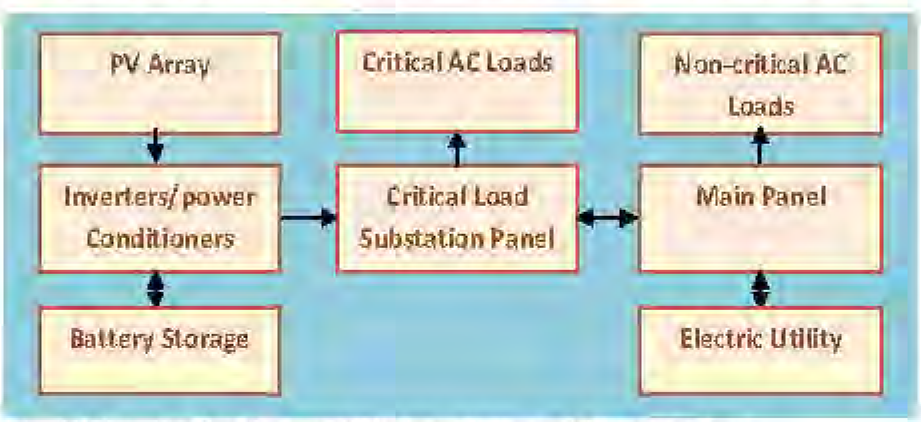


Fig. 3: Schematic of grid-connected battery storage and PV array systems

Flywheel energy storage (FES)

Regarding power-quality applications, the most important characteristics are energy discharged speed and cycling ability. In this sense, flywheels and supercapacitors are the most appropriate.

A flywheel is a mass spinning around an axis. Flywheels store energy mechanically in the form of kinetic energy. The increase of kinetic energy is proportional to mass and quadratic to speed. It is, therefore, necessary to use low density, high tensile strength materials, which can spin extremely fast, rather than high-density materials.

The conversion process from electrical to mechanical energy and back to electrical energy is very efficient. Friction can be significantly reduced by installation in a sealed vacuum chamber and by magnetic suspension. Flywheels typically have a long lifetime and high energy density. With respect to the environment, FES systems are less potentially damaging than BES systems. The charge/discharge rate is limited only by the motor/generator and can therefore be very fast, and several charge and discharge cycles within a few minutes are possible. Fig. 4 shows the flywheel energy generator.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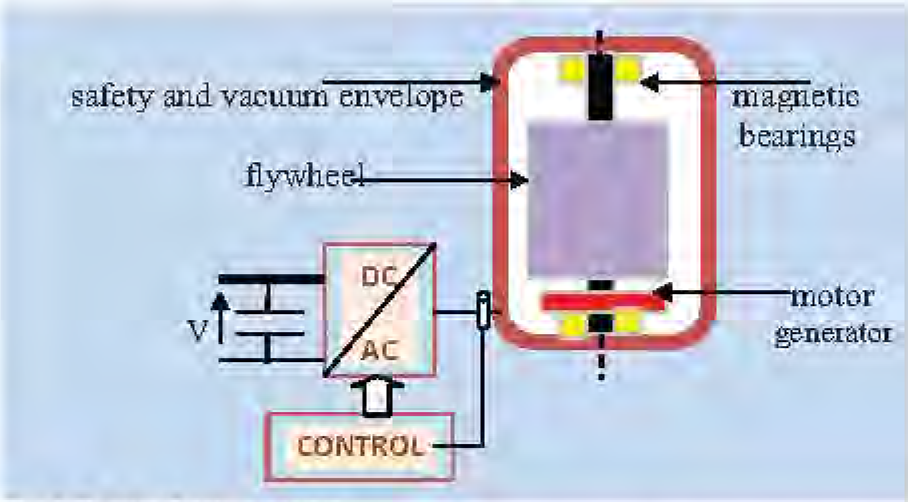

Fig. 4: Flywheel Energy generator

Being mechanical devices, flywheels require quite a lot of maintenance. Flywheels have a fairly low specific energy and the cost is too high to compete effectively with batteries for any application above the 10 minutes range. For high speeds, a converter is necessary. With regards to safety, it is difficult to use flywheels on a large scale. Due to danger of flywheel explosion, containment vessels are needed, which negatively contribute to the cost, weight, and size of the installation. Table 2 shows the technical characteristics of FES.

Supercapacitors

The modern supercapacitor is not a battery per se but crosses the boundary into battery technology by using special electrodes, the double-layer capacitor (DLC) concept and electrolyte. It is carbon-based, has an organic electrolyte that is easy to manufacture and is the most common system in use today. All capacitors have voltage limits. While the electrostatic capacitor can be made to withstand high voltages, the supercapacitor is confined to 2.5–2.7 V. Voltages of 2.8V and higher are possible but they would reduce the service life. To achieve higher voltages, several supercapacitors are connected in series. This has disadvantages. Serial connection reduces the total capacitance, and strings of more than three capacitors require voltage balancing to prevent over voltage in any cell. This is similar to the use of protection circuit in lithium-ion batteries. The specific energy of the supercapacitor is low and ranges from 1 to 30Wh/kg. Although high compared to a regular capacitor, 30Wh/kg is one-fifth that of a consumer Li-ion battery. The discharge curve of the supercapacitor is another disadvantage. Whereas the electrochemical battery delivers a steady voltage in the usable power band, the voltage of the supercapacitor decreases on a linear scale from full to zero voltage. This reduces the usable power spectrum and much of the stored energy is left behind. Supercapacitors discharge & recharge quickly.

Electrical energy can be stored directly by using supercapacitors, which are also known as ultracapacitors. Supercapacitors store electrical energy in the electric field between two electrodes by applying DC voltage. The operating principle of supercapacitors, as shown in Fig. 5, is well-known. The technology is enhanced by using modern materials, which have higher dielectric constants, thus providing much higher energy storage capacity. While conventional capacitors have high power and low energy, supercapacitors have high power as well as high energy. The back-up time is generally limited to not more than a few seconds. Supercapacitors have very fast charge and discharge rates. Supercapacitors are safe because of the fast discharge rate. The cycle life is virtually infinite and no maintenance is required. Furthermore, supercapacitors are environmental friendly. However, the DC voltage requires a converter, which negatively influences the efficiency and cost. The cost of supercapacitors is high.

Supercapacitors have a number of distinctive advantages over batteries. They can be recharged much faster than batteries and supercapacitors have lower weight and a longer lifetime, which renders them particularly suitable for transportation applications. Furthermore, the energy storage capacity of capacitors does not diminish after time. Therefore, supercapacitors can replace batteries in some applications. Another possibility is to combine supercapacitors and batteries in some applications, so that the cycling-duty of the batteries can be reduced increasing their lifetime. The combination of batteries and supercapacitors is well suited to provide power to loads that require pulsed and variable energy consumption. For utility-side application of energy storage, other technologies are more mature and cost-effective than supercapacitors. Table 2 shows the technical characteristics of Supercapacitors.

