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Editorial...

Service Supply Chain Resilience of KSEB Ltd

Our great organisation is one of the best known business entity, where service supply chain resilience takes a prime seat. Our distribution wing's preparedness to react to any natural calamity and its resultant shattering of the network is well known and is accepted by the public and the Government alike. This is evident from any of the post-monsoon natural calamity involving rain and storms; the pace with which we achieve normalcy after the disastrous disturbance is remarkable.

During August, 2018 most part of our State except Thiruvananthapuram, Kollam, Kannur, Malappuram and Kasargod districts was thoroughly inundated by the devastating flood waters and the Distribution network and certain Sub-stations went under water for a few days. The customer installations were also inundated thereby making it difficult to charge the system and the premises of various installations once the water receded. The team work of our employees, contractors, members of the Wiremen Associations etc. worked in tandem resulting in normalising the network at a very fast pace, with the help received from the DISCOMs of the neighbouring states of Tamilnadu, Andhra Pradesh, Telangana etc., both in the form of manpower and essential materials like transformers, meters etc. Where it was not safe to energise the installations of houses, single point connections were established with the help of kits supplied by various Engineering Colleges in the State.

The above incident stands as testimony to our preparedness to tide over any sort of difficulties affecting the integrity our network and is a measure of our *Service Supply Chain Resilience*.

Chief Editor

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KSEBEA Code of Ethics

- **Thou shalt maintain thy integrity under all circumstances.**
- **Thou shalt incessantly work for the advancement of the professional knowledge.**
- **Thou shalt not give an incorrect professional opinion**
- **Remember Thou art a member of a team and the achievement of the team is thy own success.**
- **Thou shalt not malign thy co-professionals.**
- **Thou shalt strive for the advancement and dignity of thy juniors in the profession.**
- **Thou shalt strive for the welfare of the community.**
- **Thou shalt enlighten the community with the correct aspect of Engineering/Technological activities.**
- **Thou shalt endeavour to develop a dignified status in the society.**
- **Thou shalt strive by conduct and character to be a worthy citizen of the Motherland.**

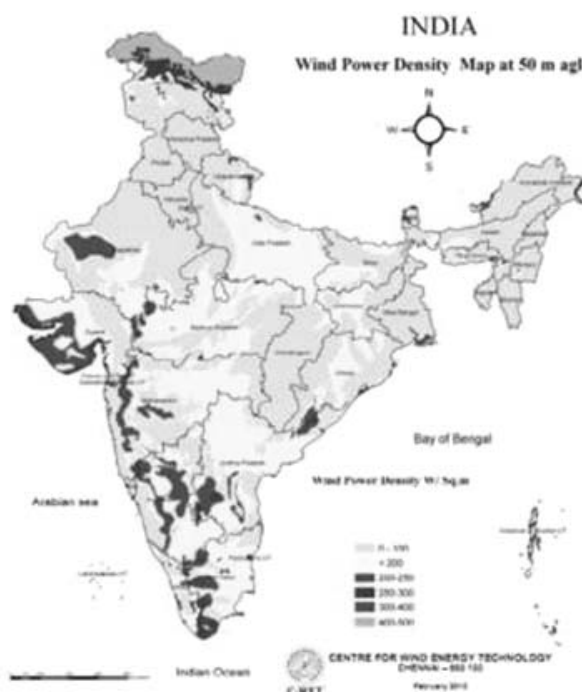
MANAGEMENT OF GRID CONNECTED RENEWABLE ENERGY SOURCES

Er C. P. George, Deputy Chief Engineer, KSEB Ltd

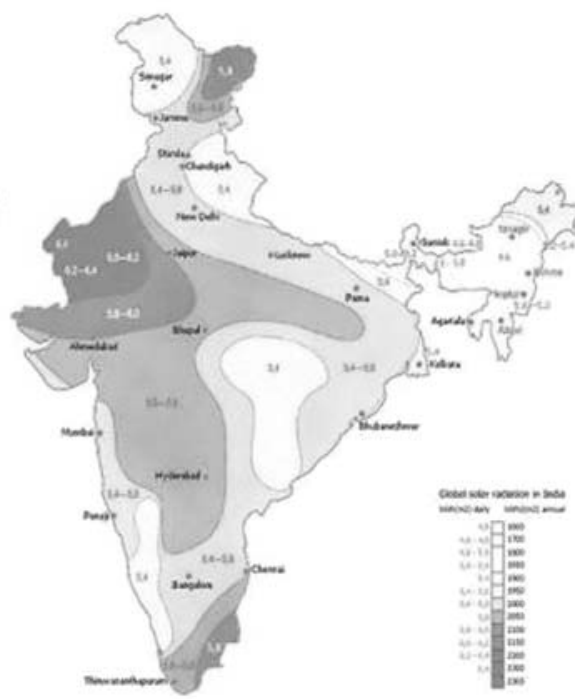
Renewable Energy is no longer “alternate energy” but has become a key part of the solution to the nation’s energy needs. With the responsibility of framing National Electricity Policy, Tariff policy and RE policy vested with Government of India and with the National Grid in place; the availability and the scope of RE along with issues in harvesting the renewable energy need to be analysed in national perspective to have a realistic grasp on the consequences that affects us in the future scenario.

The sharp decline in the prices of wind and solar technologies in the recent years by about 60% and 62% respectively between 2010 and 2018 (in kWh terms), has led to a change in the relative importance

of energy sources. Tropical countries, including India, are richly endowed with the above resources, and can harness them in an innovative manner to meet energy requirements at decentralised locations. The historic low tariff for **Solar (Rs. 2.44/unit)** and for **Wind (Rs. 2.64/unit)** achieved through the introduction of transparent reverse bidding during 2017. In the recent reverse auctions conducted by various state utilities, the derived value of solar energy was around **Rs. 3/-per unit**. Recently, large fluctuations have been noticed in the prices and it is observed that the price variation is very much depends on the import policies in general and the imported price of power modules for the relevant project.



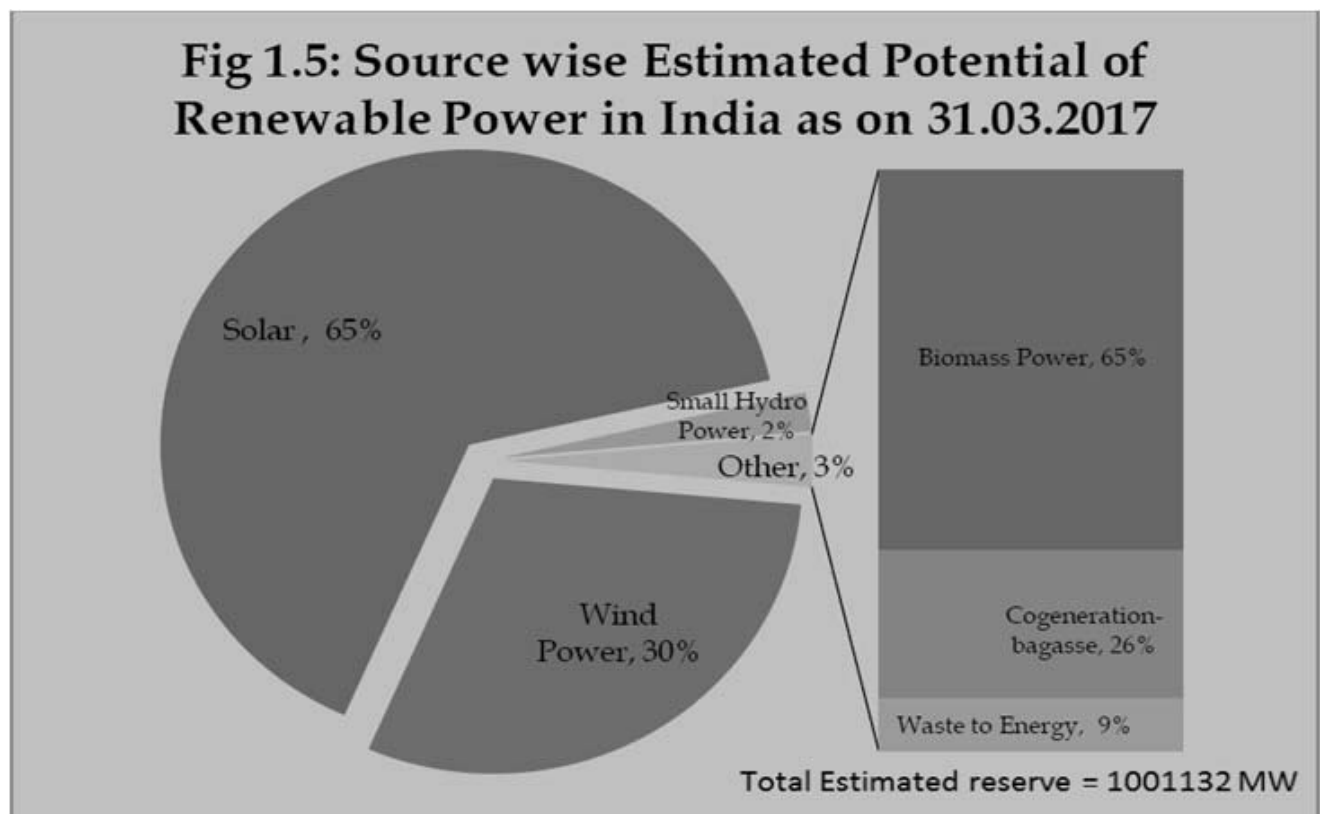
Wind Energy Resources



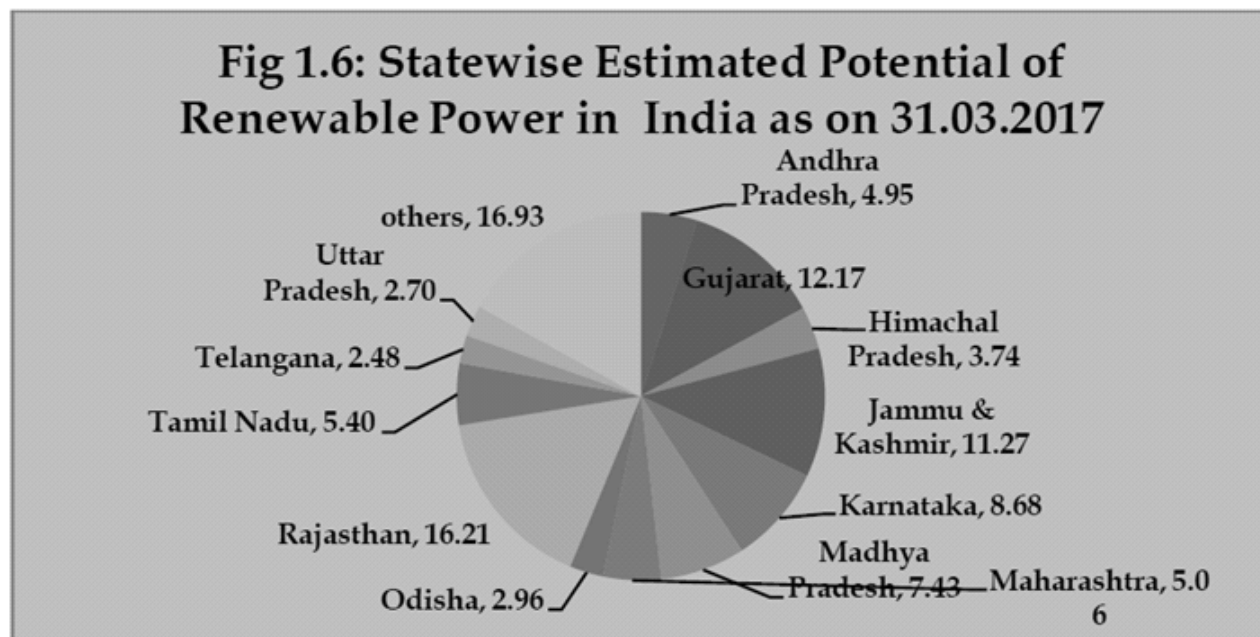
The following table gives a general idea about the potential and status of the renewable generation in India.

Resources	Estimated Potential (MW)	Total Capacity (India) As on Oct-2018 (MW)	Energy Generated in MU (2017-18)
Wind Power	3,02,000	33,000	52,666
Solar	7,50,000	26,580	25,871
Bio Power	25,000	8,100	15,252
Small Hydro	21,000	4,320	7,692
Total	10,98,000	72,000	101481

In India, the ground mounted, utility scale solar power industry is growing at furious pace. From almost nil installed capacity prior to 2010, the total installed capacity of solar power in India is over 21560 MW as on 31/03/2018. In parallel, the rooftop solar sector has started accelerating too. The falling solar panel and installation price, coupled with increasing grid tariffs especially for industrial and commercial consumers, has made solar power an attractive option for consumers.



- ❖ The geographic distribution of the estimated potential of renewable power as on 31.03.2016 reveals that Rajasthan has the highest share of about 14% (167276 MW), followed by Gujarat with 13% share (157158 MW) and Maharashtra with 10% share (119893MW), mainly on account of solar power potential.



The Scope & Future

As the entire energy security plan of the country is very much depends on achieving the targets envisaged by the National Energy Policy laid down by NITI Aayog; we may evaluate of the VISION which shall provide enough grasp on the scope and future of the renewable energy sources to determine the energy security of the country.