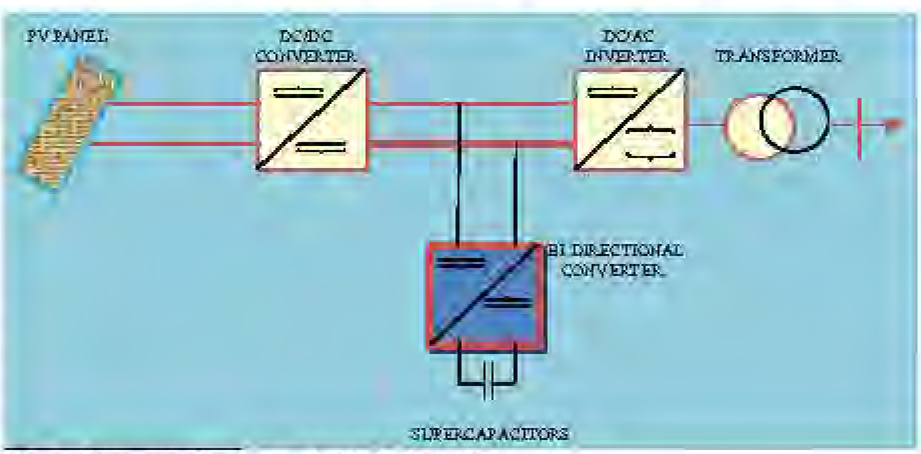

Fig. 5: Supercapacitor in an electrical microgrid

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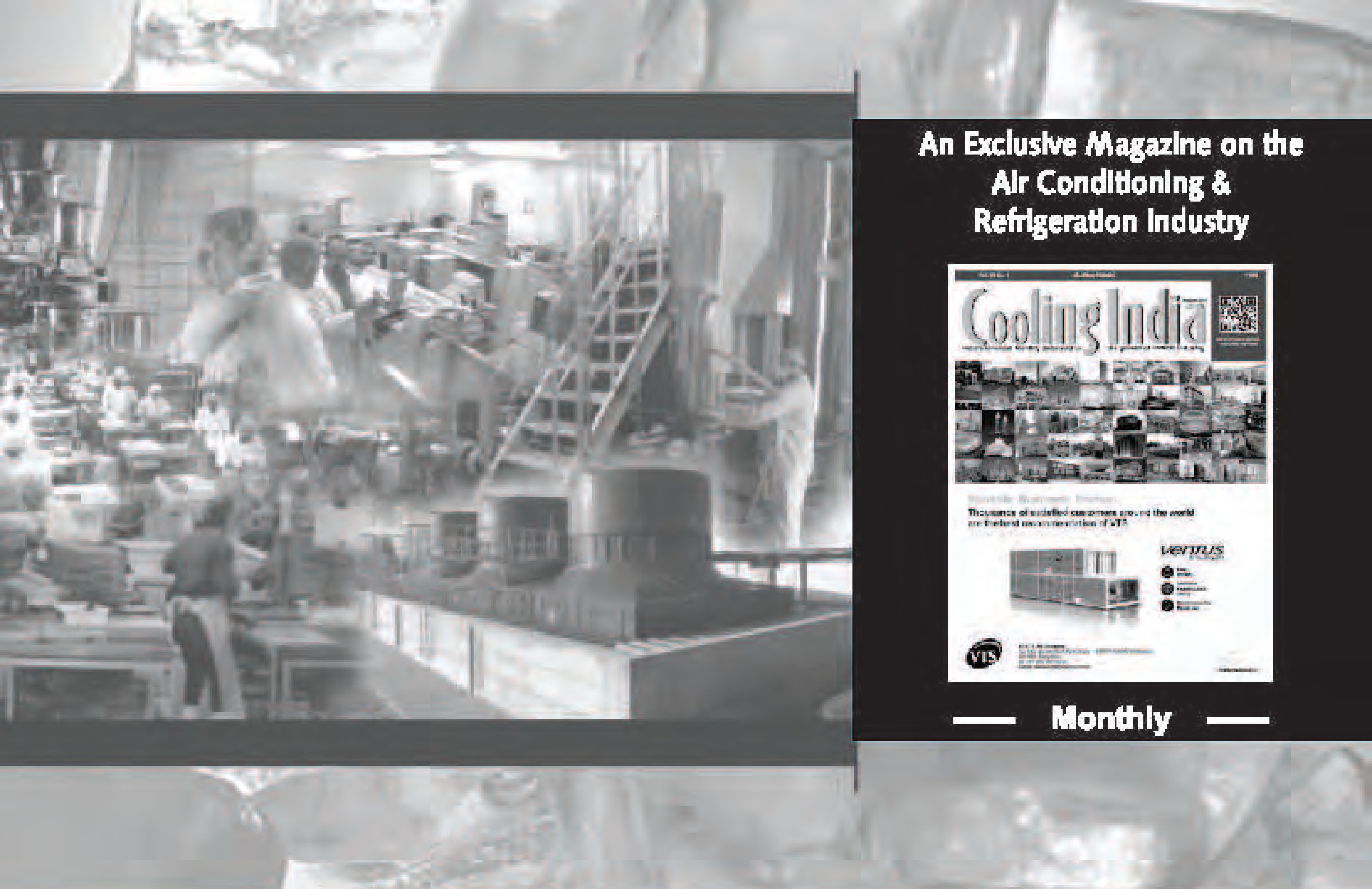
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Superconducting magnetic energy storage (SMES)

Superconducting Magnetic Energy Storage (SMES) stores electric energy in the magnetic field generated by a current flowing through a coil, generally made of niobium-titanium (NbTi) filaments, that operates at very low temperatures. While the coil is in superconducting state, it has virtually no electrical resistance, thus allowing the coil to carry currents with practically no ohmic loss. Since SMES stores electric energy directly, its efficiency is very high. There are no moving parts in an SMES system, it requires little maintenance and its cycle life is virtually unlimited. Its dynamic performance is far superior to the earlier discussed storage technology, and its response times are in the order of milliseconds. The technology is environmental-friendly.

A major drawback of SMES is price. The power converter represents the largest cost. The ongoing fast evolution in power electronics will cause a reduction in its cost, but cryogenics will remain an important cost factor. Stability is still a major issue in superconductor technology, because an SMES always has the risk of the sudden appearance of normal conducting zones. In such a case, the loss of superconductivity may damage the coil severely. There is a rising public concern about the health effects of electromagnetic fields, because of the huge magnetic fields created with SMES. Special measures (shielding) have to be taken to diminish the magnetic fields substantially. Table 2 shows the technical characteristics of SMES. Figs. 6(a) and 6(b) show the SMES coil and its configurations. Fig. 7 shows the SMES energy storage system.

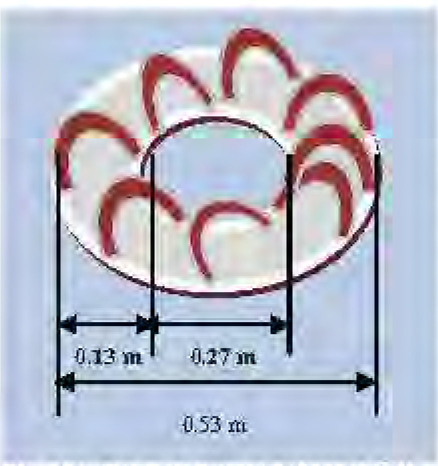

Fig. 6(a): The bare Forced Balanced Coil (FBC) of the SMES system

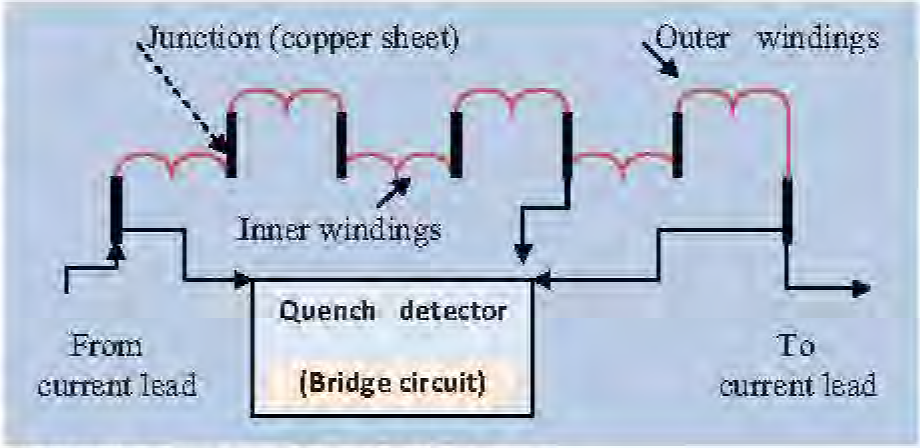

Fig. 6(b): The composition of FBC in the SMES system

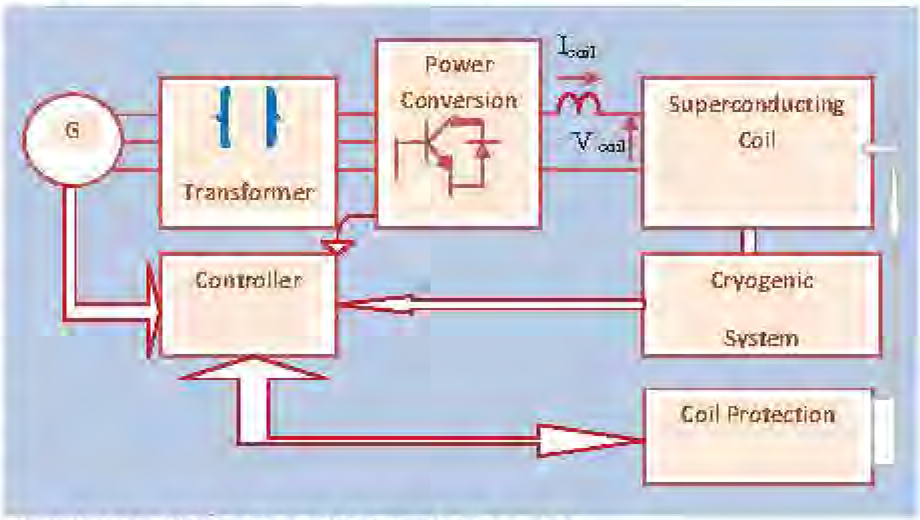

Fig. 7: Superconducting Magnetic Energy Storage system

Hydrogen Storage System

It is likely that a "hydrogen economy" could be the successor of the fossil-fuel era. The possibilities are unlimited and hydrogen could meet in future the current energy challenges. However, satisfactory solutions for storing hydrogen are a huge problem. Hydrogen is not a renewable source of energy. Hydrogen is an energy carrier and must be produced by using energy from other sources, renewable or other. It is compatible with any type of primary energy source. Hydrogen can be produced for instance by electrolysis, water decomposition using electricity as energy source. However, only 4% of hydrogen is produced using electrolysis. The energy can be extracted by a Brayton cycle, fuel cells or a gas turbine.

Hydrogen itself is not a pollutant. For example, when hydrogen would be produced by wind energy, it could provide emission free energy. Hydrogen is the most abundant element in the universe. It is a component of water, which is virtually unlimited. However, converting energy to hydrogen and back is not cheap. The conversion equipment is expensive and the process has high energy consumption. The volumetric energy density is very low, which means that a lot of space is required to store it. Two methods are used to increase volumetric energy density. The first one is compression and is the most widely used. The second one is liquid hydrogen storage. The compression process and especially the liquefaction process

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TEFZEL® CABLE TIES


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HEAT RESISTANT CABLE TIES


MARKER TIES


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DOUBLE LOOP TIES


MOUNTABLE HEAD TIES


BUTTON HEAD TIES


SELF ADHESIVE CABLE TIE MOUNTS


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SELF ADHESIVE TWIST LOCKS


CABLE CLIPS


DUAL NAILS CABLE CLIPS

CABLE PROTECTION


SLOTTED/SOLI WALL WIRING DUCTS


TELEPHONE WIRING DUCTS


WRAPPING BANDS


BUTTON TUBES


HOOK & LOOP TUBES

CONDUITS AND FITTINGS


PE FLEXIBLE CONDUITS


FIVE-PIECE CONDUIT ADAPTORS

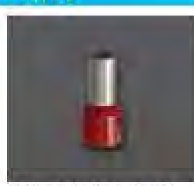

ANGLE TYPE CONDUIT ADAPTORS

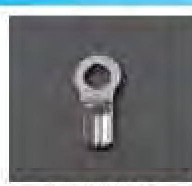

QUICK-FIXED CONDUIT ADAPTORS

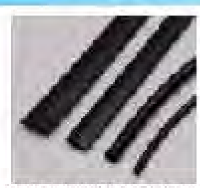

CONDUIT MOUNTING BRACKETS

WIRE TERMINATION


WIRE CONNECTORS


CORD-END TERMINALS


TERMINALS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COPPER / CABLE LUGS

TOOLS


CABLE TIE TOOLS


BANDING TOOLS


MULTI-CUTTER


WIRING DUCT CUTTER


TERMINAL TOOLS

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Email: dhananjay@giantlok.com; http://www.giantlok.com

require a lot of energy. However, the restrictive carbon dioxide emission norms and the higher prices of fossil fuels could be an incentive to accelerate the development of hydrogen technology.

Hydrogen production, storage, and conversion have reached a technological level, although plenty of improvements and new discoveries are still on. Hydrogen storage is a challenge, because materials with either a strong interaction with hydrogen or without any reaction are needed. The conventional hydrogen storage methods are high pressure gas cylinders and liquid hydrogen storage. Further research and technical development will lead to higher volumetric and gravimetric hydrogen density. The best materials known today show a volumetric storage density of 150 kg • m 3, which can still be improved.

At present, hydrogen cannot compete with any other energy storage technology. The losses in production, storage, and conversion to primary energy sources are too high. In the near future, hydrogen storage might be justified in very specific situations, e.g. Seasonal storage in areas, where pumped hydro or CAES are not possible. In the long run, hydrogen could become a very clean and flexible element in the energy supply system.

Conclusions

Bulk energy storage is required at generation level. At present, only pumped hydro, CAES and BES are technically and economically viable for bulk energy storage. Pumped hydro is only suited for large-scale energy storage applications. It is excellent for load levelling, providing black-start capability, and as an operating reserve. There is limited prospect for new pumped hydro projects due to environmental issues. There is room for other large-scale energy storage systems such as CAES facilities. Due to geological constraints, the construction of new CAES, and particularly of new pumped hydro, is, however, limited. However, BES systems have few geological requirements and can be used for all energy storage applications. Battery energy storage systems are technically feasible for bulk energy storage. They are less economic than pumped hydro and CAES. In the small-scale range, BES systems have to compete with newer technologies, such as SMES and supercapacitors.

Many applications are cost-effective with battery storage technologies. The cost-effectiveness is enhanced, if several applications are combined, say for the purpose of load levelling and power line stability.

Small-scale energy storage can be used on transmission and distribution level, where response time is much more crucial than size. BES, SMES, supercapacitors and flywheels are the possible energy storage system. The choice of an energy storage system depends on the requirements of the application. Generally, BES systems are the best choice, because no other system can compete in terms of cost.

However, in applications, where battery systems begin to reach their limits, other solutions like SMES, supercapacitors or flywheels become advantageous. Flywheels are proven for a number of applications, notably motion smoothing and providing of ride-through power for power disturbances. A possible application is the coupling of flywheels with wind turbines to dampen voltage fluctuations. In the higher power ratings, the cost of flywheel energy storage devices becomes too high.

Currently, the application of SMES devices is limited to a few markets, such as the semiconductor industry, where even the shortest voltage dip can be extremely costly. Theoretically, SMES systems could be used for all utility-side applications of energy storage. They can be used to flatten fast-changing loads, even at distribution level. Large-scale systems cause additional problems; e.g. the long coil lengths and the enormous electromechanical forces that require underground imbedding in rock. The R&D efforts are almost solely focused on small-scale SMES systems in applications that benefit the most from the specific characteristics of SMES systems, notably fast response. Examples are oscillation damping, flicker diminishing and power factor correction.

The supercapacitor releases its energy in quick bursts; it does not deliver a steady stream of power for hours at a time. Although supercapacitors clearly have numerous applications in combination with batteries in UPS, telecommunications and in vehicles, they are not suitable for utility-side energy storage.

However, in future, they could have a role in protecting the grid. By using large banks of supercapacitors as a buffer between systems, a complete blackout can be avoided. Hydrogen also will probably have an important role in the future. However, the overall efficiency of the Hydrogen system is too low and the cost is also too high.

Profile

C S Indulkar

IIT Delhi Professor and Head of Electrical Engineering Department (Rtd.), authored a number of technical papers. He has been a reviewer for several International Journals of Electrical Engineering, and also Journal of the Institution of Engineers (India). He was Chairman of IEEE Delhi Section during 1991-92. He is Life Fellow of the Institution of Engineers (India), and Life Senior Member of IEEE.

Dr K Ramalingam

PhD in Electrical Engineering from IIT Delhi, is MD, Super Airport Infrastructure (I) Pvt Ltd, has been Independent Director on the Board of CIAL Aviation Academy, Cochin International Airport, ED (IT) and Regional Executive Director, Airports Authority of India. He has written a number of books, published research papers in journals. He is a reviewer for two International Journals of Electrical Engineering. He is a Life Fellow of Aeronautical Society of India.


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Reduce Diesel Consumption Today - in your DG Set

The air intake suction from the DG skid is ducted out to the cooler ambient area of the DG house.

We are now understanding the prevailing national & regional power position and are facing the stark reality of the necessary costly usage of our own DG set sometimes, with no other alternatives in hand practically as standby. Long back, we have used our DG set sparingly few hours in a week in the industry but now we are forced to use our old & aged (due to neglected maintenance) DG set. So giving the priority to the ageing condition, we can comfort our DG set to get more Units per Liter from the set.

Ashok Sethuraman

Whatever steps we take to increase the power output and decrease the waste outputs like damage control exercise and this will definitely improve the sustained UPL for years, say up to 10 - 20 % to rated output of the given size & condition by the above. Now in any industry we see the trend, first they put the Ridge type for full length of shed / Power-less roof ventilators on their DG & Compressor house only. The roof vents do an excellent work to remove hot radiating air from DG skid area.

DG Set building should be Positive cross ventilated. Increase in air intake temperature from 25⁰C to 40⁰C, the air fuel ratio decreases by about 5%; that is diesel losses happen by 1 % for every 4 ⁰c rise above the outside ambient temperature.

DG Set Optimum Loading in KVA & KW – UPL varies from "2.4 to 3.6" due to loading

Till date, many industries were talking about the ampere output drawn from the DG set as the basic criteria to load the same and are loading up to 60 % only even in the new DG set due to lower PF and religiously following the safest loading as per the guidelines of their DG OEM. Optimum loading around 75 % depending on the load, will give 10 % more units per liter.

Running at the optimum Rated KVA Loading is the priority to get the better UPL, when other parameters of DG set are healthy. Care is taken not to exceed 0.8 to 0.9 PF as the PF of the running loads measured at the DG set. The average loading of motors in the industry indicates around 60 to 70 % it is wise to operate the DG set so as to get at 400 – 405 volts instead of 420-430 volts at heavy load end motor terminals at the plant. This gives

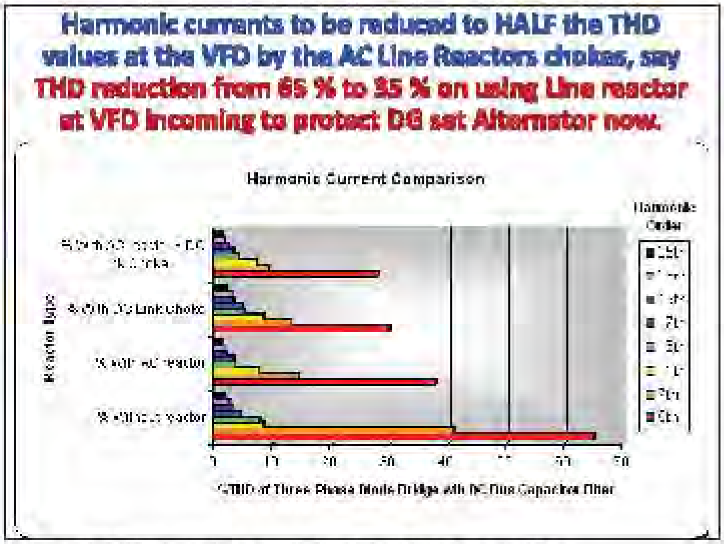
THE TABLE BELOW COMPARES THE BEHAVIOUR OF 5 HP MOTOR AT HIGHER THAN 400 VOLTS

Study taken by Reputed Servo stabilizer Manufacturer

The savings are more visible in lower HP motors than the higher HP motors in the industry.

Input Voltage	Current	KVA	PF
400	7.5 Amps	5.2 Kva	0.8
425	8.3 Amps 11% More	6.2 Kva 18% More	0.7

5 HP motor demands more KVA at 425 volts than at 400 volts.



All the VFD loads to have matched Line Reactor chokes.

instant savings in Diesel and the motor output does not reduce at its shaft.

The DG set is rated by KVA only and hence how much KVA we can take from the DG set is the focus point now. The power factor improvement capacitors on linear loads only not at the incoming of VFD loads etc. The symptom of a good VFD along with line reactor choke is that the VFD maintains PF 0.95 + at the input at the minimum & maximum level of motor loading.

To discuss with the DG vendor about the nature of load if non linear load like UPS, VFD etc, the % of non linear loads and its impact on incoming power quality from the DG to the load, the precautions to oversize the alternator etc. alternatives.

If at all the industry has decided to install Active Harmonic Filter, then it needs to be installed in the Point of Common Coupling so that the THD pollution is not only dumped to EB side but also saves DG alternator, improves DG loading and better UPL.

Hence to have control over the DG output in terms of KVA, KW, and the PF, automation of DG set energy parameters is one of the ways to take the best out of the DG set. So the Maximum Demand Controller MDC & APFC operating at PF 0.9 instead of 0.7 now. These are retrofitted to the existing DG set then, it will cap the max demand from the load to the DG set as well DG set is put to max optimum rating. Its audio visual alarm & trip function to the operator is useful.

If the DG set is forced to run for more hours of month, then it is better to install APFC for a portion of Capacitor requirements at the output of DG set to improve the overall PF of total incoming linear loads to 0.9 PF. After we had done the shifting of many capacitors from MV panel to the major loads like 10 HP motor and above as compensation upto 0.9 PF.

The user can think of replacing ordinary KWH meter in his DG set with this MDC which gives per phase KVAH, KWH, and average PF and he THD in % and this not only acts to monitor but also control max KVA demanded by the load automatically.

The air intake filter Delta P indicator with remote alarm instead of ordinary vacuum red / green band indicator

See the image how the louvers are positioned all round the engine to ensure positive cross ventilation. Umbrella cover at the top of skid ensures that the heat from insulated exhaust piping does not short circuit to the engine suction and internals of skid. We the energy auditors have suggested putting slope duct from alternator to vent at the top of skid from the alternator hot exhaust on both sides of engine.

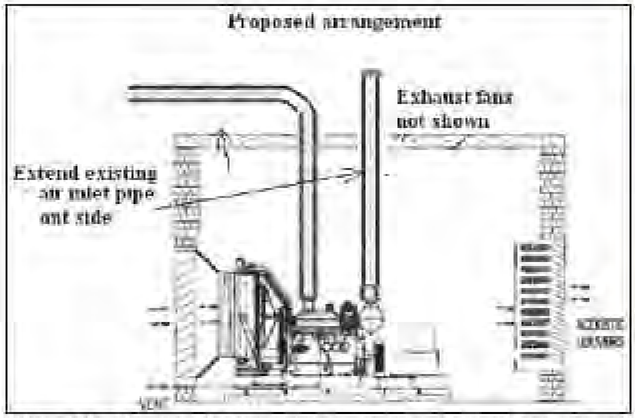
Some users are providing duct into air intake and duct out the heat exchanger exhaust to restore ambience in the room. That is they keep the air intake along with pre filter away from the skid and bring in only the duct to the DG set.