Installed Capacity (Power) in GW										
(1GW = 1000 MW)	2012		2022				2040			
			BAU (Business as Usual)		Ambitious		BAU (Business as Usual)		Ambitious	
	GW	%	GW	%	GW	%	GW	%	GW	%
Gas Power Stations	24	10.9%	34	6.1%	39	7.1%	46	3.8%	70	5.6%
Coal power stations	125	56.6%	266	47.9%	251	45.8%	441	36.6%	330	26.2%
Carbon Capture Storage (CCS)	0	0.0%	1	0.2%	1	0.2%	26	2.2%	26	2.1%
Fossil Fuel Based	149	67.4%	301	54.2%	291	53.1%	513	42.6%	426	33.8%
Nuclear power	5	2.3%	12	2.2%	12	2.2%	23	1.9%	34	2.7%
Hydro Power Generation	41	18.6%	61	11.0%	61	11.1%	71	5.9%	92	7.3%
Solar PV	1	0.5%	59	10.6%	59	10.8%	237	19.7%	275	21.8%
Solar CSP	0	0.0%	4	0.7%	5	0.9%	28	2.3%	48	3.8%
Onshore Wind	17	7.7%	62	11.2%	62	11.3%	168	14.0%	181	14.4%
Offshore Wind	0	0.0%	2	0.4%	2	0.4%	19	1.6%	29	2.3%
Distributed Solar PV	0	0.0%	36	6.5%	36	6.6%	102	8.5%	120	9.5%
Other Renewable Sources	8	3.6%	18	3.2%	20	3.6%	43	3.6%	56	4.4%
Renewable Based	72	32.6%	254	45.8%	257	46.9%	691	57.4%	835	66.2%
Total	221		555		548		1204		1261	

Electricity Generation (Energy) in TWh										
(1TWh = 1000 MU)	2012		2022				2040			
			BAU (Business as Usual)		Ambitious		BAU (Business as Usual)		Ambitious	
	TWh	%	TWh	%	TWh	%	TWh	%	TWh	%
Gas Power Stations	115	10.7%	128	5.4%	154	6.5%	181	3.8%	302	6.3%
Coal power stations	708	65.7%	1526	64.8%	1482	62.5%	2606	54.8%	1984	41.6%
Carbon Capture Storage (CCS)	0	0.0%	5	0.2%	5	0.2%	137	2.9%	137	2.9%
Fossil Fuel Based Electricity	824	76.4%	1659	70.4%	1641	69.2%	2924	61.5%	2423	50.8%
Nuclear power	27	2.5%	82	3.5%	87	3.7%	164	3.5%	237	5.0%
Hydro Power Generation	144	13.4%	214	9.1%	214	9.0%	248	5.2%	324	6.8%
Hydro and Nuclear	170	15.8%	296	12.6%	301	12.7%	412	8.7%	561	11.8%
Solar PV	2	0.2%	99	4.2%	99	4.2%	422	8.9%	489	10.2%
Solar CSP	0	0.0%	11	0.5%	14	0.6%	105	2.2%	185	3.9%
Onshore Wind	32	3.0%	129	5.5%	129	5.4%	390	8.2%	423	8.9%
Offshore Wind	0	0.0%	6	0.3%	6	0.3%	62	1.3%	92	1.9%
Distributed Solar PV	0	0.0%	55	2.3%	55	2.3%	164	3.5%	193	4.0%
Other Renewable Sources	46	4.3%	86	3.7%	101	4.3%	203	4.3%	281	5.9%
Renewable Based Electricity	80	7.4%	386	16.4%	404	17.0%	1346	28.3%	1663	34.8%
Electricity imports	5	0.5%	15	0.6%	25	1.1%	71	1.5%	126	2.6%
Total	1078		2356		2371		4753		4773	

The data itself is self-explanatory. The share of RES in the total installed capacity is envisaged to jump from 32% in 2012 to 47% in 2022 and to 66% in 2040 in ambitious scenario.

Similarly, the energy share from the Renewable Energy Sources which was only 7.4% during 2012 is planned for a leap with 17% during 2022 and then to 34.8% in 2040.

Kindly note that the Hydro Power generation and Nuclear Power generation is also considered as renewable energy. In case of Kerala, with the inclusion of higher capacity hydro, we shall have enough non-solar renewable generation. Based on the relevant amendment proposed in the policies, Kerala may be in a position to sell the non-solar REC (Renewable Energy Certificates) to other utilities for their RPO compliance.

Issues with Grid Integration of RES

While the advantages of the Renewablesources are undeniable, *some natural constraints should be*

considered, such as solar power being generated only during daytime and its unpredictability and intermittency creates issues for its grid integration.

Grid integration means minimizing and/or managing the variability and uncertainty aspects of the Renewable Energy. Unlike fossil fuel-based electricity that can be generated steadily, renewableenergy cannot be made to generate on demand (or be shut down for later exploitation). The renewable energy-based generation may actually rise or fall suddenly, causing inconvenience to grid managers. Technically, Solar Energy/ Wind energy is described as an intermittent source of electricity, where intermittency consists of two distinct aspects

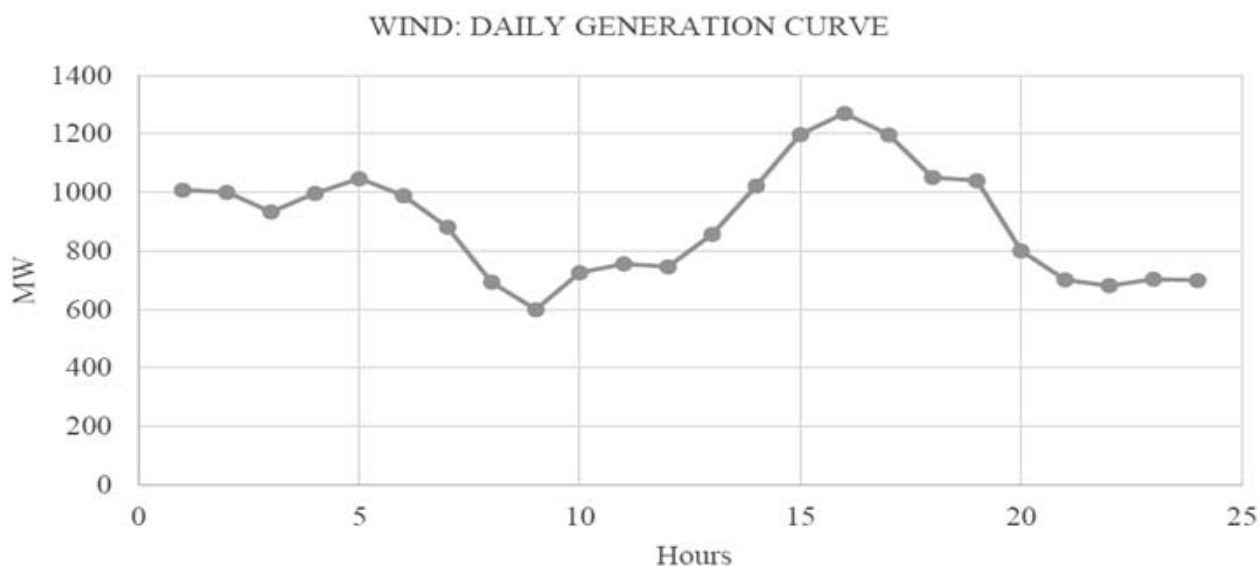
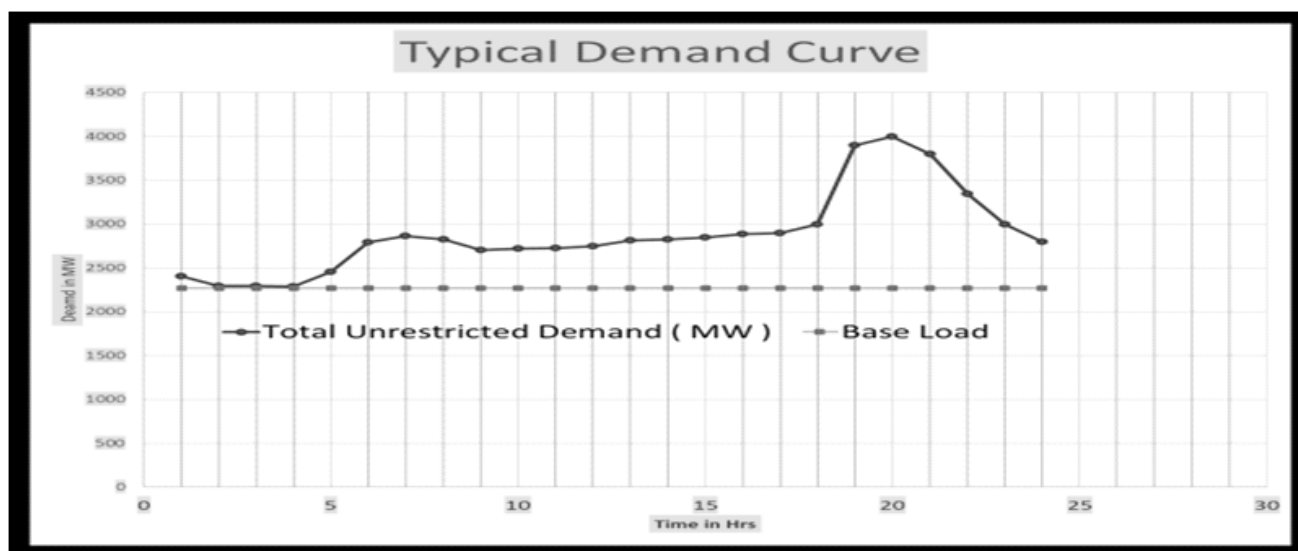
- “Predictability/Uncertainty” refers to the lack of accurate knowledge about future Solar/Wind Energy generation (e.g. sudden drop in solar power).
- “Variability” is the known natural variation in Solar Energy generation just as it exists on the demand

side. (e.g. low demand at late mid- night and high demand during late afternoon).

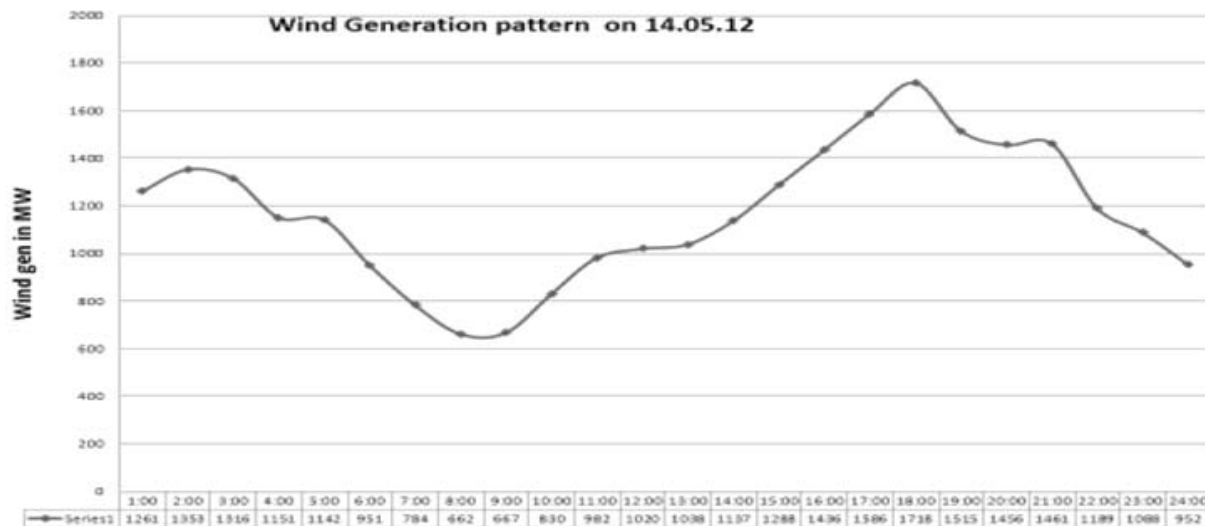
According to the Expert Group constituted by NITI Aayog, meeting the 175 GW renewable installed capacity target by 2022, would not be as much a financial challenge as a technical one. In Kerala Scenario, the integration of solar with the state grid is a greater financial as well as technical challenge due to the fact that Kerala Grid is being managed with

uncontrollable variations in the peak and off-peak demands along with wide variations in the seasonal demands. As such, it is very important that we choose and use our resources with great care and vision to ensure proper financial viability for the organisation along with the technical feasibility for the grid operation as well as for ensuring most reasonable price for the consumers in the state.

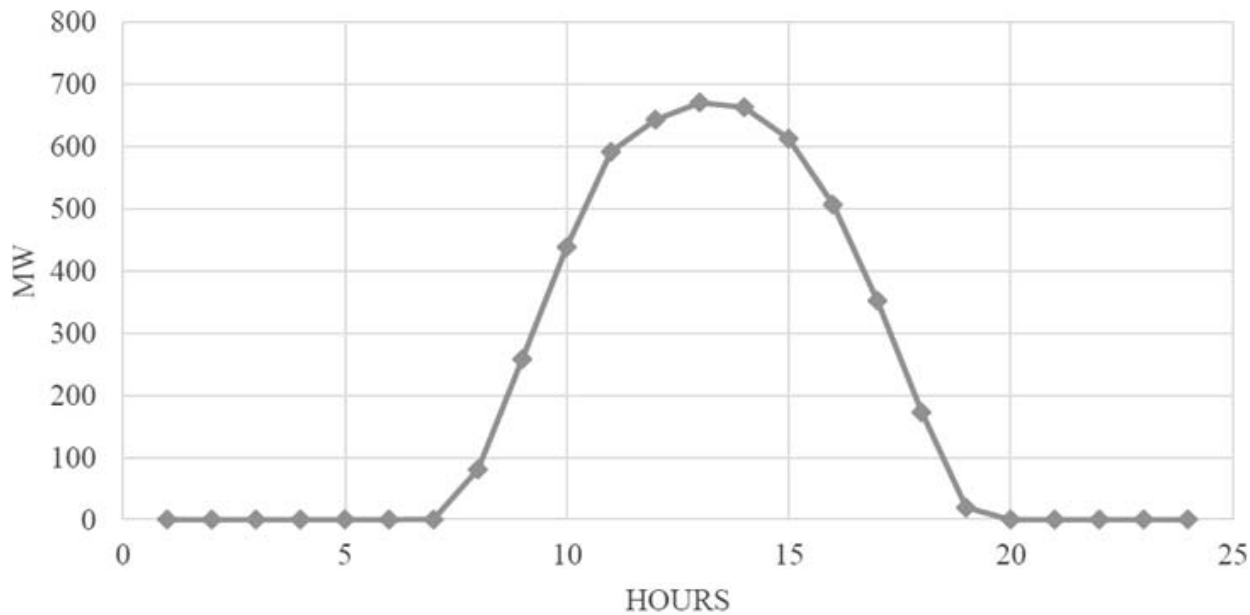
A typical demand curve of Kerala System.



Intermittency issue with Wind (Tamil Nadu)

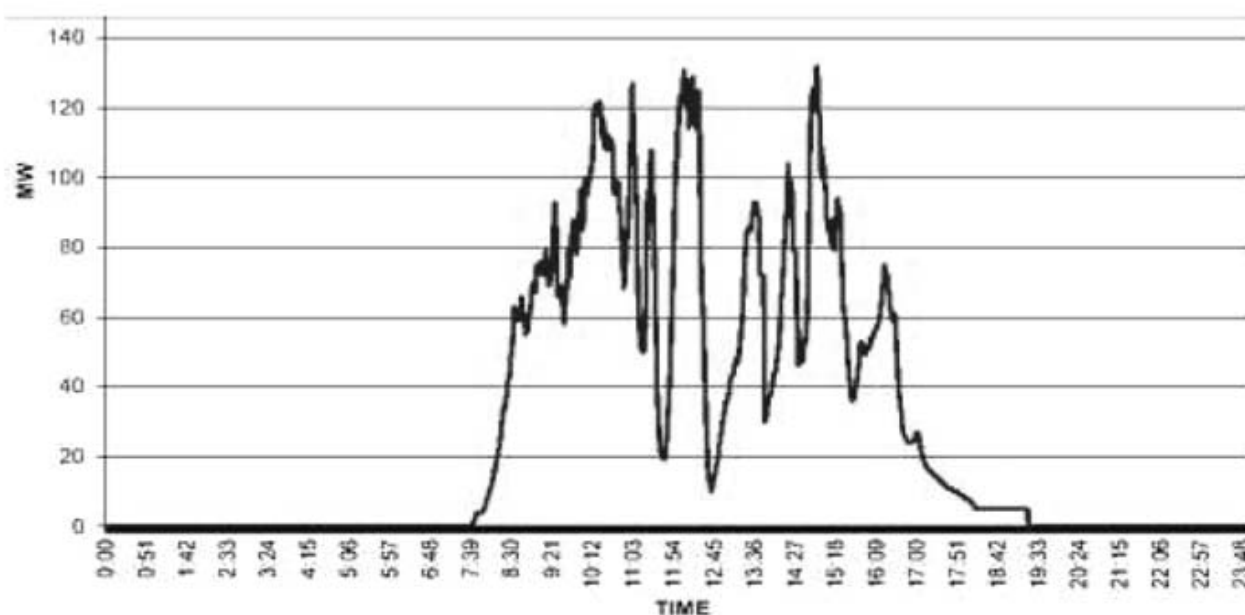


SOLAR DAILY GENERATION CURVE



Intermittency issue with Solar(Charanka Solar Park Gujrath)

On 10th September, 2012



Requirement of extra spinning reserve for harnessing RES.

As such, we need to have spinning reserves with enough generation capacity as reserve to ensure grid stability and reliability. As these unpredictable variations along with the natural variation in the generation output of the solar and wind results in the lower capacity utilisation (lower Plant Load Factor- PLF) of the conventional generating sources to ensure grid stability and reliability of the supply.

Issues in Harnessing RES in Kerala Grid

It is observed that the distribution of consumer pattern in the Kerala grid do not help us to augment the aggressive growth of renewable energy due to the fact that nearly 65% of the energy is consumed by 95% domestic plus LT commercial consumers and their demand dominate the time slot beyond solar energy availability, that is 06.00 AM to 06.00 PM and peaks during 6.30 PM to 10.30 PM. Moreover, their consumption rate is very much depending on the climatic conditions such as summer, rains or winter. Harnessing solar energy with battery backup is the option for these consumers, but its viability with present tariff structure is a point of debate. The integration of the solar power, and particularly the roof top solar in large scale need careful evaluation of the grid

parameters and the existing generation resources available with us to tackle the possible technical as well as the financial issues arising out of its integration to the grid. Kindly note that with the present level of connectivity specifications and data integration, it is practically impossible for a Grid Manager to have clear assessment of the solar power in the grid and take appropriate action in the event of demand crash or a grid eventuality. As such, this necessitates the introduction of smart grid technologies for large scale integration of RES to the grid. The implementation of smart grid technologies needs to go hand in hand with large scale integration of RES to the grid to ensure grid security and efficient harvesting of renewable energy. In case of Kerala & Tamil Nadu, the wind season (May to September) coincides with the Monsoon. During the season, the demand in the Kerala system is the lowest due to monsoon and monsoon related calamities, the small hydro stations shall be under full mode of operations with flooding of rivers, spillage from the small reservoirs and even spill threat from some major reservoirs. Thus, the investment in wind generation need some in depth study on the system requirement, demand forecast etc. Moreover, as in the case of the solar, the variability and intermittency issues need to be tackled through appropriate smart grid technologies.

Complexity of Kerala Grid and Integration of RES

Generation Resource with Firm Power	Capacity/ Share(MW)	Average availability (MW)	Remark
Central Generating Stations	1650	1320	@ 80% PLF
Long Term Agreement	1200	900	@ 75% PLF
Internal Hydro ++	2050	1600	Subject to water availability
Total	5800	3820	Total availability is Less than 4011 MW; the recorded peak

As already stated, the complexity with the Kerala Grid is its variability in the demand which normally varies from 2000MW during night off peak (01.00 – 04.00 hrs) to 4000 MW during night peak (18.00 – 22.00 hrs). The demand variation is further complicated with unprecedented consumption due to the soaring heat during summer and heavy demand crash during the rainy seasons. With the integration of solar with

variability and intermittency, the system will get further complicated with the management of unpredictable loads and unpredictable generating sources.

To evaluate the technical issue and its financial consequences, let us make an evaluation on the annual energy requirement for 2018-19 along with average MW demand of the state grid for various time slot in a day, as furnished in the table below.

FY: 2018-19	Average Demand and Annual energy requirement at various time slots in a day										Total
Time Slot	00.00 - 05.00		05.00 - 08.00		08.00 - 18.00		18.00 - 22.00		22.00 - 24.00		
MW/MU	MW	MU	MW	MU	MW	MU	MW	MU	MW	MU	MU
Average Demand / Annual Energy	2350	4290	2925	3200	2725	9942	4050	5910	3100	2260	25602
Generation Sources											
Central Generating Stations : 1650 MW (Average availability @ 80% PLF=1320 MW)	1320	2008	1320	1446	1320	4818	1320	1927	1320	964	11163
Long Term Agreement (LTA): 1200 MW (Average availability @ 75% PLF = 900 MW)	900	1643	900	986	900	3285	900	1314	900	657	7885
Hydro Management (1600 MW Average max. availability)	400	730	750	823	550	2008	1600	2336	1000	657	6554
Total Availability without Solar	2620	4381	2970	3255	2770	10111	3820	5577	3220	2278	25602
Excess/ deficit without solar	270	91	45	55	45	169	(+) 230	(-) 333	120	18	
With 1000 MW Solar @ 4000 units/MW/day	0	0	0	0	400	1400	0	0	0	0	
Excess/ deficit with solar during the day	270	91	45	55	445	1629	(+) 230	(-) 333	120	18	

It is observed that even without much penetration of solar in the grid we have excess energy and power during all the time slot except the peak time. The aggressive integration of solar shall lead to further excess energy during the day time slot (08.00 -18.00) except the night peak slot of 18.00 – 22.00 hrs. And during the night peaks, we have serious deficiency in the availability of generation resources and solar is not a solution. Further excess energy during the day time slot (08.00 -18.00) and will further complicate technical issues in the grid management along with the financial viability of the organisation. If we are not able to find market to ensure sale of these excess electricity at reasonable rate, the entire investment shall be subjected to the risk of not getting a reasonable return and its consequence shall adversely affect KSEBL and the state energy sector.

It is observed that the average cost of electricity is much less than Rs.3/- per unit in the day ahead markets and power exchanges during the 08.00 – 18.00 time slot when the solar energy is available. This excess energy has been estimated consequent to the bare minimum must run hydro power capacity of 550MW from internal hydro and further reduction of hydro may not be possible. As the backing down the roof top solar is not technically feasible with the present level of grid technology, the grid manager shall be forced to maintain LGB (Load Generation Balance) by surrendering the energy from Central Generating Stations or the LTA. As such, KSEBL shall be forced to pay at least the Capacity charges (FC) of surrendered power and ended up in payment of substantially higher per unit energy charges during the time slot between 08.00 -18.00 hrs. Moreover, the running of Hydro Stations with technical minimum throughout the day slot can lead to the underutilisation of water resources and spillage of reservoirs

In the present scenario of single National Grid with a National Policy for open access without transmission charges, surcharges and transmission losses for encouraging solar and wind energy, ***the investment in solar projects shall be competitive only if the per unit charges are comparable with that of other states.*** Though the capacity utilisation factor (CUF) of the solar has been specified as 19% by CERC, due to the highest rain fall for 3-4 months, it is observed that

the CUF in Kerala is practically 16% only. This means less than 4 units of energy per day per kWp of solar in Kerala whereas 4.6 to 4.8 units of energy per day per kWp of solar from other major states like AP, Karnataka, TN, Gujrat, Rajasthan etc. In addition, the O&M cost for maintaining the solar panel in Kerala is practically at higher side due to the highest rainfall and humid condition along with higher labour cost prevailing in the state. This shall have great impact on the competitiveness of the projects on commercial aspect as same shall ended up at higher cost for solar energy generated in the State. *The saving in loss reduction aspect shall be nullified and over compensated by such state specific heads of expenses.*

Extra investments and costs involved in Harnessing RES and its complexities

Following extra costs and investments are involved in the integration of solar and wind to the grid.

1. Grid Infrastructure Cost

- a. Grid connection Cost: include the cost of a new transmission line from the variable RES plant to the existing grid, which would be higher than those for a coal-based plant, due to lower CUF. This cost depends basically on the distance between the plant and the grid, the voltage level of the connection line, and the availability of standard equipment.
 - i. For Solar, the grid connection cost is estimated to be up to 5% of the project investment cost for Solar;
 - ii. For onshore wind farms, it ranges between 11% and 14% of the total capital cost
- b. Grid upgradation Cost: include the cost of additional network equipment needed to strengthen the grid in order to integrate renewable power into the existing grids. They depend mostly on the amount of renewable capacity, the location of the power plants and the structure of the existing grid. This cost for a system with 20% to 30% Renewable energy share is estimated as Rs. 40/- to Rs.240 /- per MWh

2. System Operation Cost: Refer to extra costs incurred in the conventional part of the power system to accommodate the integration of RES in the grid.

- a. Profile Cost: is a broad concept that captures all three impacts of the temporal mismatch between VRE generation and load profile: 1) capacity costs (adequacy costs) due to a low VRE capacity credit; 2) reduced average utilization of thermal power plants; and 3) curtailed VRE generation to maintain grid security when power supply exceeds demand.

i. For 30%–40% wind/solar penetration the cost is estimated in the range of Rs.1200–2000/MWh

b. Short-term system balancing costs: Due to the variability and uncertainty properties of VRE generators, the reserve capacity needed for up-and down-regulation increases as compared to the case where the same energy is delivered by conventional generation. The increased requirements for reserve power lead to the extra costs for the conventional part of the power system. These extra costs originate from the measures taken to ascertain increased reserve power, for example, by the operation of conventional plants at partial load, the start-up costs and contribution of conventional power plants with higher operating costs in the power system, increased wear-and-tear and maintenance costs of plants. Kindly note that a flexibility

of 30% is allowed in scheduling of solar & wind in the prevailing ABT regime and at least that much reserve is required in the system to ensure grid security and stability.

Appropriate investment and development of the existing grid to the tune of smart grid is the pre-requisite for proper integration of renewable energy sources to the grid. *Aggressive investment in the renewable energy sources with out appropriate investment in the grid infrastructure will lead to great financial risks consequent to grid operational complexities in harvesting the RES. This can end up at grid security issues and inefficiencies in economic utilisation of resources and inefficient harvesting of the renewable energy from the resources.*

The Renewable Purchase Obligation (RPO)

Based on KSERC's (Renewable Energy) Amendment Regulations, 2017, the non-solar RPO requirement is 7% of the energy consumed excluding hydro power and solar RPO requirement is 2.75% the energy consumed excluding hydro. The table below, which is based on honourable KSERC's (Renewable Energy) Amendment Regulations, 2017, provides some insight into the actual requirement of 'Solar RPO' for KSEBL.

Financial year	Consumption (excluding hydro power)	Solar RPO % of total consumption (excluding hydro)	MU Requirement of Solar Capacity in MW for the RPO energy
2018-19	13833	2.75	380 261

As per the KSERC's (Renewable Energy) Amendment Regulations, 2017; Solar energy during 2018-19 is estimated as 380 MU. Based on the average energy production from the solar plant in Kerala, the estimated requirement of solar capacity for generation of 380MU is 261 MW only. As per the data available in KSEBL official website, we have 118MW of Solar available with us now in Kerala and various projects up to 21MW is nearing completion. In addition, 70 MW floating solar by NTPC

Kaymakam and 50 MW floating solar by NHPC along with the grid connected solar roof top from individual consumers are getting integrated to the system in a big way. As such, we have more than 261 MW of solar plants in the state during this financial year.