Here the user monitors the Delta P across the air intake filter and never allows the pressure drop to happen across the filter. DP indicator is a must to be viewed regularly for choke in air intake which may lead to higher diesel consumption.

In the DG set the Higher back pressure at exhaust leads to Lower fuel economy, and so to keep the exhaust piping to be minimum and take short cut with minimum Long bends / no bends to out of the DG area in premises. Care is taken not to short circuit the exhaust gas back to the DG house to DG air intake.

When running DG set, use Thermal Imager (nowadays basic imager costs Rs 50 K +) to check the hot spots on the engine, surrounding the engine, like the Air intake, Engine jacket, exhaust piping insulation, Alternator exhaust, etc.

The engine room temp must be near to ambient & not rise more than 5°C above ambient temperature. Keep a temperature sensor (with the visual indicator + remote alarm) near air intake area of DG set. This is easy symptom of DG running health.



The air intake mouth extended to the top of hood and as well alternator side exhaust openings ducted to top.

Micro vee type Pre-filter in place in one industry so as to avoid the open type choked air intake filter.

Exhaust temperature limits the loading and KVA on DG Set. So monitoring exhaust temp is important to know about the possible running rating of engine & optimum loading. Over years we must know how much de-rating in KVA has happened? We understand now why the DG OEM doesn't' allow the consumer to ramp up to 100 % loading and limit to suit to above?

The exhaust piping and the silencers shall be insulated using 50 mm thick mineral wool inside the container & up to the exhaust stack. The insulation shall be cladded with 24G aluminium sheet. Exhaust pipe must not radiate to the skid area.

All over, we find the DG set vendors are selling DG set with acoustic hoods as open terrace mountable type in domestic and commercial areas. But in the industry, when relative noise level difference is within the limits, it is better to go in for open type DG set as long as the DG noise is not polluting the others in the industry as well as the industry or commoner located in next compound. To provide louver type doors / doors with bottom air filters to meet the noise safety levels without starving the engine. But as a user we should give umbrella type sun shade protection with sufficient head room and all sides open area. This is followed by the Telecoms buildings in the open terrace machines, for all their HVAC condensers and other equipments.

Few users are relocating the heat exchanger from the DG skid to out of the house and put the HX in the open area like that of a typical coil cooler all side open with sun shade protection adjacent to the building. The costly but better efficient correction is to have water cooled version instead of air cooled heat exchangers.

Ultimately it is in the hands of the user to comfort the DG set (or the compressor) by ambient cooling and take the best output from the same efficiently and effortlessly by going from air cooled radiator type to water cooled coil cooler type exchanger.

Always Plan Ahead for your DG Set Sustained Efficiency

The low efficiency & the de-rating of the DG set is due to Ageing, Inadequate maintenance, inadequate operation practices, Low capacity utilization, fluctuating load and de-ration effect due to higher flue gas temp & excess back pressure in the exhaust piping. Every component in our running appliance has its wear & tear. The worn & torn parts if replaced in the right interval, gives sustained efficiency to the appliance. This is what the medical world is following now in replacement surgery!

Here in our DG set, we had postponed the preventive maintenance due to few hours run time only per month. Now if we take up the condition based monitoring of the same by first comforting through above steps, definitely will achieve Diesel Savings!

Profile

Ashok Sathuraman

BEE Accredited Energy Auditor has 35 years of Field Experience in India and Abroad. He conducts Energy audits under M/s POWERON Projects, Coimbatore. He shares & publishes energy articles in national magazines and through his website.

Cables for use in Photovoltaic Solar Installations

The energy deficit, Kyoto protocol, legislative support and a growing awareness with respect to renewable energy world-over has lead to the development of so-called "Solar Parks".

Hemant K T

Apart from roof top photovoltaic installations, solar Parks are PV modules installed in groups in rural land and next to a substation of the utility power network, where they are connected to inject the transformed solar power in low or medium voltage. The solar radiation is transformed into current using the PV cells of the modules and transported through a connector to an inverter, which converts the direct current into alternate current to introduce into the network. The power developed will depend on the number of modules installed, for which a range of cables should cover all possibilities. The properties taken into account for these cables are thermal, electrical, conditions under fire and mechanical resistance. The Solar PV cables have to be specifically designed to withstand the above mentioned most demanding conditions.

Solar PV cables form an ideal solution for connection between modules to modules and modules to array junction boxes, operating at room temperature of up to 90 deg C. These cables though not exposed to direct sunlight are throughout the day exposed to diffused/ indirect sunlight and atmospheric temperatures in open air. They have a useful life of 30 years at 90 deg C, and are able to withstand up to 120 C continuous operation in the conductor. Moreover, photovoltaic installations tend to be exposed to all possible atmospheric weather and in all their intensity, especially to ultra-violet radiation, humidity and sudden changes in temperature. For this reason, photovoltaic cables must have a specific weather resistance guarantee that guarantees their operation in time. The materials of the Solar PV cable have to be specially designed to withstand the most demanding weather conditions without suffering important changes in their mechanical and electrical characteristics.

Solar PV cables are essentially Low Smoke Zero Halogen (LSZH) cables. They are designed to assure maximum protection in the event of a fire. These cables are sheathed with fire resistant compounds and do not emit toxic gases or fumes should the cable catch fire. The absence of halogens makes these cables eco-friendly. It also has to offer protection against attacks by rodents in addition to any mechanical aggression. Solar PV cables are manufactured by the normal CV line process or Electron Beam Curing process. The various characteristics of the cables are as follows-

Design Standards

As per TUV 2 Pfg 1169/08-2007

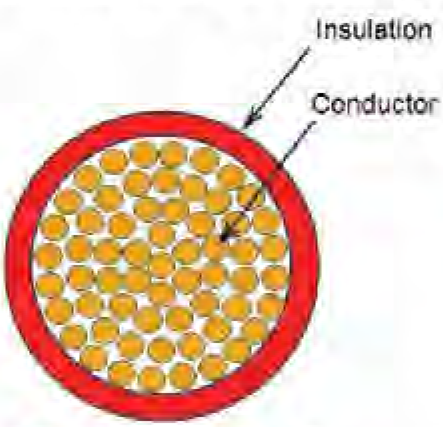
Electrical Characteristics

- Rated AC Voltage: 0.6/1 kV
- Rated DC Voltage: 1.5 kV
- Maximum Permitted DC Voltage: 1.8 kV with circuit in no load condition.
- Maximum Permitted AC Voltage: 0.7/1.2 kV
- Insulation resistance: 1000 m -km
- Spark test: 6000 V AC (8400 V DC)
- Voltage Withstand: 6500 V as per EN-50395 for 5 min.

Construction Characteristics

- Conductor – Electrolytic grade multi stranded tinned copper flexible, class 5 as per IEC 60228.
- Insulation – Cross-linked Halogen free & flame retardant
- Sheath – Cross-linked Halogen free & flame retardant.

The Solar Cables from Array Junction Box to Main Junction Box and Main Junction Box to Inverter are generally not exposed to sunlight and are always routed through PVC Pipes, which are installed on building walls or laid underground. These DC cables should also follow the same specifications as mentioned above. However, there is a general tendency to go for XLPE insulation/LSZH sheathed cables in this area to reduce costs, which is not advisable. The cables from Inverter to Transformer primary side and from the Transformer secondary side to the RMU/Switchyard can be normal underground armored Cables. These cables are either Copper or aluminum XLPE insulated, GI armored, UV stabilized PVC ST2 Sheathed cables of appropriate voltage grade. The EU directives for solar cables are ROHS compliance as per 2002/95/EC.



Stranded core cable

The general practice in India is to purchase cables in bulk and join the same on site with connectors. This depends on the skill set of the installers, which as we all know is becoming a rare commodity now. However, in Europe or many other countries the practice is now to get cables harness as per the site designs. This improves the installation time and also improves the safety standards of the cables eliminating human errors on sites. One of the other practices found in India is the usage of Non TUV approved cables in solar installations. It is mentioned to end users that this is primarily due to cost considerations. However, if these cables are tested you will find that they will not pass the UV resistance tests and are prone to fires. Today most of the fires in the country are attributed to short circuits. Under the circumstances, it is very important to use the proper TUV approved cable. All the users must insist on TUV approved cables to ensure that their installations last for the designed life of 25 years.

Thermal Characteristics		
1.	Ambient temperature	$-40^{0}C$ ~ $+90^{0}C$
2.	Maximum temperature at Conductor	$120^{0}C$
3.	Short Circuit temperature	$200^{0}C$ (at conductor max. 5 sec)
4.	Thermal endurance test	As per EN 60216-2
5.	High temperature Pressure	As per EN 60811-3-1
6.	Damp – Heat test	As per EN 60068-2-78
Mechanical Characteristics		
1.	Minimum bending radius	5 x OD
2.	Dynamic Penetration	As per 2 Pfg1169 annex f
3.	Notch Propagation	As per 2Pfg1169 annex g
4.	Tensile Strength	As per EN 60811
Chemical Characteristic		
1.	Oil resistance	As per EN 60811-2-1.
2.	Ozone resistance	As per EN 50396.
3.	Weathering- UV resistance	As per DIN 53367 or HD 605/A1.
4.	Acid & Alkaline resistance	As per EN 60811-2-1.
Fire Performance		
1.	Flame retardance	As per IEC 60332-1-2.
2.	Low smoke emission < 20%	As per ASTM D-2843.
3.	Halogen Test	As per EN 50267-2-1/-2, IEC 60754-2.
4.	Toxicity	As per EN 50305.

Conclusion

Solar Cables though cost less than 1% of the Capex, form the backbone of any solar installation. Solar installations are pretty new to Indian market and we will come to know of the problems in the solar system only once time passes. Whilst the country has massive expansion plans in Solar, the opportunity for the Cable industry is immense. It is hence imperative for the cable manufacturers to invest in quality and testing standards and at the same time educate the customers of using quality cables.

Profile

Hemant K T

BE Electrical, NIT-Jaipur has been promoting Indian Electrical Cables and accessories in international market for around 3 decades. He was Director of Ravin Cables & presently an Advisor to Sun Cables who specialise in rubber and speciality cables. He has published various articles.

Reliable & Rodent Resistant solar cables with Electron Beam Irradiation Technology

Traditional Fossil fuels are increasingly facing depletion & their harmful effects, both through usage & extraction, have been identified as the key reason of environmental & ecological damage across the globe. These reasons have compelled industries & governments to look for alternative fuel solutions that fulfill the twin objective of being widely available besides having little to minimal impact on the environment.

The Solution - Solar Power

An infinite source of energy available naturally. Diligent research over the last few decades has yielded sophisticated technology to harness solar energy. The successful use of this technology depends on two critical components, viz the solar panels for generating photovoltaic power & the cables to transmit it.

The solar power plant requires cables to

- Transmit from solar panels to invertors - DC Cables
- Output of invertors to transformer input in the substation - LT Power Cables
- Output of transformer to busbar connected to power grid - HT Cables.

Out of these DC Cables are in open, exposed to UV rays of sun, easy access to rodents & squirrel & laid up in trays to inverter input. LT power cables may be buried or laid in trays. This DC Cable transferring to inverter DC power at low voltage through Junction/ Array boxes have the main features as:

- Cables to have 25 years of life: This matches with life expectancy of solar modules so that a solar firm can operate for 25 years without any disruption due to cable failure. However damage due to rodent & squirrel biting needs to be prevented. We have successfully designed & commercialized the rodent resistant solar cable(described later) first time in India.
- Unique Properties: The cables are to be UV & Ozone resistant & also should have Zero halogen & Low smoke properties.
- Contact Resistance: Contact resistance at both ends is to be minimum to prevent loss of power.

Apar Industries Ltd (AIL) (Unit: Uniflex Cables) has successfully developed such a cable variant, using in-house developed special polymeric compounds & electron beam cross linking technology, that meets all of these exacting requirements. A product that is unquestionably far superior to the inefficient substitutes that are lining the domestic market, & in fact, completely on par

Fig. 1: Wire irradiation

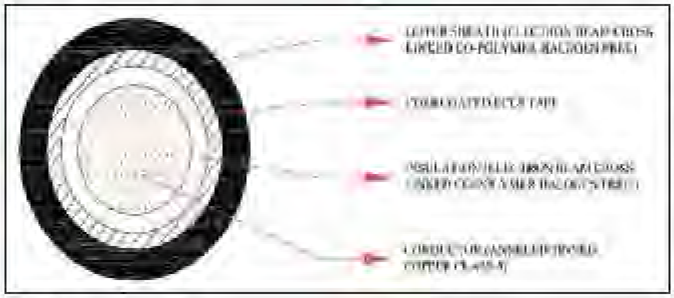


Fig. 2

with similar cables that are manufactured & used in some of the developed countries. MNRE, the Nodal Agency in India is looking for reducing dependence on imported items & is looking forward to Indian manufacturers to come up with indigenous products. AIL's effort is a response to this natural demand. Salient features of Apar's electron beam solar cables are as below.

DC Solar cables for On-Grid/Off-Grid Application –Specification

Flexible Single core cable with flexible electroplated tinned copper conductor insulated with special Electron Beam (EB) cross linked halogen free copolymer, low smoke zero halogen EB crosslinked polyolefin sheathed, UV & ozone resistant. Fig. 1 shows the cables undergoing process of cross linking under electron Beam. Available colors of the external sheath: BLACK & RED.

Features	Requirement / Standard
Rated Voltage (Nominal) Uo /U	0.6 / 1KV or 0.9 / 1.5KV / DC
Maximum Voltage	1.8 KV / DC
Ambient operating temp range	-40^{0}C to +90^{0}C
Max Core Temperature	+120^{0}C (for 20000 hrs)
Max short circuit temp	250^{0}C (max 5 sec)
Test voltage in water (5 min)	6.5 KV AC/15 KV DC
Min Bending Radius (fixed)	5 x Cable dia
No flame propagation	IEC 60332-1-2
No fire propagation	IEC 60332-3 cat C
Gases Corrosively	IEC 60754-2 (pH>4.3) Conductivity < 10µ S/mm
Smoke Density	IEC 61034-2 Light transmittance > 60%
Halogen free	IEC 60754-1 (HCL content < 0.5%)
Ozone resistance	IEC 60811-2-1 & IS6380
Chemical & oil resistance	IEC 60881-1
Weather resistance UV	EN-ISO 4892
Estimated Life	25 years 90^{0}C IEC 60216

The cable is able to satisfy the latest requirements for PV systems as per TUV Spec No.2 Pfg-1169/08.2007 reference standards & technical characteristics given below.

Applications

Flexible cables are suitable for Mobile & fixed installations; Connection between photovoltaic panels to junction box / inverter; Indoor & Outdoor use in dry, damp & wet situations; On trays & in ducts open closed and also meet the weather –UV test. Exceed the thermal endurance test as per EN IEC 60216 for +120^{0}C (temperature index)-

- 20000 hours at 120^{0}C
- Estimated life > 25 years at 90^{0}C

Construction Conductor

Electrolytic annealed electroplated tinned copper conductor, class 5: EN 60228/ IS 8130

Insulation

Halogen free electron beam cross linked thermosetting Elastomeric extruded as solid & homogenous.

Outer Sheath

Halogen free fire retardant electron beam cross linked thermo setting Elastomeric outer sheath, & should have smooth finish Red or Black in colour.

Rodent Resistant

A thin corrugated laminated wild steel tape is provided between the insulation & sheath to prevent damage to solar cable & disrupt its operation. We can also provide glass yarn envelope applied longitudinally between the insulation & sheath. Both of these constructions have been tasted in an external lab & found to be effective in resisting rodent damage successfully. (See Fig. 2.) These cables have undergone TUV testing to specification TUV 2 Pfg-1169/08.2007 & are available commercially.

Conclusion

Thus it is technically evident from above that to meet today's demanding requirements of higher performance standard of cables such as Solar Cables to TUV 2 Pfg 1169/08.2007, Apar Industries Ltd has successfully adopted the state of art electron beam irradiation crosslinked technology to meet the direct and indirect (rodent resistance) needs of our customers and achieve complete satisfaction.

This write up is on APAR's Rodent Proof Solar Cables. Apar Industries Ltd, a technology driven customer focussed company is characterized by realiability, adapability, innovation an leadership in product categories. Apar is into speciality oils, conductors, power, control and telecommunication cables & now commissioned Electron Beam Irriadation facility at Khatalwada Dist. Vapi, Gujrat. APAR is constantly coming with innovative cable solutions. Solar Cable user find that Rodent or Squirrels are damaging PVC outer sheath resulting in short circuiting. It has come out with Rodent Proof Solar Cables after lot of R&D.

Profile

Dr V K Tikku

is PhD in Nuclear Physics from Saha Institute of Nuclear physics, calcutta. He was visiting Scientist in USA & Canada & is a visiting faculty of IIT, Kharagpur. He has published more than 100 papers.

Application of Soft Computing Techniques in **Fault Diagnosis** of Power Transformers

Soft computing techniques play a major role now days for analysis and control of various systems. As fault diagnosis is very important to understand the protection of power transformers, apart from conventional techniques soft computing can be used for fault diagnosis of power transformers. In this article fuzzy logic and artificial neural networks are used and compared for this purpose.

Sukhbir Singh

Transformer is one of the most important but complex component of electricity transmission and distribution system. The trend toward a deregulated global electricity market has put the electric utilities under severe stress to reduce operating costs, enhance the availability of the generation, transmission and distribution equipment and improve the supply of power and service to customers. Much attention is needed on maintenance of transformers in order to have fault free electric supply and to maximize the life and efficiency of a transformer. Thus, it is important to be aware of possible faults those may occur. It is equally important to know how to detect them early.

Formation of Gases in Transformer Oil

The faults that occur within the transformer protection zone are internal faults. Transformer internal faults can be divided into classification: internal short circuit faults and internal incipient faults. Incipient fault detection in power transformer can provide information to predict failures ahead of time so that the necessary corrective actions are taken to prevent outages and reduce downtime. Incipient faults can produce hydrocarbon molecules and carbon oxides due to the thermal decomposition of oil, cellulose, and other solid insulation.

Because the insulating oil used in power transformer is organic (i.e., composed primarily of hydrocarbons), certain fingerprint gases are generated at specific temperature ranges therefore, allowing the traditional methods to identity a possible fault temperature range and therefore the possible fault type. In the normal operation of the transformers, the released gases: Hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon monoxide (CO), carbon dioxide (CO_2) and so on are small in quantities as ageing effects. When there is an abnormal situation, as occurring a fault, some specific gases are produced more than in normal operation and the amount of them in transformer oil increases. This decreases the insulation properties of the transformer oil.

Dissolved Gas Analysis

The faults in power transformers can be detected and monitored for abnormal conditions with dissolved gas analysis (DGA). Throughout the world, different countries/ utilities are using different fault interpretation techniques/tools to diagnose the faults; According to the pattern of the gases composition, their types and quantities, the conventional interpretation approaches below for dissolved gases are extensively followed as:

- IEEE Gas Guide C57.104TM- 2008
- IEC Standards 60599
- IS 10593: 1992 Standards

At first a sample of transformer oil is taken and calculations for sampling intervals can be decided between typical and pre-failure values (e. g. every year for transmission transformer and every six months for nuclear transformers/ power transformer), dissolved gases concentration requiring monthly, weekly, and daily sampling. Then the dissolved gases are extracted, separated and measured by means of chromatography. In order to interpret the results of experiment a data in suitable form to diagnose the faults is produced. The forming of the data is based on different standards.