Another important aspect is the introduction of "**renewable generation obligation**" and mandatory requirement of bundled purchase of renewable energy for the future purchases of electricity from coal and lignite sources. Moreover, tariff policy recommends

bundled sale of renewable energy even by the existing coal and lignite generators by setting up additional renewable generation plants. Solar REC (Renewable Energy Certificate) is one of the best options to comply the RPO requirement and it is abundantly available for Rs.1/- per unit where as non-solar REC cost Rs.1.20/- per unit. As per the KSEERC's (Renewable Energy) Amendment Regulations, 2017; the net levelized tariff for Solar PV is Rs.5.08 per unit in Kerala. With electricity available in the market at much cheaper rate during the off - peak hours, the best option is direct purchase of solar from short term market or the RPO requirement REC (Renewable Energy Certificate) route. In short, there shall be adverse impact with respect to financial as well as grid operational aspects in the policy of direct investment by KSEBL for aggressive integration of roof top solar generating plants in the Kerala Grid.

Conclusion

Renewable energy is a great opportunity. The integration of Renewable Energy Source to the Kerala grid is a greater financial as well as technical challenge

due to the fact that Kerala Grid is being managed with uncontrollable demand variations during the peak and off-peak time slots along with wide variations in the seasonal demands. With the integration of solar and wind with variability and intermittency, the system will get further complicated with the management of unpredictable loads and unpredictable generating sources. As such, it is very important that we choose and use our resources with great care and vision to ensure proper financial viability for the organisation along with the technical feasibility for the grid operation as well as for ensuring most reasonable price for the electricity sold to the consumers in the state. The implementation of smart grid technologies needs to go hand in hand with large scale integration of RES to the grid to ensure grid security and efficient harvesting of renewable energy. The large-scale integration of RES without in-depth studies in demand forecast and without timely implementation of smart grid technologies shall end up in adverse consequences in grid security aspects as well as to the per unit cost of electricity sold to the consumers.

National Energy Conservation Day

14th of December.

National energy conservation day is celebrated every year by the people all over the India on 14th of December. The Energy Conservation Act in India was executed by the Bureau of Energy Efficiency (BEE) in the year 2001. The Bureau of Energy Efficiency is a constitutional body which comes under Government of India and helps in the development of policies and strategies in order to reduce the energy use. The Energy Conservation Act in India act aims to employ the professional, qualified and energetic managers as well as auditors who are with expertise in managing the energy, projects, policy analysis, finance or implementing the energy efficiency projects.

ENERGY AUDIT AND MANAGEMENT

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Abstract: Educational Institutions are the major contributors to energy intensive operations in India. Energy cost is one of the problems in the institute's budget. Electricity consumption can be reduced with targeted efforts and by using various energy management methods. Resultant energy saving provides a venue for the reinvestment in the educational institute itself. This paper presents an energy audit of the college site (Amal Jyothi College of Engineering, Kottayam). The review begins by gathering data of all the feeders in the college and the past record of electricity bills. This data is then inspected to realize how much energy is used. The load curve of each feeder in the college along with the power consumption data was obtained. From the above data we noticed that some buildings consume more energy. So, we mainly concentrated on these buildings that are RB (Resource Block), STP (Sewage Treatment Plant), Laundry and Kitchen. The data are obtained using some devices such as power quality and energy analyzer, clamp meter and lux meter. Power quality analyzer technology tracks numerous electrical parameters which include voltage, current, frequency, peak demand, harmonic distortion etc. Lux meter is used to measure the lumens and clamp meter is used to measure the power respectively. After analyses of this readings, we have suggested some of the energy and demand side management that can be implemented in each of this buildings so that energy consumption can be reduced to a minimum level. Time of working of all the buildings was also analyzed along with the data.

Keywords: Energy Audit, Power Quality Analyzer, Clamp meter, Lux meter

I. INTRODUCTION

Energy has been in use by the humanity for several years now and demand has been rising day by day.

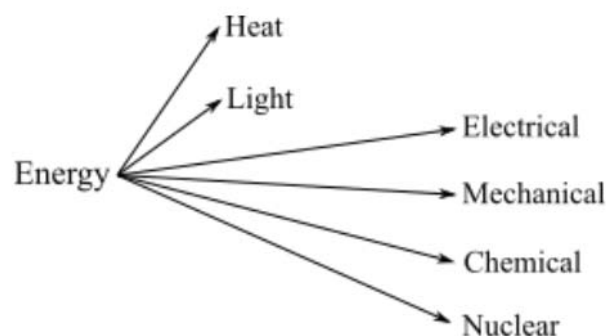


Figure 1: Classification of Energy

Coal and other fossil fuels like Petrol, Diesel, which have taken three million years to form, are likely to deplete near future due to lack of conscious energy use. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures. Today, 85% of primary energy comes from non-renewable and fossil sources (coal, oil, etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generations. In this paper we study energy conservation and energy efficiency by how to reduce energy demand to reasonable minimum Cost, recover and re-use heat where possible and also study the use of energy efficient equipment and provide a means to manage use of energy and study how to carry out energy audit.

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

II. LITERATURE SURVEY

An Energy audit is an inspection survey and an analysis of energy flows for energy conservation in a building. It may include a process or system to reduce the amount of energy input into the system without negatively affecting the output. Lighting constitutes a major portion of electricity consumption in commercial and industrial sector [1]. This electricity consumption can only be reduced by detailed study of energy consumption of the selected buildings and by energy management methods. Power Quality Audit allows the transformation of conservation ideas into realities for techno-Economic solution for an organization within a specified time frame [2]. LEED certification helps in the designing for rating new and existing commercial, Institutional and residential buildings [4]. Kitchen, Laundry and Sewage Treatment Plant- This buildings are selected for the study of energy consumption patterns and various suggestions are given to provide ways for the energy management in this buildings.

III. ABOUT INSTITUTE

Amal Jyothi College of Engineering is having NAAC accreditation with 'A' grade and to secure the prestigious NBA accreditation for prime departments. The college campus is spread over 60 acres with nearly 1,650,000 square feet. The institute offers 20 courses (B.tech, M.tech and others) and provides hostel facilities with a capacity of 2500 (including boys and girls). The number of students and staffs in college are 3725 and 397 respectively. The campus has its own two 100 Kw solar and 1120 KVA power plant.

IV. ELECTRICAL DISTRIBUTION SYSTEM

The 11kV, 3 phase supply is coming to "Amal Jyothi College" from Kerala state Electricity Distribution

(KSEB). It is step down to 415V by step down transformer. The power supply is for the academic sector and also the hostel is provided with the same transformer. An APFC panel of 20 kVAR, is provided to maintain power factor close to unity. The incoming supply to college is 11kV which is step down to 415 V by using 500kVA transformers. The DG set provides continuous supply if there is any cutoff from KSEB by any fault or by any reasons. There are 4 DG sets where, 500kVA and 380kVA are connected to the whole campus, 160kVA to kitchen and 82.5kVA to Resource Block section. The central block and P.G block are installed with 50kW solar panel and the 100kW solar panel is equipped on automobile block. The following figure 2 gives the single line diagram.

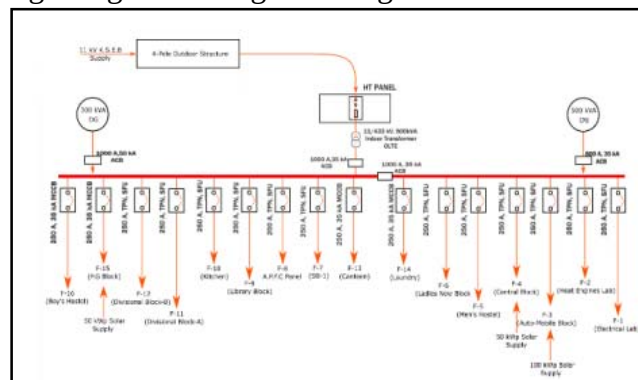


Figure 2: Single line diagram of the electrical distribution of the college

V. METHODOLOGY

The energy audit is defined as "the verification, monitoring, and analysis of the use of energy including submission of technical report containing a recommendation for improving energy efficiency with cost-benefit analysis and an action plan to reduce energy consumption". The energy audit is one of the essential tools for energy conservation so as to accomplish energy efficiency. It includes monitoring and analysis of various energy consuming equipment and convenient action plan to reduce additional energy consumption in the building. Energy auditing of any institute or building can be done by collecting energy-consuming data (electricity bills) and analyze that information to find out unnecessary utilization of energy. Following methodology adopted for an energy audit.

A. Data Collection

Data collection is the very first step in energy audit. Data collection includes.

1. Collected data like electricity bills of three years (2016, 2017, and 2018).
2. List of lighting load, fan, computer, and air conditioner of Resource Block.
3. List of lighting loads, motor, and other loads in S.T.P, Laundry, and Kitchen.
3. List of lighting loads, motor and other loads in S.T.P, Laundry and Kitchen.
4. Voltage, Current and Power are measured at each feeder.

B. Data Analysis

Data analysis is the next step after data collection. Here we identify the areas for implementation and energy conservation opportunities. Thus finally focus on 4 feeders, which are Resource block, Laundry Sewage treatment plant(S.T.P) and Kitchen. This result is obtained from the energy consumption graph of the campus (includes all feeders).

C. Actions Taken

Actions taken involves the implementation of opportunities based on the measurement of actual energy consumption in each feeder.

VI. RESOURCE BLOCK

The RB(Resource Block) section consumes more power during class-hours and on any events(such as arena(sports tournaments), azure(tech fest), conferences, etc)conducted in the auditorium, basketball court or connected to the RB and UPS supply of 16 kVA is also provided. The survey of the electrical load is carried out to determine the connected load of the block. The measured value of connected load in the

block is measured and presented in table 1. The electrical load can be categorized into lighting, AC and others such as computers, printers.

Name of Load		Quantity Measured
Lighting Load	CFL	26 (11 W), 24 (10 W), 24 (15 W), 29 (18 W), 71 (22 W), 5 (42 W)
	Flurescent Tube	242 (40 W)
	LED	5 (10 W)
FAN Load	Ceiling Fan	163 (60 W)
	Table Fan	16 (60 W)
Other Loads	AC	6 (1.5 Ton), 2 (8.5 Ton), 1 (1 Ton)
	Refrigerator	2 (490 W)
	Computers	35 (200 W)
	Printer	13 (250 W), 5 (1100 W)
	Projector	12 (270 W), 1 (450 W)
	Heater	1 (3kW)
	Audio Loads	2 (800 W), 6 (200 W)
	Air Cooler	2 (185 W)
	UPS	16 kVA*0.895=14.32 kW
	TV	1(110 W), 4(80 W)
Total Load:		103.6 kW

Figure 3: Electrical Load

Power quality analyzer is used for the measurement of power in this building and the below graph is plotted with respect to the measured value.

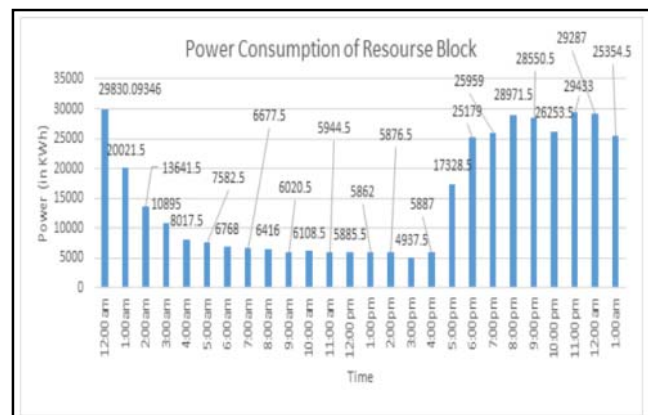


Figure 4: Power Curve plotted for Resource Block
Power consumption graph for the whole college with respect to the measurement taken

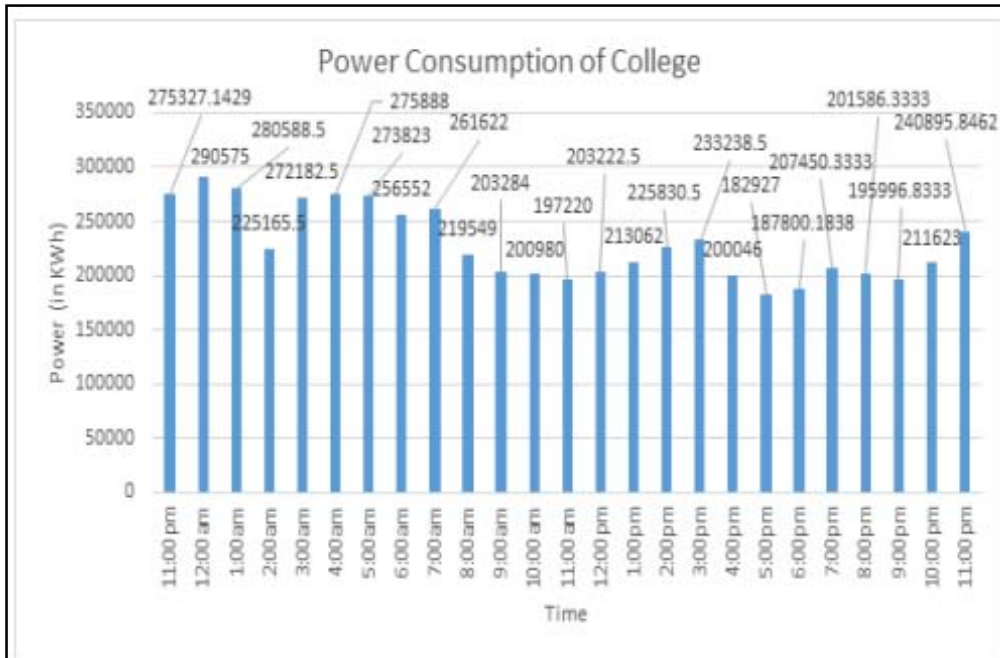


Figure 5: Power Curve plotted for College campus

VII. LAUNDRY

Laundry energy consumption usually depends upon the type and quantity of clothes. Laundry services work in a way to maintain the quality of material required by customers.