Duval Triangle 1 Fault Interpretations

Conventional Duval triangle 1 technique used in fault diagnosis through dissolved gas analysis (DGA) in a power transformer is shown in Figure 1. The faults have been divided in seven zones in an equilateral triangle. There are two different procedures to find the faults by the use of Duval triangles;

- By using total accumulated gas
- By using total increase between conjugative samples

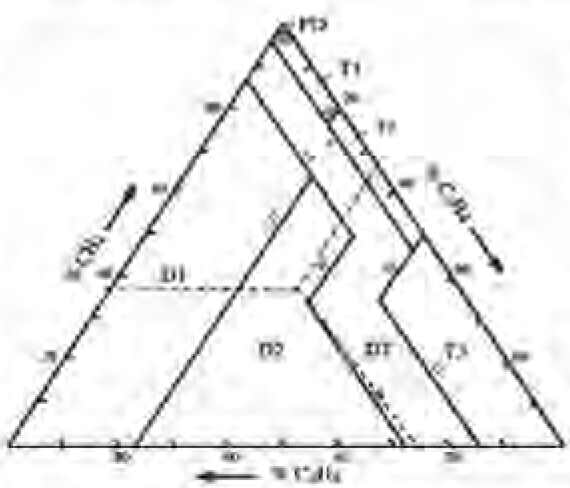


Fig. 1: Duval Triangle 1 fault boundaries

The Dissolved gas analysis involved percentage of these gases only in three dimensional arrangements: Methane (CH_4), Ethylene (C_2H_4) and Acetylene (C_2H_2) in Duval triangle 1 where:

$$\% CH_4 = \frac{100x}{x+y+z} \text{ for, } x = [CH_4] \text{ in ppm (1)}$$

$$\% C_2H_4 = \frac{100y}{x+y+z} \text{ for, } y = [C_2H_4] \text{ in ppm (2)}$$

$$\% C_2H_2 = \frac{100z}{x+y+z} \text{ for, } z = [C_2H_2] \text{ in ppm (3)}$$

First calculate the sum of these three values: ($CH_4 + C_2H_4 + C_2H_2$) = S, in ppm, then, calculate the relative proportion of the three gases, in %:

X = % CH_4 = 100 (A/S), Y = % C_2H_4 = 100 (B/S), Z = % C_2H_2 = 100 (C/S).

X, Y and Z are necessarily between 0 and 100%, and (X + Y + Z) should always = 100 %.

Methodology used for Fuzzy Logic Approach

Step 1: In this research work, firstly, polygon coordinates for the numerical zone boundaries of seven key faults of Duval Triangle 1 have been generated in terms of percentages of CH_4, C_2H_4 and C_2H_2, from 0% to 100% respectively.

Step 2: Fuzzy Diagnosis System, The fuzzy logic analysis involves three successive processes; namely fuzzification, fuzzy inference, and defuzzification. Fuzzzification converts the crisp, the gas percentage into a fuzzy input membership. The fuzzy inference system (FIS) is responsible for creating the knowledge-based fuzzy rules set of If-Then linguistic statements. Defuzzification then converts the fuzzy output values back into crisp output actions.

Fuzzy inputs- gas percentages; in this diagnostic each crisp value of gas percentages (CH_4, C_2H_4, C_2H_2) from table 2 changed to triangular fuzzy-membership function ranges (ie. A.......L, A1.......G1 and A2.......H2 respectively). Fuzzy-membership function for % CH_4 obtained in MATLAB fuzzy-box tool is illustrated in Figure 2.

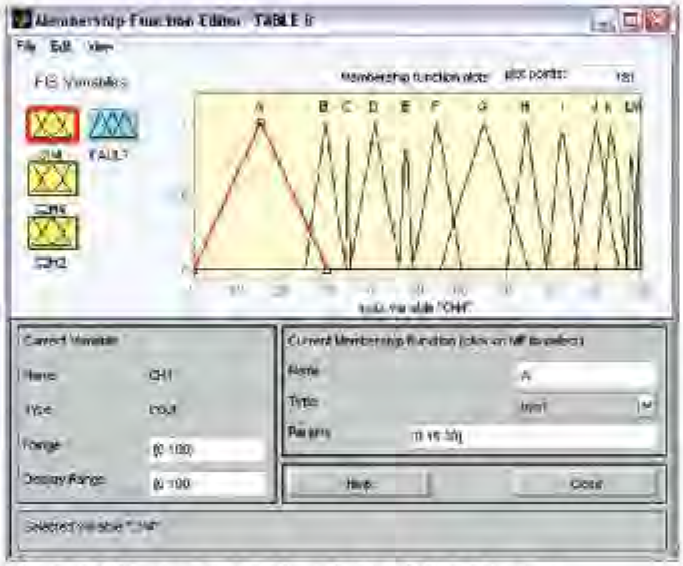


Fig. 2: % CH_4 membership-function in MATLAB toolbox

Fuzzy-rule base; The set of fuzzy inputs (% three gases) with their respective membership function form the integral part of fuzzy logic analysis. The fuzzy rule set (If-then linguistic statements) with AND operator for minimum and OR operator for maximum fault conditions is then used form 'judgement' on the fuzzy inputs derived from the 3 gas percentages, whose sum is always 100%. For example;

Rule 10. If (CH_4 is E) and (C_2H_4 is E1)and (C_2H_2 is D2) then (FAULT is D24)

All such 32 fuzzy rules just derived by mapping the fault types and screenshot of these rules is shown in figure 3 in MATLAB environment. Although these faults are defined strictly for the percentages of the zone boundaries of 7 faults in Duval triangle 1 coordinates. Only 34 rules are just mapped on the joining points of the numerical zone boundaries of the faults in Duval triangle 1 coordinates. Membership function plot of the faults is also illustrated in figure 3 in MATLAB environment.

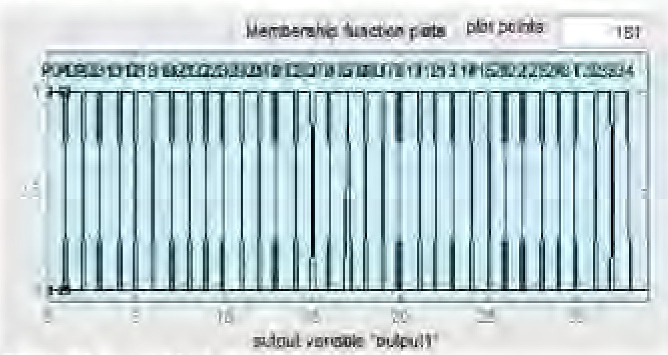


Fig. 3: Membership function of faults

Fuzzy Inference System (FIS) FIS involves the operation between input fuzzy sets as 'Mamdani' type. This derives output fuzzy sets 'judging' all the possible fuzzy rules by finding the membership for the fault types as represented by 32 fuzzy output rules. The solution is reached by weighted average of the fuzzy inputs.

Methodology used for Artificial Neural Network Approach

Feed-forward Back-propagation Artificial Neural Network (ANN)

A well suitable Feed-forward Back-propagation Two-layer artificial neural network has been applied in Duval Triangle 1 method of fault diagnosis in power transformers in this study. A sigmoid activation transfer function is also applied because of its two advantages: firstly, it is highly nonlinear, and secondly, it has good performance when working with back-propagation learning algorithms. Typically, for the conventional back-propagation (BP) training algorithm, the mean square error (MSE) is used.

Following steps are used to achieve the goal;

Step 1; polygon coordinates for the numerical zone boundaries of seven key faults of Duval Triangle 1 being used to create stings of three gas ratios (CH_4, C_2H_4 and C_2H_2).

Step 2; Input and Output Patterns: A complete ANN includes selection of inputs, outputs, network topology and weighted connections of nodes. Input selections is one of the essential part, which is to be chosen carefully so that the input features will correctly reflects the characteristics of the problem. Another major task of the ANN design is to choose network topology. This is done experimentally through a repeated process to optimize the number of hidden layers and nodes according to training performance and prediction accuracy. In this study the input pattern are obtained from the DGA fault diagnosis reports of the faulty transformers collected from organizations/utilities across INDIA. For each input pattern there exists an output pattern which describes the fault types for a given diagnosis criterion. Both input and output pattern formulate an ANN training set. If at all ANN training is slow or/and shows little convergence, then both patterns are poorly correlated or not correct. Since Duval triangle 1 needs only three combustible gases methane (CH_4), ethylene (C_2H_4) and acetylene (C_2H_2) are used. Therefore, for this study, input and output patterns for fault diagnosis in power transformers are as follows:

$[x] = [\%CH_4, \%C_2H_4, \%C_2H_2]^T$ (4)

$[o] = [PD, D1, D2, DT, T1, T2, T3]^T$ (5)

Assigned faults from table 1 are: thus $[o] = [1, 2, 3, 4, 5, 6, 7]^T$.

Step 3; Neural Network Configurations and Training: the invention of BP algorithm has played an important role in the resurgence of interest in an ANN. Back-propagation is a systematic method for training multi- layer ANN. It has a strong mathematical foundation. For this study two-layer feed-forward network consists of number of neurons connected by links divided into two layers. A set of inputs is applied from outside or from previous layer. ANN training is the process by which synoptic weights in the network are adjusted according to signal received. These signals are the input and output vectors defined previously. Here BP network with tan-sigmoid (TANSIG) transfer function has been used. Also ANN training purposes Levenberg-Marquardt (trainlm) is used.

For training purposes of ANN, there are three fault gases as input to the BP network, N = 3. Types of faults are chosen as network outputs, thus M = 7. Therefore, number of nodes in the input and output layers are determined. The number of hidden neural nodes is decided accordingly be 10. Then raw data out of 1236 samples are used for

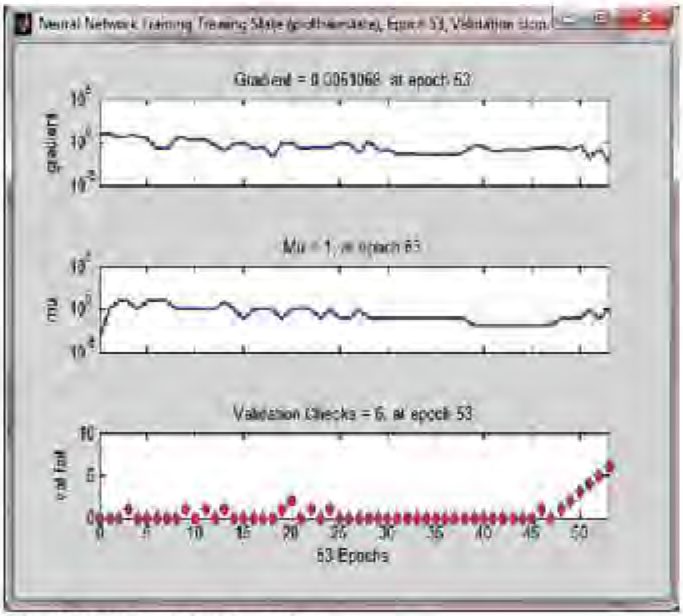


Fig. 4(a): Mu and Gradient plot

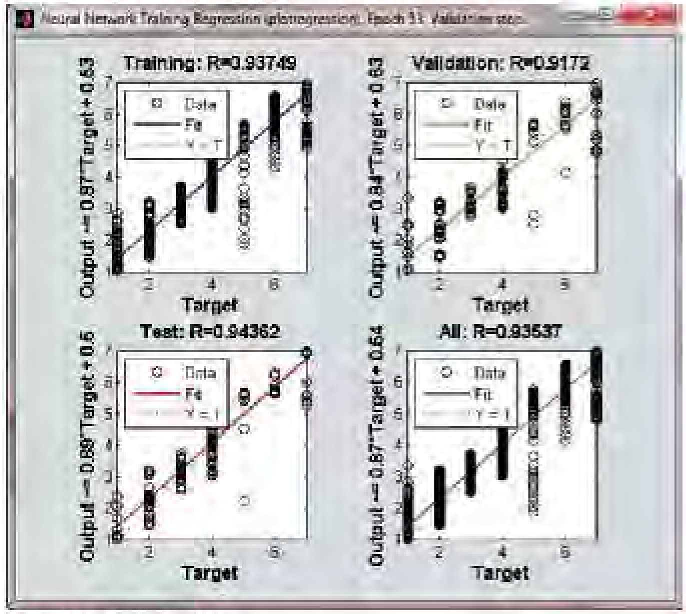


Fig. 4(b): Target plots

training the patterns to train this neural network with the desired error goal set to 0.0. After successful training, the weight matrices and biases are stored as files. The final number of hidden nodes is confirmed to be 11 and the 3-11-7 'network topology' is fixed.

Step 4; ANN result outputs-A two-layer BP-ANN with 53 epochs is designed and trained by different training patterns obtained from different power transformers' fault diagnosis reports having capacities from 6.3-250 MVA, 11/0.4-420/21 KV collected from various organizations/utilities in INDIA. From the MATLAB environment, best validation performance is 0.49576 at epoch 47 out of 53 epochs.

Similarly, from training states, the Mu (the momentum) for the weights and biases is set at 1, and also the gradient (local minima) is 0.0051068 can be observed from Figure 4 (a). Though output goal is set to be 0 and other input /output targets for this study are given in Figure 4 (b).

Results and Discussions

Fuzzy logic

In order to evaluate the performance of the proposed fuzzy logic for fault diagnosis in power transforms through DGA, transformers' fault analysis reports collected from different utilities and authorities are tested. Reported faults by different conventional diagnostic tools such as IEEE C-57, 104TM 2008, CIGRE, IEC Key gas ratios, Roger's gas ratios, Doernenburg' gas ratios and others are reconfirmed and cross verified with fuzzy logic Duval triangle 1 based diagnosis. This approach can be explored to improve the incipient fault diagnosis technique by adding more and more fuzzy rules and adding membership functions. Fuzzy rules can be mapped for possible real number input percentages. Fuzzy logic is applied as the practical representation of the relationship between the fault type and the dissolved gases percentages with fuzzy membership function. To increase the accuracy of this method, more

Sr. No	Transformer Ratings		Gases (ppm)			Gases (%)			DGA Fault Diagnosis Comments				Duval Results	
	MVA	KV	CH_4	C_2H_4	C_2H_2	CH_4	C_2H_4	C_2H_2	CEBG	IEC, CIGRE	IEEE/Reco.	Comnts.	ANN	Fuzzy logic
1	315	400/220	79	89	0	47.02	52.98	0.00		300-700^{0}C	<700^{0}C		T2	T21
2	250	16/420	40	10	0	80.00	20.00	0.00	200-300^{0}C	NF	200-300^{0}C	Ind. Gases	D1	T12
3	16	132/33	3	64	42	2.75	58.72	38.53			OH	OH	DT	D22
4	6.3	33/11	2	28	0	6.67	93.33	0.00			OH	OH	T3	T32
5	200	420/21	1	1	0	50.00	50.00	0.00	PD	NF	N	IG	T2	T22
6	16/20	132/33	17	17	0	50.00	50.00	0.00			T	OH	T3	T33
7	75	NG	14	0	0	100.0	0.00	0.00	PD	PD, D1, T1	N	H_2, CO_2	PD	PD2
8	16	NG	50	61	43	32.46	39.61	27.92	N	D1, D2	SRQ		D2	DT8
9	250	NG	547	530	ND	50.79	49.21	ND		300-700^{0}C	Cir. C		T2	T22
10	50	NG	92	120	4	42.59	55.56	1.85	>700^{0}C	D2, T3	N	H_2, C_2H_4	T3	T33

Table 1: Comparative table for reported faults in power transformers with FL and ANN Duval triangle 1

transformers fault reports should be analyzed to compare the practical faults from power industry. Therefore, appropriate membership functions and fuzzy rules are necessary to obtain higher accuracy and to reduce the ambiguity between the fault zone boundaries.

Artificial neural network

For this article, a string of 1236 input samples between the range of 0-100% in the variations of 0.1%, 0.2%, 0.25% and 0.5% as per requirements were developed for three input vectors. This sting of sample vectors is used for feed-forward BP-ANN Duval triangle 1 diagnostic method. Selected 10 vector samples of DGA fault reports by other conventional diagnostic methods, and also cross verified with fuzzy logic diagnostic approach are used for neural network training. Their vector input ranges were rounded-up to the first digit of decimal (0.50) to match the variations in increasing/decreasing trend. Many unknown new input vectors were also used for neural testing. Neural network does not know these vectors, tries to settle to the nearest input vector.

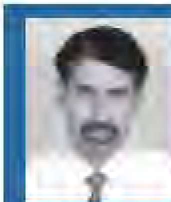
Results and Discussions

Fuzzy logic diagnostic results are found to be more specific and crisp. Result table has been prepared for integers (round up values) and nearer numerical values at the fault zones for three input gas percentages. Duval triangle 1 approach is cross verified to provide more than 90% accurate results applied to the available fault reports. In some cases this DGA method could not provide the results, reasons are unclear fuzzy rules and the membership functions. This approach is more effective in case faults are ambiguous on zone boundaries.

The results obtained for reported faults which are cross verified with other fault diagnostic schemes and then ANN method reveals that neural network efficiency for this set of input vector is in the range of 95-98%, which is quite acceptable. These 10 faults were already cross verified with fuzzy logic fault diagnostic Duval triangle method in power transformers. The comparative diagnostic results between fuzzy logic and artificial neural network methods are shown in Table 1.

From the results of the above table it is concluded that soft computing techniques which are appreciable in other applications can also be utilized for fault diagnosis of power transformers.

Profile



Dr Sukhbir Singh

Master of Engineering (C&I) (Delhi College of Engineering, D.U. Completed PhD research work from NIT Kurukshetra, on "Fault Diagnosis on Power Transformer" has earlier been working in Indian Air Force as a combatant member in the engineering field and since 1993 teaching in India and abroad. He also has an interest in Fuzzy and Neural Networks.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Coil Winding, Stamping & Transformer Manufacturing Exhibition & Conference: June 2015, BEC, Mumbai

The CWST-Expo in association with ITMA (Indian Transformer Manufacturers Association) has evolved as a solution for various motor, coil winding, magnetic material and transformer manufacturers to interact and boost their presence in the category. Over & above the fact that a range of cutting-edge concepts and products will be displayed here, major attractions would be the knowledge oriented concurrent conferences on Transformer industry and Automotive industry. The synergy between the show and conferences ensure interaction with a broader set of audience from a wide cross-section of industries.

Trafosem Conference June 5, 2015

ITMA has held number of highly popular, productive international conferences on transformers in the past on regular basis as one of its normal activities of the association. In fact these seminars have been well appreciated, commended by all, over the world with overwhelming participation of national & international manufacturers, allied industries, Technocrats, Electrical Industries, Prominent consultants. Energy planners, R&D organizations, Senior Engineers & CEOs of PSUs, top ranking officers of central & state government of India. It gives an opportunity to manufacturers and their counterparts abroad to deliberate and discuss their issues with users and policy makers.

Prime Minister dedicates Chutak Hydro Power Station at Kargil, Ladakh

Narendra Modi dedicated Chutak Hydro Power Station (44 MW) of National Hydro Power Corporation (NHPC) to the nation at Kargil Ladakh in Jammu and Kashmir. He was accompanied by the Union Minister of State (Independent Charge) for Power, Coal and New and Renewable Energy, Piyush Goyal, N N Vohra, Governor J&K, Omar Abdullah, Chief Minister of J&K, MPs Mukhtar Abbas Naqvi & Shri Thupstan Chhewang and other dignitaries.

Addressing the function in Kargil, PM said with the commissioning of Chutak Hydro Power Project, we have come one step closer towards meeting the power requirements of Ladakh. On this occasion Prime Minister announced an additional fund of Rs. 8000 crore for development of road projects in the state. He said he wish to make Kargil one of the fastest growing districts in the country.

The Prime minister said it is time to change the old adage-Paani aur jawaani pahaad ke kaam nahin aate. He said through hydropower, the rivers (paani) are being harnessed for the benefit of the mountains. And electricity is not just for industry - but would also help the youth of the mountains hone their skills and find suitable employment, without having to migrate to urban areas. Piyush Goyal welcomed the dignitaries. On this occasion, Omar Abdullah also addressed the gathering and hoped this project will help developing the region and state as a whole.

Chutak Hydro Project is a run-off-river scheme on the river Suru, to generate 216 Million Units in a 90% dependable year having installed capacity of 44 MW (4 x 11 MW). Barrage site is located about 14 km upstream of Kargil near village Sarzhe. It utilizes a rated head of 52 meter developed by construction of a 15 meter high barrage. It has 4.78 Km long 5.9 meter dia Head Race Tunnel. Power generated from Project is being supplied to Kargil District of Ladakh region of J&K. The 1st unit was commissioned on Nov'2012 and all the balance three units were commissioned in Feb.'2013. It has been completed at a cost of Rs 894 crore and total power generated from this power station will be supplied to Jammu & Kashmir state only.