In our college, Laundry services start in the morning hours after collecting clothes from both ladies and men hostels. Our Laundry has power loads of 3 washing machines and 3 driers aligned opposite to each other for easy operation. Each motor in washing machine has a connected load of each 1.5 kW motors for washing and extraction. Dryer has two 1.5 kW motor with heat pump and blower motor. The plant has 6 tube lights, 1 fan load, with an elevator with 1.5kW motor. An uniform ironing press with 9 kW heater and 0.37 kW suction motor handles all the uniforms like shirts, pants, overcoat, etc[8]. Other non-uniforms are switched to vacuum table ironing with steam spray. An air compressor with 4 kW motor for pressurising air also used for door operation and extrac-

tion for washing machine and dryer as well as for operation of ironing press. The waste water coming out of the plant is passed to S.T.P.

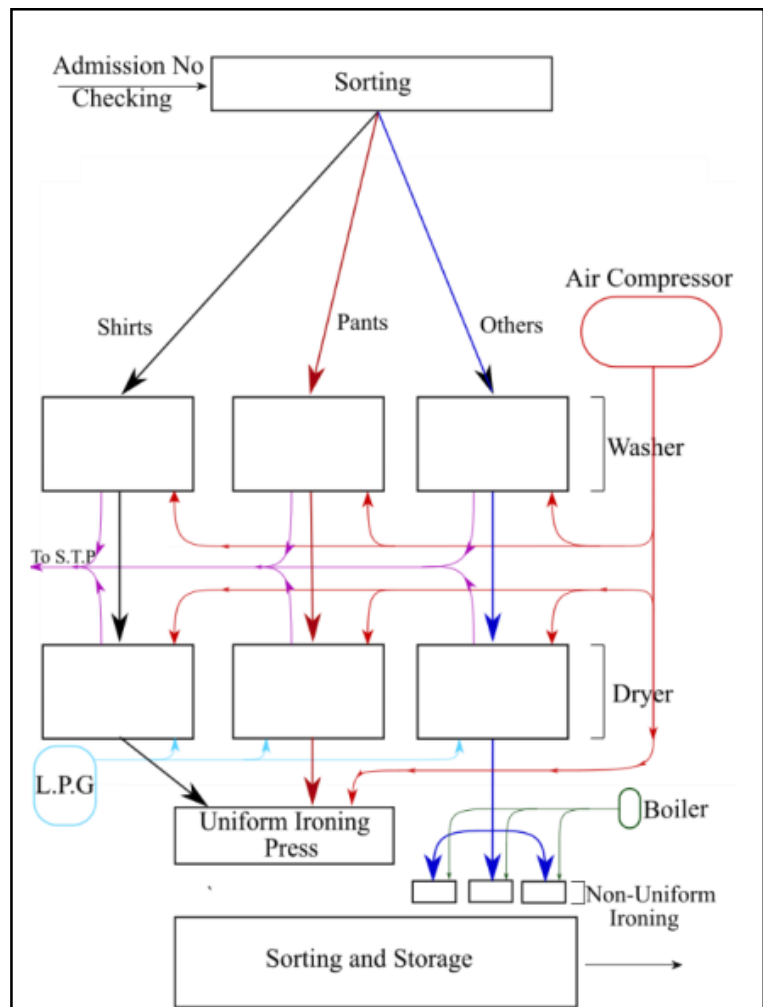


Figure 6: Process Diagram of Laundry

Power quality analyzer and Clamp meter is used for the measurement of power in this building and the below graph is plotted with respect to the measured value.

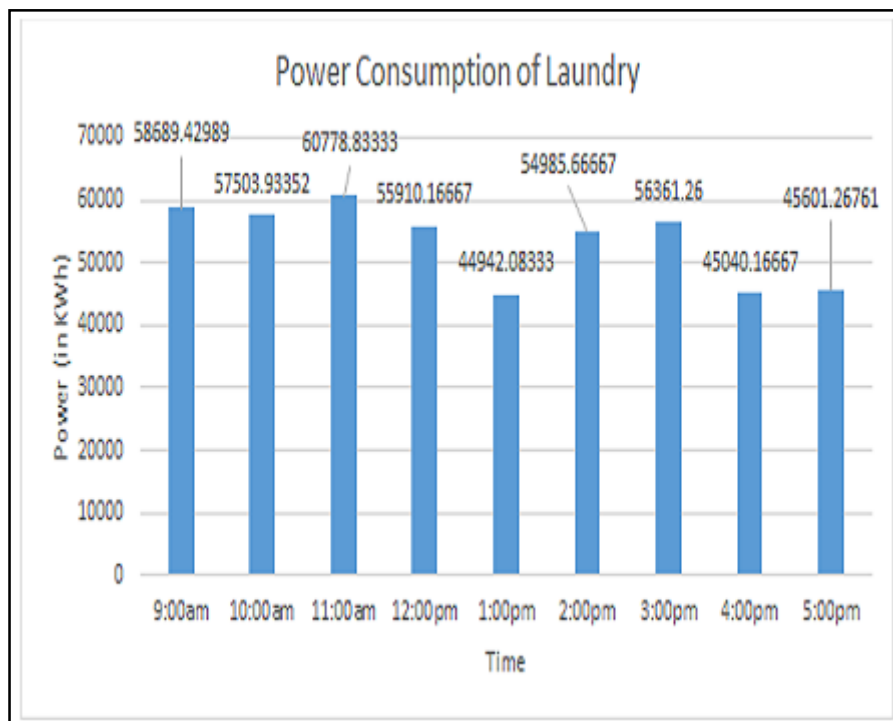


Figure 7: Power Curve plotted for Laundry

VIII. SEWAGE TREATMENT PLANT(STP)

Wastewater treatment is the process of removing contaminants from wastewater and household waste. The physical, chemical and biological process is used to remove contaminants from wastewater. The sewage treatment plant in our college is having the capacity of 6,00,000 litres per day. The processes involved in the treatment are preliminary treatment, primary treatment, secondary treatment and tertiary treatment.

Preliminary treatment consist of separating solid wastes such as sand, organic food materials, debris etc. Treatments such as bar screen, grit chamber and oil grease trap are used as the waste-

water enters first in the treatment plant. During the primary treatment suspended particles are removed and preparing it for the next stage. In secondary treatment both BOD(biological oxygen demand) and COD(chemical oxygen demand) can be reduced by using An-aerobic operation incorporated with SAFF(Submerged An-aerobic Fixed Film Reactor) followed by Aerobic reactor incorporated with MBBR(Moving Bed Biofilm Reactor).In tertiary treatment product water after disinfection and filtration can be collected in a tank can be used for flushing of toilets, for gardening and agricultural purpose.

Power quality analyzer and Clamp meter is used for the measurement of power in this building and the below graph is plotted with respect to the measured value.

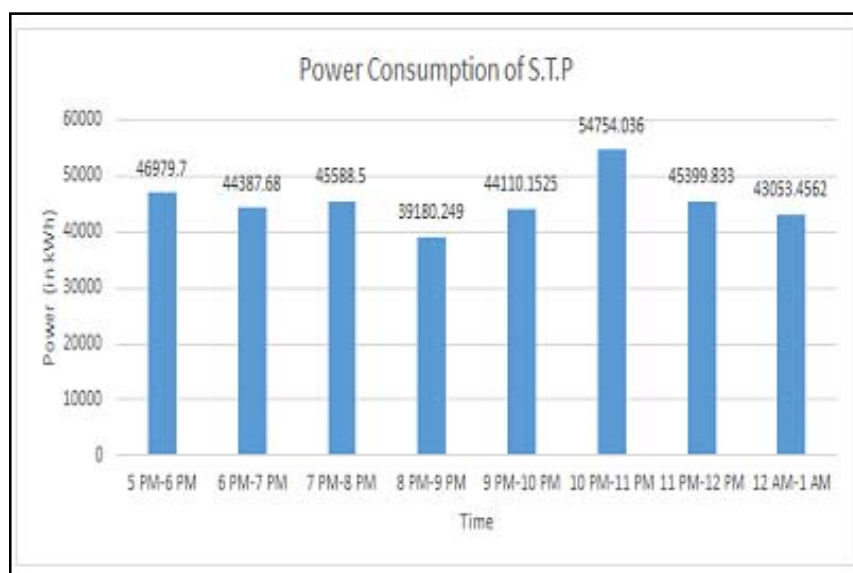


Figure 8: Power Curve plotted for STP

Major connected loads of STP

Connected load	Power rating (kW)
Blower 1	22.5
Blower 2	22.5
Filter feed pump 1	3.75
Filter feed pump 2	3.75
Sludge pump 1	3.75
Sludge pump 2	3.75
Feed pump 1	3.75
Feed pump 2	3.75
Storage pump 1	7.5
Storage pump 2	3.75
Tube (40W)	1.2
Total Load:	79.95 kW

IX. KITCHEN

Kitchen consume more energy in our campus than any other buildings as the food making process starts early in the morning from 3:30am till 1:00pm in the afternoon. As the campus enhances

more than 2300 students, the food making for them is a major part in the day to day program and major energy consumption unit in the campus. From cutting of vegetables to making different dishes are performed by different alternatively aligned machines which have different power ratings. Other than electricity some machines uses energies such as gas, steam from cooking etc. Our study in kitchen reveals that the overall energy can only be reduced by demand side management as devices such as dish washers,

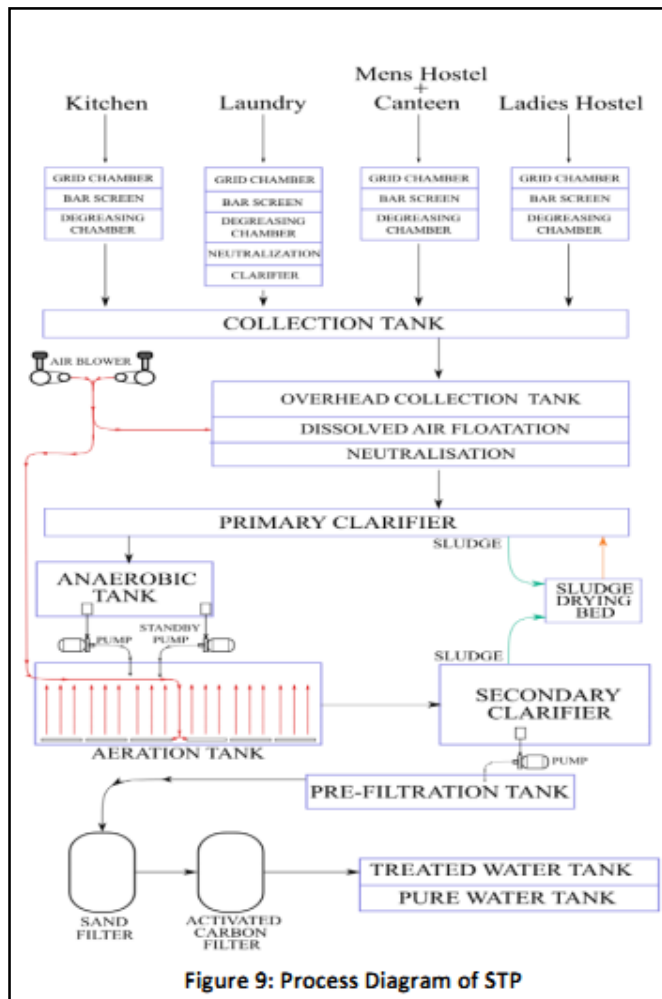


Figure 9: Process Diagram of STP

management as devices such as dish washers,

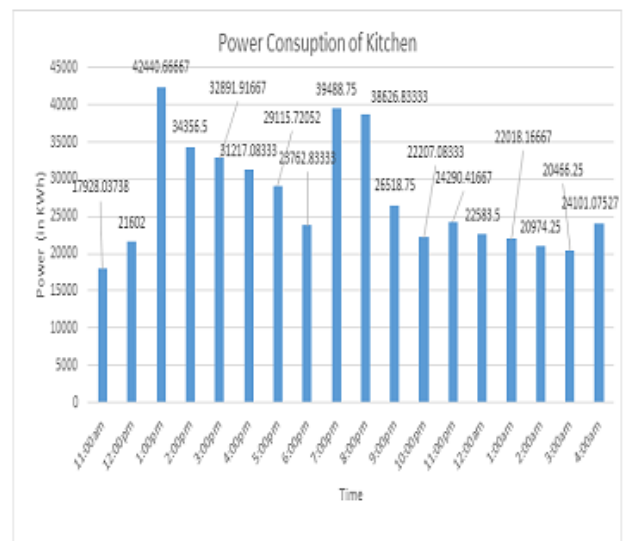


Figure 10: Power Curve plotted for Kitchen

X. DEVICES USED FOR MEASUREMENT

A. Power Quality and Energy Analyzer

The power quality analyzer is a multi-function power analyzer device that measures precisely direct current, alternating current, AC-Voltage, DC-Voltage, the in-

tensity of DC or AC, phase rotation and idle, apparent and effective power. The reading of AC power is considered the real value and has a maximum range of 6000Watts.

Power quality analyzer have many features such as insulated current input, measurement of harmonics, AC and DC current measurement, AC and DC voltage measurement, Frequency measurement, phase rotation measurement. All this data can also be logged and analyze with the delivered PC-software. Power analyzers of the type PCE-PA 6000 can determine the energy in single-phase systems. Power quality analyzer of type PCE-PA 62 allow the energy measurement in symmetrical loaded three-phase systems. Power analyzers of type PCE PA-8000, PCE-360 and PCE-830 support professional power and energy measurements in single and three-phase systems.