NHPC is today a premier organization in the country in the field of development of hydroelectric projects. A total installed capacity of 6507 MW is under operation, which includes 2 projects with a total installed capacity of 1520 MW in Joint Venture. There are 4 projects (3290 MW) under construction. The technical capabilities of NHPC in executing hydroelectric projects are unmatched in the country.

Senior Central & State Govt. officials along with Devender Chaudhary, Additional Secretary Power Government of India, J K Sharma, Director (Projects), R S Mina, Director (Personnel) NHPC were also present on the occasion.

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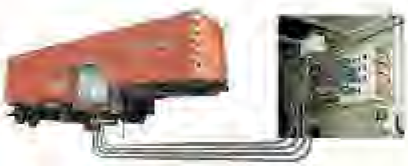
Efficient Power transfer: mobility of the storage units



Electric power generation from renewable energy is subject to substantial fluctuations. In order to ensure uninterrupted supplies at all times, in future it will be necessary to transport larger amounts of electric power, as for instance from wind power stations in Gujarat, Karnataka, Tamil Nadu and Maharashtra to consumers in northern/eastern India; this can lead to grid bottlenecks. The expansion of the grid system over wide areas is regarded as the solution to this problem. In reality, shortages are more likely to have a local or seasonal character, a fact that is hardly taken into consideration. One alternative could be the temporary connection of large, mobile storage units: such local relief arrangements could be put into effect more quickly and at lower cost than a general increase in capacity, and thus speed the shift to renewable energy. Mobile battery storage units, in the form of truck trailers or containers, permit a flexible grid relief as and when necessary. In the event of bottlenecks they are locally connected to the appropriate grid nodes, e.g. in summer to grid node-A with a large input from PV systems, and in winter to grid node-B with a high wind power input. The mobility of the storage units enables their capacity to be optimally utilised during the year and allows a flexible adaptation to variations in demand and demographic changes. The use of tested technology allows the extensive use of such storage units. Multi-Contact's insulated round connectors with bayonet locking are already installed at many grid infeed points, and ensure rapid and safe connection. Microswitches on the connector indicate that connection is correctly made and can be used to control the system. For connection from the solar cells to storage point MC has MC4 connectors and Silicon insulated cables which have good age resistance, high impact value, maximum elongation and tear strength, halogen-free and thus environment-friendly. For the connection of lithium ion batteries MC has developed a battery connector. This permits rapid, safe and simple installation and requires no maintenance.

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india@multi-contact.com

ElMeasure brings Intelligent Earth Leakage Relay (iELR)

One more milestone ElMeasure proves that to be in the controlling segment is "Intelligent Earth leakage Relay" (ELR). Conventional ELR works with the settings through the potentiometers / DIP switches and whenever it crosses the limit it trips. Problem with this kind of relays are accuracy and malfunctioning. ElMeasure committed to have good products and first time Microcontroller based IELR with 4digit 7 segments RED bright Digital display, which is very unique as compared to conventional ELRs.

Features

Inverse curve - Trip time is inversely proportional to leakage current. This IELR is Intelligent, when the Leakage current is 10 times higher than the set current it trips 10 times faster.

Continues leakage current display (Programmable) - Leakage current displays to enhance the user to understand the quality of Electrical network / Machine online. This can be disabled through setup.

Continuous Display of Trip Leakage current (Programmable) - In case of tripping IELR captures and Displays the tripped Current with the resolution of 4 digit helps the user to analyze and correct the problem. This can be disabled through setup.

Continuous scrolling display for set current and set Time.

Field Programmable through front panel keys with password protection - No limitations on the Leakage Current settings.

Wide input range 60mA to 12A and the trip time programmable from 300ms to 30 seconds.

Manual test and Reset Keys.

Specification:

1 Second update.

Auxiliary supply 80 to 300 VAC. Burden 4VA max.

4 Digit 7 segment RED bright display

Panel mountable 96 x 96 x 45

Accuracy : Class 1.0 FS

Relay contacts – One pair of potential free NO & NC, 2A at 250VAC or 24VDC

CBCT standard size – 40, 65, 100, 150, 200, 250, 300mm Tape wound.

Weight (Approx): Unpacked – 250 Grams

Shipping - 350 Grams

For further details contact:
marketing@elmeasure.com

Two New Digital Multi-meters: Fluke 15B+ & Fluke 17B+ by Fluke India

Fluke India launched 2 New exciting professional Digital Multi-meters Fluke 15B+ & Fluke 17B+.

These New multi-meters are aimed at Industrial technicians and maintenance staffs that need a rugged, reliable yet affordable DMM which can withstand day-to-day rigor of industrial environment.

Fluke 15B+ & Fluke 17B+ are compact, easy to use tool that deliver safe, reliable measurement. They carry all the features & benefit of their predecessor Fluke 15B & 17B and have added many new features & benefits which make them even better.

Products Highlights:

NEW - CAT III 600V safety rated

NEW – 50% Bigger LCD Display with bright white backlight

NEW – Overvoltage indicator (17B+)

Fluke 15B+ and 17B+ are CAT III -600V tested DMM with AC/DC voltage, AC/DC current, mA, mV, Resistance, Capacitance, Temperature (17B+) measurement. These new DMMs also offer Diode check, Continuity check & Duty cycle measurement feature.

These new multi-meters also have Min/Max measurements, increased capacitance range up to 1000uF and increased resistance measurement speed for faster measurements. They now come with Integrated Meter Stand attached to body.

'All DMM are designed and tested as per IEC 61010:1 for CAT III 600V have a large & easy to read backlit 6000 count LCD display for easy readout with data hold and auto ranging. All DMMs carry Fluke TL75 test Lead set, Fluke India Calibration Certificate and Genuine Warranty certificate' informs Prashant Jain-Product Manager-Fluke India.

Fluke 15B+ is priced at Rs 5,899 and Fluke 17B+ is priced at Rs 7,300 which makes them one of the most affordable full featured industrial multi-meters in India.

These new exciting DMMs are available through a large nationwide Fluke India Retail Channel Network.

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

PowerRouter Solar Battery for UPS backup (on-grid) by Nedap N. V.

The PowerRouter is designed to make you energy self-sufficient. In areas where the power grid is unreliable and unstable, this compact all in-one system provides a stable power source by making use of solar energy and energy from the batteries. When the grid fails, the PowerRouter switches over to "island mode" and the user obtains uninterrupted power from self-generated solar energy or from connected batteries in an optimal balance. It is available in 5.0 kW, 3.7kW and 3.0 kW versions; integrated intelligent battery manager; it is compatible with all modern PV technologies, including thin film; 2 fully independent MPP trackers; uninterruptible power supply (UPS) within 20ms switch overtime; integrated remote monitoring & management; optional remote monitoring via GSM modem; compact, easy to install, all-in-one system. It has an intelligent battery manager, grid export limiter (on-grid)); energy management; monitor & manage.

For further details contact:
www.nedap.com

KUSAM-MECO offers Temperature and Humidity Transmitter

Model-KM-THS-03/04/33/34 is a new Temperature & Humidity Transmitter introduced by "KUSAM-MECO", an ISO 9001-2008 certified company. This model is a compact and robust temperature & humidity signal transmitter. This model is one of the most desired instruments for applications in monitoring for HVAC process/ air conditioning/ environmental ventilation control & environmental monitoring for building/ factory/ clean room/ Lab & for storeroom/ crisper/ agriculture/ food industry. Other important applications are for use in hospital/ pharmaceutical industry/ textile industry. This model is at reasonable price with compact design. It is easy to install. It has High-Tech sensor with high accuracy and long-term stability. It has LCD display with back light, double line character & 3-wire loop connection of signal. The input humidity range is 0-100% & a wide temperature range from -40^{o}C~60^{o}C & output range is 4-20mA. It is used in installation for indoor/ duct-mounting/ remote type with flange. It also has ZERO & SPAN adjustment for output. The power supply used for this instrument is 24VDC. It also has protection degree IP 65 (sensor: IP 20).

For further details contact:
kusam_meco@vsnl.net

Ha-VIS eCon Switches introduced by Hartings India

Hartings India Pvt Ltd introduces the high efficiency and performance, along with simple and quick operation – the new Ha-VIS eCon switches place a premium on meeting these demands. Optimized and designed for jobs in harsh industrial environments, unmanaged Ha-VIS eCon Ethernet switches equally enable the cost-effective expansion of existing network infrastructures, as well as the development of new industrial networks. The compact, cost-effective Plug & Play switches can be easily and quickly put into operation. Two different compact, space-saving housing designs guarantee the best possible use of available space in the switch cabinet. Powerful Power over Ethernet Plus (PoE+), full Gigabit Ethernet and an industrial temperature range of -40^{o}C to +70^{o}C broaden the wide product portfolio with additional functionality. Due to their approval for use in industry as well as the maritime market and transportation technology, the switches can be optimally selected for each application.

HARTING

Pushing Performance

For further details contact:
www.harting.in

Ceramic (SPC) Metal Halide Lamp from Venture Lighting India Ltd

Venture's Ceramic Master-PLUS Metal Halide system use the latest developments in slip cast, single piece, arc tube technology. These robust design ceramic lamps provide an unbeatable combination in terms of both performance and reliability. Consuming less energy than their halogen equivalents and reduced heat emissions, the ceramic lamps deliver up to 100 lumens per watt to provide a clean and even white light. The excellent colour rendering qualities of Venture's Ceramic Master-PLUS makes them perfect for interior applications where the light can enhance the colour, features and textures on display.

Features and Benefits:

It has a superior color performance;

Best in class performance for lumen output,color & life;

Warm, 3000K/4000K CCT, up to 90CRI;

Environmental friendly compact size;

Excellent efficacy upto 118 LPW;

25% Longer life compared to conventional ceramic lamp.

For further details contact:
marketing@vlindia.com

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POWER GENERATION 250–650 kVA OFF-ROAD 105 –565 kW
COMPACT. POWERFUL. FUEL-EFFICIENT.
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• Certified for CPCB Stage II
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• Advanced Combustion Technology
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