Figure 11: Power Quality Analyzer

B. Clamp Meter

Current clamp or current probe is an electrical device which uses jaws like opening to allow clamping around an electrical conductor. This allows measurement of the current in a conductor without the need to make physical contact with it and to disconnect it for insertion through the probe. Current clamps are typically used to read the magnitude Of alternating current (AC) and with additional instrumentation. The phase and waveform can also be measured using this meter.

Some clamps meters can measure currents of 1000 A and even more. Hall effect and vane type clamps can also measure direct (DC).

A clamp meter measures the vector sum of the currents flowing in all the conductors passing through the probe which depends on the phase relationship of the currents. Only one conductor is normally passed through the probe. In particular if the clamp is closed around a two-conductor cable carrying power to equipment. The same current flows down one conductor and up the other then the meter correctly reads a net current of zero.



Figure 12: Clamp meter with its components

C. Lux Meter

A lux meter is an equipment that measures brightness of light falling on an object at a particular area. In other words, it properly gauges the intensity at which brightness appears to the human eye. A lux meter works by making use of a photo cell to capture light. The lux meter the converts this light to an electrical current stream and after measuring this current, the device allows to calculate the lux value of the light which it has captured. Lux meters are used for measuring brightness in lux, fc or cd/m^2 . Some lux meters are equipped with an internal memory or data logger to record and save measurements. The measurements of light intensity with a lux meter is becoming increasingly impor-

tant in the workplace due to safety concerns. The lux meters with data loggers are highly regarded in the industry due to the devices cosine correction of the angle of incident light. Many lux meters include software for detailed analysis and offer different interfaces for transferring measured data to a computer.

The Lux meter auditing of all the selected buildings where quiet accurate with respect to the IS 3646(Indian Standard code for recommended illumination) and the buildings with illumination problems where solved by the addition of more LED lights.



Figure 13: Lux Meter

RECOMMENDATIONS

A. KITCHEN

The proposed design for dish washer in the kitchen is that the water after cooking (water from washing of vegetables, rice etc.) is allowed to flow into the water tank. This normal water is moved to the flash mixer where the mixing of steam from boiler or from solar heater takes place. There are two ways for the heating of water. First, the steam from boiler is allowed to pass to the flash mixer, this steam can provide temperature up to 80°C which is the required temperature for the dish washer then the hot water is directly passed into the hot water storage tank.

Second, the temperature provided by the steam can sometime vary as this temperature can sometime only reach up to 70°C so a relay circuit is provided for turning on the solar heater which will latter provide the remaining heat or temperature(10°C) to the water. An electric heater is also provided for the standby purpose incase of any failure from the remaining sources. This proposal is energy efficient as it does not use any electricity for its usage so the dish washing process used now which works fully on electricity can now be reduced which in turn reduce the overall electricity bill in the kitchen.

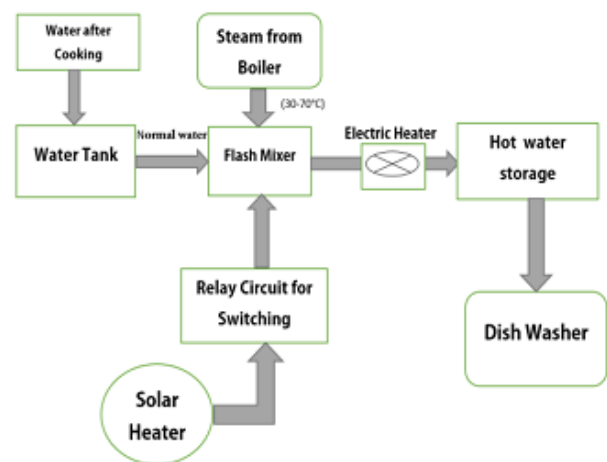


Figure 14: Process diagram for Dish Washer

B. LAUNDRY

Washing machines used now should be reassembled or replaced with other washing machines which can be fully operated with the help of solar energy.

C. SEWAGE TREATMENT PLANT

STP has more CFL lighting loads which should either be replaced by LED lights or the lighting circuit should be reduced to a minimum level as the building has only one occupant (Operator) and the lights are always turned on, which is not required in this building so reduction of lighting loads can reduce the energy bill to a minimum level.

CONCLUSION

Energy audit was conducted in the above buildings

to know the energy consumption patterns of the buildings. From the graphs plotted it is seemed that the working process of all the buildings cannot be stopped during the working hours and the energy can only be conserved by implementation of energy management methods. Solar energy is the best optioned method in this buildings as the above mentioned buildings take electricity directly from the KSEB supply. This energy is the best method as it is a non-renewable source of energy and will not cause any problems to the environment. Other implementations in the buildings are discussed in the above chapter.

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Earth Day-April 22

Earth Day is an annual event, celebrated on April 22, on which day events worldwide are held to demonstrate support for environmental protection. It was first celebrated in 1970, and is now coordinated globally by the Earth Day Network,[1] and celebrated in more than 192 countries each year.

When is Earth Day? : Earth Day is observed around the world on April 22, although larger events such as festivals and rallies are often organized for the weekends before or after April 22. Many communities also observe Earth Week or Earth Month, organizing a series of environmental activities throughout the month of April.

Why do we need an Earth Day? : Because it works! Earth Day broadens the base of support for environmental programs, rekindles public commitment and builds community activism around the world through a broad range of events and activities. Earth Day is the largest civic event in the world, celebrated simultaneously around the globe by people of all backgrounds, faiths and nationalities. More than a billion people participate in our campaigns every year.

What can I do for Earth Day? : The possibilities for getting involved are endless! Volunteer. Go to a festival. Install solar panels on your roof. Organize an event in your community. Change a habit. Help launch a community garden. Communicate your priorities to your elected representatives. Do something nice for the Earth, have fun, meet new people, and make a difference. But you needn't wait for April 22! Earth Day is Every Day. To build a better future, we all must commit to protect our environment year-round.

What is Earth Day Network? : Founded by the organizers of the first Earth Day in 1970, Earth Day Network (EDN) promotes year-round environmental citizenship and action, worldwide. Earth Day Network is a driving force, steering environmental awareness around the world. Through Earth Day Network, activists connect, interact and impact their communities, and create positive change in local, national, and global policies. EDN's international network reaches over 22,000 organizations in 192 countries, while the domestic program assists over 30,000 educators, coordinating thousands of community development and environmental protection activities throughout the year.

A NOVEL CONTROL TECHNIQUE FOR POWER QUALITY ASSESSMENT OF RAILWAY TRACTION USING RPC

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Abstract— Railway traction has become an important part of power system. It creates power quality issues in the grid. Negative sequence and harmonic currents have become the main issues in high speed train traction systems. A V/V traction transformer has been adopted for power supply to the traction. Railway static power conditioner (RPC) has been developed to mitigate the power quality issues. A comprehensive technique for compensation of negative sequence and harmonic currents has been discussed. RPC is a back to back connected converter with a dc link. The controller also provides a constant dc link voltage and thus helps in the compensation of power quality problem. Thus RPC improves the power quality in railway traction.

Keywords— Power Quality, Harmonics, Negative sequence current, V/V transformer

I. INTRODUCTION

Railway transport is being considered as the most popular mode of public transport. Increase in passenger journey and goods delivering in both short and long distances have made railway transportation highly demanding. To provide power propulsion and to get higher-speed, more stable and reliable sources are required. From several decades, electrification has been the first choice when modernizing most of the railway system across the world.

The growing complexity of the electrified railway systems in terms of both new technologies and automation requires a careful control of power quality disturbances they cause; the disturbances depend upon the traction system structure. Electric transport systems

have power electronic devices which have a direct impact on the normal operating conditions.

The power quality problem that can appear are: voltage fluctuations, voltage and current distortion, voltage sags, voltage and current unbalances. The above mentioned problems are due to non-linear loads. This is the case in traction systems because the power demand on the substations is non-linear due to heavy vehicle traffic. AC traction has rectifier at the load side used to supply dc to the motor driving the engine. It produces waveform distortion and harmonic current generation. Also the power factor of the grid reduces due to use highly inductive circuits and also injection of negative sequence current to grid. The widespread use of static converters in the locomotive drives has produced additional increase of current and voltage harmonic pollution inside the traction systems where the distorting effects of the electronic devices add on to the other harmonic issues.

Both AC and DC traction systems generate disturbances to the power quality. In AC traction negative sequence current and harmonic current are the major problems. This creates adverse impacts on the electrical devices and threatens the safe operation of the grid, such as increasing power losses of the electric devices and feeder line, reducing the output ability of the traction transformer, disturbing the relaying protection devices to do mis-operation. The amount of negative sequence current depends upon the traction power system, basically the transformer used. Typically transformers used are Scott transformers, Woodbridge transformer and V/V transformers. When balanced transformers are used, no negative sequence current is

injected into the grid when both the phases are loaded. For the traction power system with V/V transformer, negative sequence current is injected into the grid. But due to their simple structure and high capacity utilization they are widely used.

Several methods are available to improve the power quality issues in traction. They are shunt capacitor compensation, static synchronous compensator, thyristor controlled capacitor- Fixed capacitor arrangements, static var compensator, UPFC etc. Here a new topology for compensation is adopted, that is Railway Static Power Conditioner (RPC). RPC which contain two converters connected back to back by a common dc capacitor, which can compensate for the negative sequence current and harmonic currents for the traction system. A reasonable control strategy to adjust the output currents of two converters, it would transfer the active power from one power supply arm to another thus providing the suitable compensation. The control strategy adopted is implemented with the fuzzy hysteresis controller. Also the dc-link capacitor voltage is controlled using a PI controller in order to maintain a constant dc voltage for the converter action to be performed.

The paper, analyse the principle of RPC with three phase V/V transformers to compensate negative sequence and harmonic current and a method to provide the compensating current references. In particular, the stable control of dc- link voltage is the prerequisite for normal operation of RPC.

II. Train Traction Power Supply Systems

The structure of railway static power regulator is shown in Fig. 1. Three phase 220 kV high voltage is stepped down into two single phase power supply voltages of 27.5kV by the V/V transformer. RPC is made of two back to back connected voltage source converters and a common dc capacitor, which can provide a stable dc link voltage. Two converters are connected to V/V transformer's secondary power arms through the output reactance and step down transformer. A reasonable control strategy to adjust the output currents of two converters, it would transfer the active power from one power supply arm to another

thus providing the suitable compensation. The turn's ratio of the V/V transformer is K_v .

The step down transformer ratio is K_D . The two reactances are L_a and L_b . U_a and U_b are the secondary voltages of the V/V transformer

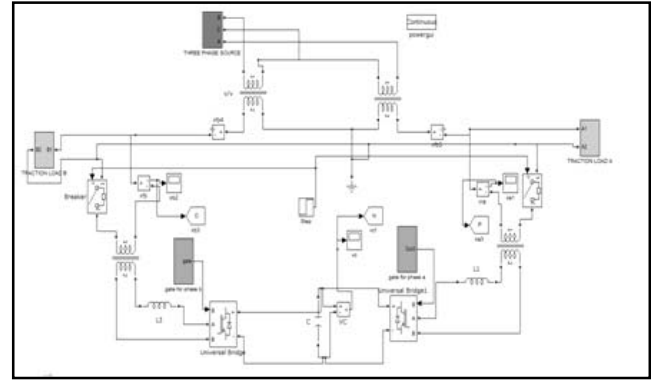


Fig. 1 Topology of RPC

III. ANALYSIS OF COMPENSATION PRINCIPLE AND REFERENCE SIGNAL ACQUISITION

A. Analysis Of Negative- Sequence Current Compensation

In order to analyse the compensation principle of NSC, we assume the ratio of V/V transformer as K_v . The left side of the feeder section is phase a and right side is phase b. The three phase primary voltages of the traction transformer are U_A , U_B and U_C .

Three phase voltages of the power grid are

$$\begin{aligned}\dot{U}_A &= Ue^{-j0^\circ} \\ \dot{U}_B &= Ue^{-j120^\circ} \\ \dot{U}_C &= Ue^{j120^\circ}\end{aligned}\quad (1)$$

The currents of both the feeder are in phase with U_{AC} and U_{BC} and can be expressed as

$$\begin{aligned}\dot{I}_{La} &= I_{Laf}e^{-j30^\circ} \\ \dot{I}_{Lb} &= I_{Lbf}e^{-j90^\circ}\end{aligned}\quad (2)$$

where I_{Laf} denotes the rms value of Phase a (fundamental) current and I_{Lbf} is the rms value of Phase

b (fundamental) current. The three phase currents of the power grid are then

$$\begin{aligned} \dot{I}_A &= \frac{I_{Laf}}{K_v} e^{-j30^\circ} \\ \dot{I}_B &= \frac{I_{Lbf}}{K_v} e^{-j90^\circ} \\ \dot{I}_C &= -\left[\frac{I_{Laf}}{K_v} e^{-j30^\circ} + \frac{I_{Lbf}}{K_v} e^{-j90^\circ} \right] \end{aligned} \quad (3)$$

The phasor diagram of the system without compensation is shown in Fig. 2. From the figure it is clear that the three phase currents of the grid are not balanced. Phase A current lags Phase A voltage by 30° ; Phase B current leads Phase B voltage by 30° ;

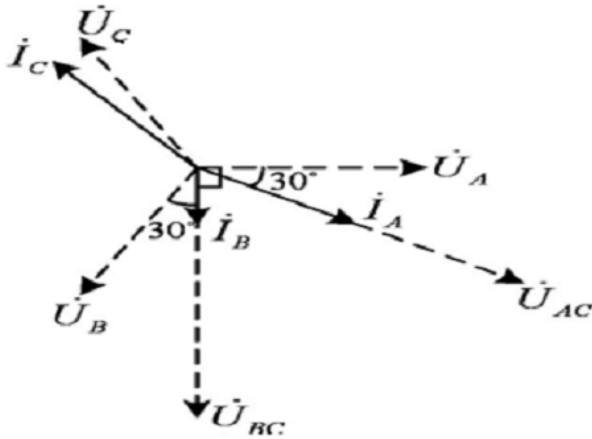


Fig. 2 Phasor diagram of the system without compensation

A. Shift of Active Power

Before RPC's compensation, a- phase power arm has load current I_{aL} and the b- phase power has load current I_{bL} . The RPC can shift half of the current difference of the two section currents from the heavily loaded section to the lightly loaded section. Fig. 3 shows the phasor diagram when the RPC shifts $\Delta I = (1/2)(I_{Laf} - I_{Lbf})$ from Phase a to Phase b, which is purely active. This brings the current of Phase A and Phase B to

$$\begin{aligned} \dot{I}'_A &= \dot{I}_A - \frac{\Delta I}{K_v} e^{-j30^\circ} = \frac{1}{2K_v} (I_{Laf} + I_{Lbf}) e^{-j30^\circ} \\ \dot{I}'_B &= \dot{I}_B + \frac{\Delta I}{K_v} e^{-j90^\circ} = \frac{1}{2K_v} (I_{Laf} + I_{Lbf}) e^{-j90^\circ} \end{aligned} \quad (4)$$

Phase A and Phase B have the same rms value but Phase C does not. Phase A current lags Phase A voltage by 30° ; Phase B current leads Phase B voltage by 30° ; and Phase C current is in phase with Phase C voltage.

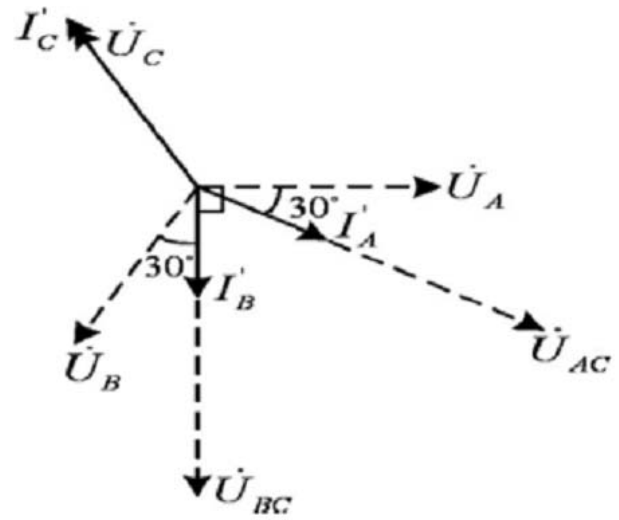


Fig. 3 Phasor diagram after shifting the active power difference

C. Compensation of Reactive Power

In order to make the three phase currents balanced, it is necessary to add certain reactive current to phase a and phase b to shift the phase angle to the currents to be in phase with the phase voltage. It can be seen from Fig. 4 that the reactive current to be compensated by the converters should be

$$\frac{1}{2K_v} (I_{Laf} + I_{Lbf}) \tan 30^\circ \quad (5)$$

Phase a generates reactive power and Phase b consumes reactive power. This brings the three phase currents $\hat{I}_A$, $\hat{I}_B$ and $\hat{I}_C$ on the grid side balanced and in phase with the grid phase voltages, respectively. The peak value of the three- phase currents $\hat{I}_A$, $\hat{I}_B$ and $\hat{I}_C$ is

$$\frac{\sqrt{2}}{2K_v}(I_{Laf} + I_{Lbf}) \times \frac{2}{\sqrt{3}} = \frac{\sqrt{2}}{\sqrt{3}K_v}(I_{Laf} + I_{Lbf}) \quad (6)$$

The phasor diagram on the secondary side of the V/V transformer after shifting the active power and compensating the reactive power is shown Fig. 4. The phase currents on the secondary side are

$$\begin{aligned} i_{af} &= \frac{\sqrt{2}}{\sqrt{3}}(I_{Laf} + I_{Lbf}) \sin \omega t \\ i_{bf} &= \frac{\sqrt{2}}{\sqrt{3}}(I_{Laf} + I_{Lbf}) \sin(\omega t - 120^\circ) \end{aligned} \quad (7)$$

Hence, the compensating current of two RPC converters can be obtained as

$$\begin{aligned} i_{ra} &= i_{af} - i_{La} \\ i_{rb} &= i_{bf} - i_{Lb} \end{aligned} \quad (8)$$

The positive direction of the compensating currents is the direction when the currents flow into the RPC.

IV. CONTROL OF RPC CONVERTERS

A. Real-Time Implementation Of Compensation Principle

The current reference for the RPC converter developed from equation (8) and is depicted in Fig.5, where u_a and u_b are the voltages of Phase a and Phase b respectively. RPC is composed of two back to back converters connected by a dc capacitor essentially, and we can independently control the two converters.

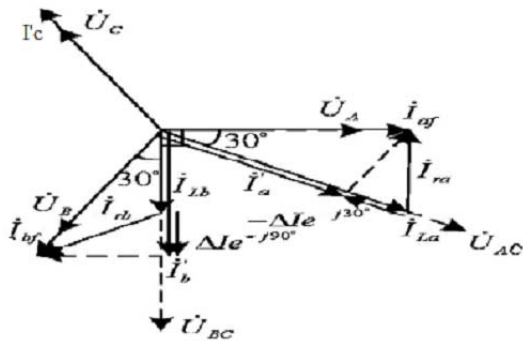


Fig.4 Phasor diagram on the secondary side of the V/V transformer after compensation

One converter can be used for rectification absorbing active power $(P_a - P_b)/2$ to maintain the dc-link voltage, while the other one is used for inversion releasing energy for dc-link capacitor to provide the train with active power. In this way they can transfer the active power and correspondingly output the reactive power and reference currents for compensation of NSC and harmonic compensation. FBD method is adopted for the reference current generation.

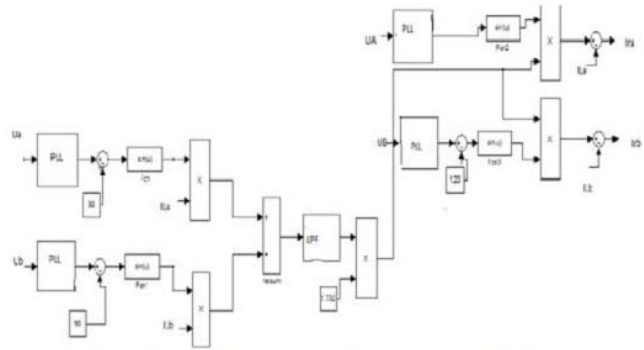


Fig.5 Generation of current reference for RPC

When the phase angle δ varies between 0° and δ , the converter is used for rectification and the energy of power grid flows to dc capacitor and as δ varies between 0° and $-\delta$, the converter is used for inversion and the energy of dc link will flow to the traction power arm. For harmonic suppression, the total harmonic distortion (THD) of traction power supply voltage should be less than 5% according to IEEE standards.

A. Current Tracking Controller for the RPC Converter

The main function of the RPC converter is to track the reference currents i_{ra} and i_{rb} , respectively, which include the active, reactive and harmonic components needed to compensate the negative sequence current and harmonic currents. A fuzzy threshold bandwidth hysteresis current tracking control is adopted. In order to solve the high switching frequency fluctuation problem in traditional hysteresis method, the hysteresis bandwidth, H is designed to be dynamically changed. Fuzzy control has good dynamic characteristics and good robustness and is not sensitive to changes of system parameters and can overcome the effects due

to some non-linear factors in the system. Also the hysteresis controller has high precision and fast response. Both the fuzzy and hysteresis when added up will provide all these advantages and thus better control.

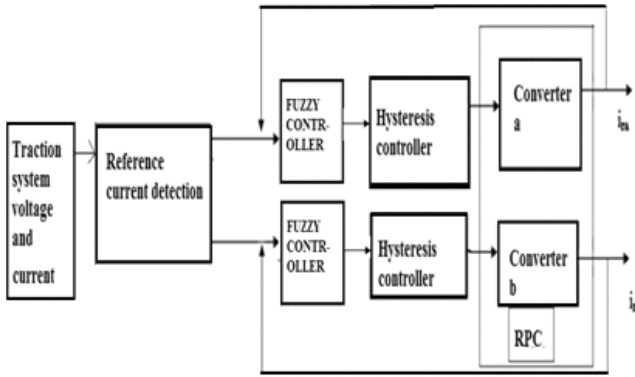


Fig.6 Structure of RPC current controller with fuzzy hysteresis control

The input of fuzzy controller contains two parts: ΔI_r , the deviation of reference current and the sensed actual

min synthetic method is used as fuzzy interference method. After fuzzy inference, de-fuzzification is required to obtain the correct value of hysteresis bandwidth H . This paper adopts centroid method of de-fuzzification. The required H bandwidth is given to the hysteresis controller to track the reference current and thus provide harmonic and negative sequence compensation. The control signals from the hysteresis controller is given to the converter a and b gate signals in order to vary the firing angle of the converter and to obtain the require compensation.

C. DC- Link Voltage Controller

In order to make sure that the RPC converters track the reference currents i_{ra} and i_{rb} properly a stable dc – link is essential. The two converters can be considered as independent parts and the dc-link voltage has to be kept steady by the converters absorbing or releasing active power. The converters should charge the dc-link capacitor when the voltage U_{DC} is below the reference value U_{ref} . On the other hand, the dc –link

capacitor should be discharged when the voltage is above the reference value. This can be achieved by adding a PI controller. The output is multiplied with the synchronous voltage signal so that the current is in phase with the corresponding voltages of Phase a and Phase b.

V. RESULTS AND DISCUSSION

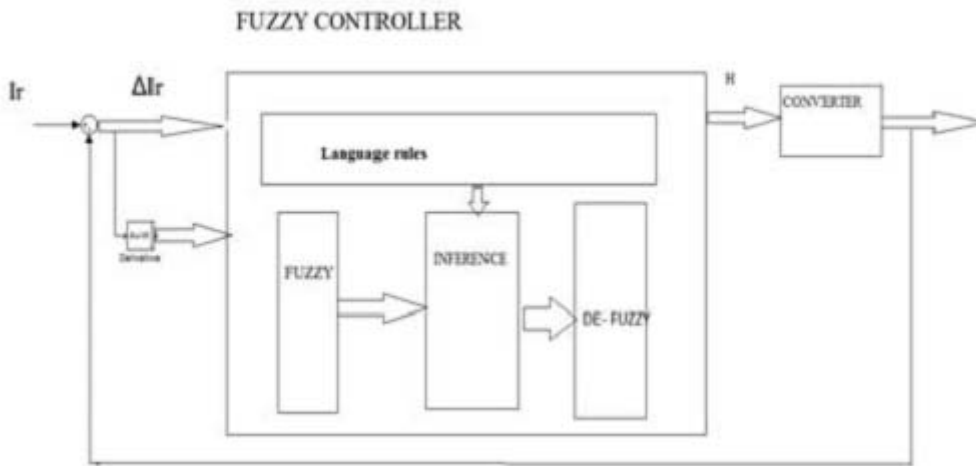


Fig 7 Schematic diagram of Fuzzy Controller

current and $\frac{d\Delta I_r}{dt}$, the rate of change of current deviation. The fig 7 shows the schematic diagram of fuzzy controller. Three linguistic values for three linguistic variables are considered: Big (B), Middle (M) and Small (S). Triangular function is developed is selected as fuzzy variable membership functions. Mamdani max-

Simulations were carried in MATLAB tool. Section B was loaded and its power is 4800kW. The THD for the locomotive current was 11.5% without compensation. The grid currents I_A , I_B and I_C are shown in the Fig. 8 without compensation. The corresponding THD values are 5.4%, 11.4% and 11.3% without compensation. RPC

was introduced to the system after 0.1 sec and the corresponding power quality issues were mitigated. After switching RPC, a certain amount of active power was transferred from Phase b to Phase a. The THD value was reduced to 3% for the grid current.

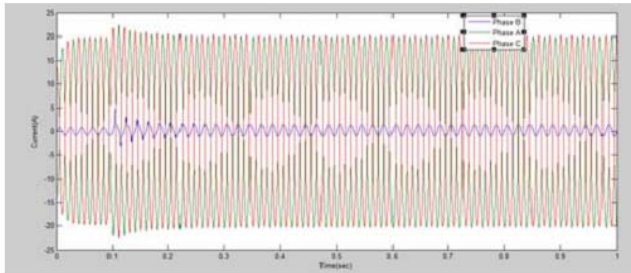


Fig.8 Grid current with No compensation

The total reference currents required for compensating the negative sequence current and harmonic currents were obtained. The total reference current needed for compensation is shown in Fig. 9 and Fig. 10. The secondary current of V/V transformer ie; the phase a and phase b currents become equal after compensation is shown in fig.11. The three phase grid current after compensation is shown in fig.12.

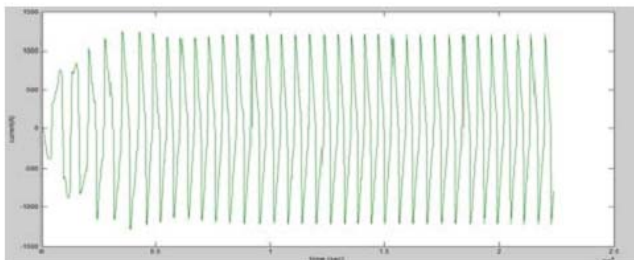


Fig.9 Reference current for Phase a

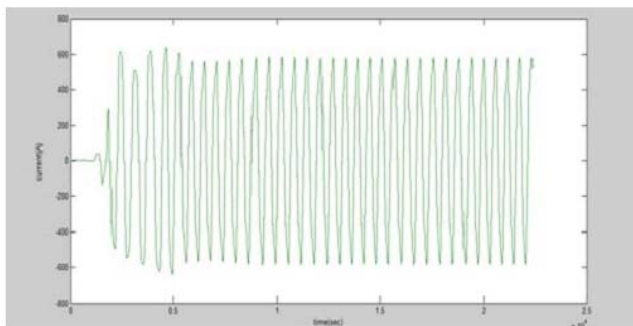


Fig.10 Reference current for Phase b

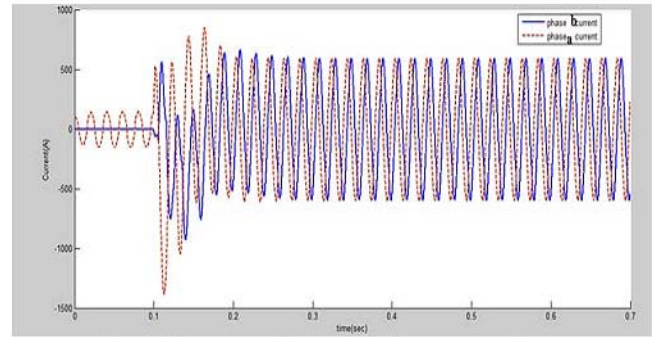


Fig. 11 Phase a and b current after compensation

VI. CONCLUSIONS

A strategy to compensate the negative-sequence and harmonic currents in high-speed train traction power supply systems with three-phase V/V traction transformers is proposed in this paper. The current references for the RPC converters are generated according to the load currents on both sections of the traction power supply system and current controllers are designed to track the current references. A PI controller is added into the system to maintain the dc-link voltage.

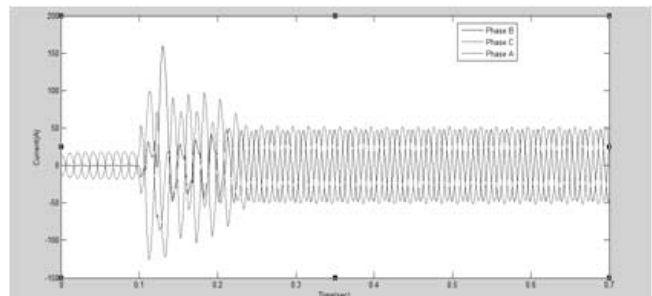


Fig.12 Grid Current after Compensation

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ENGINEERS' DAY

September 15



September 15 is celebrated every year in India as Engineers' Day to commemorate the birthday of the legendary Engineer Sir M. Visvesvaraya (1860-1962).

The KSEBEA observes the Engineers' day every year. This is celebrated throughout the state through all our units.

Er. Mokshagundam Vishveshwariah, (popularly known as **Sir MV**) was a notable Indian engineer, scholar, statesman and the Diwan of Mysore during 1912 to 1918. He was a recipient of the Indian Republic's highest honour, the Bharat Ratna, in 1955. He was knighted as a Commander of the British Indian Empire by King George V for his myriad contributions to the public good. Every year, 15 September is celebrated as Engineers' Day in India in his memory. He is held in high regard as an eminent engineer of

India. He was the Chief Designer of the flood protection system for the city of Hyderabad, now capital city of Andhra Pradesh, as well as the Chief Engineer responsible for the construction of the Krishna Raja Sagara dam in Mysore. He was born in Muddenahalli in Karnataka state.

Symmetrical components-Simplified

Er Amal Ashok, Assistant Engineer, KSEB Ltd

Part-1 : Symmetrical components

Symmetrical components is a mathematical tool to analyse conditions in a three phase power system. In 1918, Dr. C. L. Fortescue wrote a paper entitled “Method of Symmetrical Coordinates Applied to the Solution of Polyphase Networks.” In the paper Dr. Fortescue described how arbitrary unbalanced 3-phase voltages (or currents) could be transformed into 3 sets of balanced 3-phase components. He called these components “symmetrical components.”

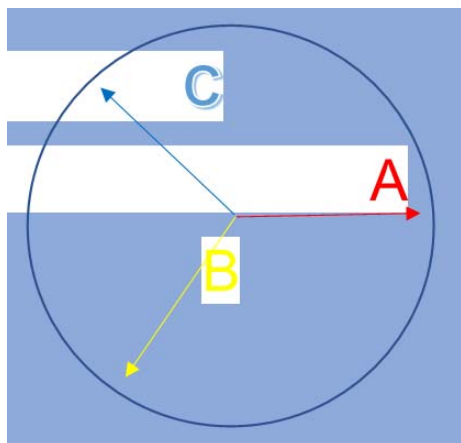
These are used in relay and protection schemes in identifying certain condition and explaining anomalies happening in our system.

Basic Rules

1. Phasors rotate in counter clockwise direction
2. Counter clockwise is the leading direction
3. Clockwise is the lagging direction
4. System values are the sum of three symmetrical components

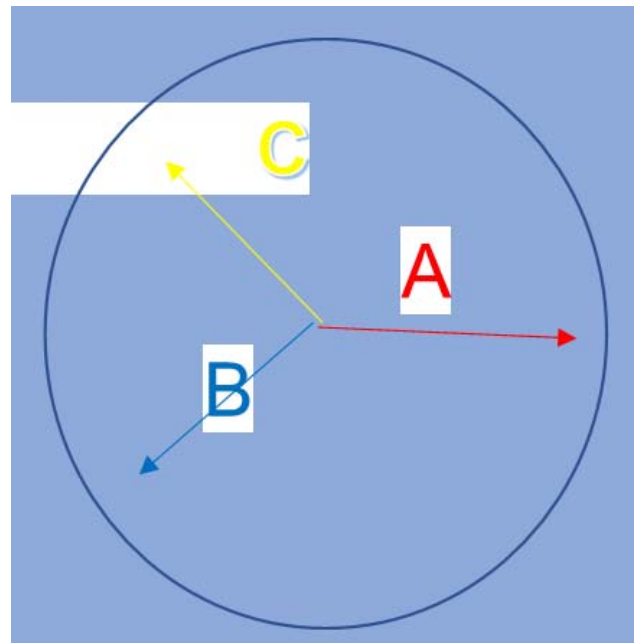
1. Positive sequence components: The following are the properties of positive sequence components

- a. All phasors are equal in magnitude
- b. There is 120 degree separation between the phasors
- c. They are symmetrical and has the same phase sequence as the system
- d. They are expressed as V_1 or I_1 .



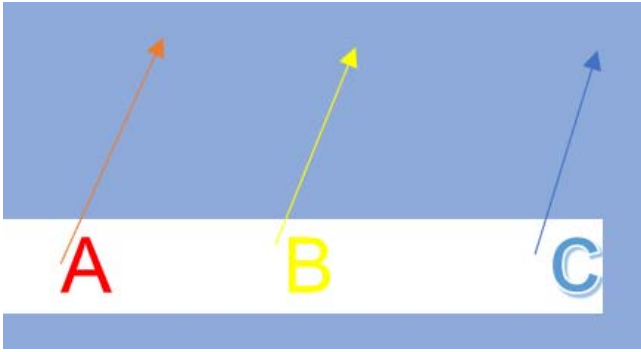
2. Negative sequence components: The following are the properties of negative sequence components

- a. All phasors are equal in magnitude
- b. There is 120 degree separation between the phasors
- c. They are symmetrical and has the opposite phase sequence as the system
- d. They are expressed as V_2 or I_2 .



3. Zero sequence components: The following are the properties of negative sequence components

- a. All phasors are equal in magnitude
- b. They have common angle between the phasors
- c. They are asymmetrical and no phase sequence
- d. They are expressed as V_0 or I_0 .



Lets now approach the math

Taking A phase as reference we can write

$$I_0 = I_{A0} = 1/3(I_A + I_B + I_C)$$

$$I_1 = I_{A1} = 1/3(I_A + aI_B + a^2I_C)$$

$$I_2 = I_{A2} = 1/3(I_A + a^2I_B + aI_C)$$

So neutral current measured by neutral current transformer in a protection system is $3I_0$.

Now lets take a balance system

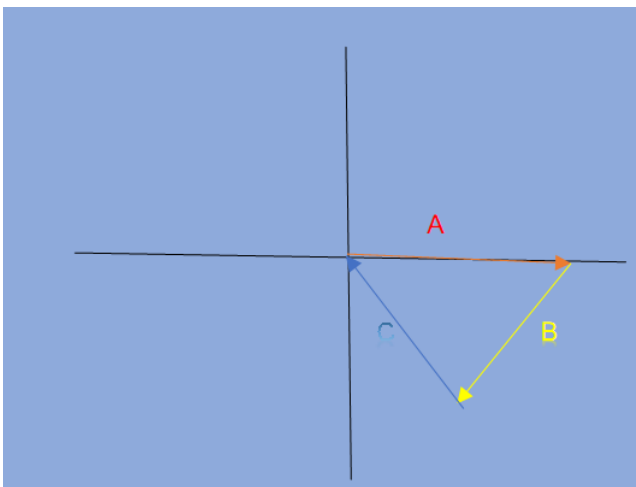
$$I_A = 10A \angle 0^\circ$$

$$I_B = 10A \angle -120^\circ$$

$$I_C = 10A \angle +120^\circ$$

$$\text{Zero sequence component } I_0 = I_{A0} = 1/3(I_A + I_B + I_C)$$

So first lets add the 3 phasors

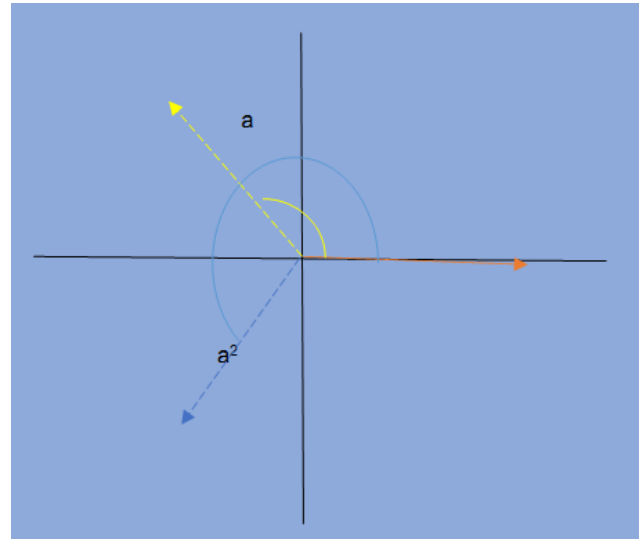


On adding the three phasors we came to the point where we started ,so the sum is zero.

Hence the zero sequence component is zero for a balanced 3 phase system.

The a operator

The a operator is a 120 degree counter clockwise operator. It shifts the phasor by 120 degrees in the counter clockwise direction. The a^2 is a 240 degree counter clockwise operator. It shifts the phasor by 240 degree in the counter clockwise direction



Now lets find the negative sequence components for the balanced system

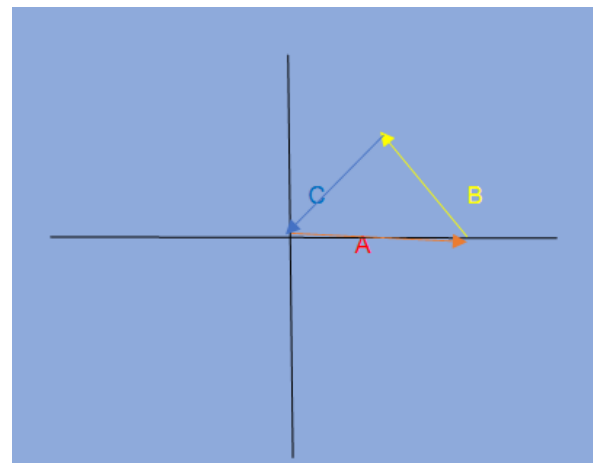
$$I_A = 10A \angle 0^\circ$$

$$I_B = 10A \angle -120^\circ$$

$$I_C = 10A \angle +120^\circ$$

$$\text{Negative sequence component } I_2 = I_{A2} = 1/3(I_A + a^2I_B + aI_C)$$

So lets added the phasor I_A with I_B (phase shifted by 240°) and I_C (phase shifted by 120°)



Now Again on adding the phasors we came to the point we started, so the sum is zero. Hence the negative sequence components is zero for a balanced three phase system.

Now let's find the positive sequence components for the balanced system

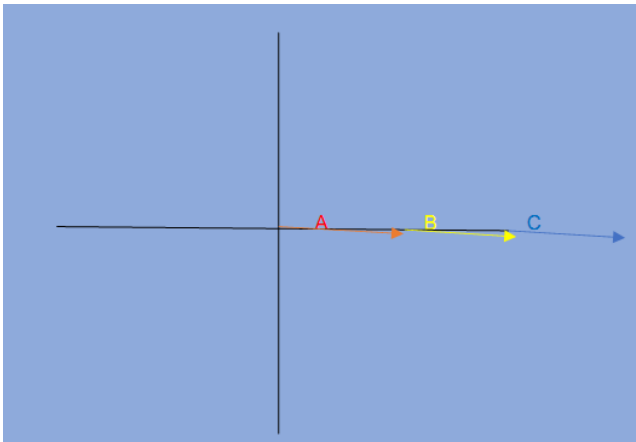
$$I_A = 10 \angle 0^\circ$$

$$I_B = 10 \angle -120^\circ$$

$$I_C = 10 \angle +120^\circ$$

Positive sequence component $I_1 = I_{A1} = 1/3(I_A + aI_B + a^2I_C)$

So let's add the phasor I_A with I_B (phase shifted by 120°) and I_C (phase shifted by 240°)



$$\text{So } I_1 = I_{A1} = 1/3(10 + 10 + 10) = 10 \angle 0^\circ$$

So for a balanced system the resultant is 100% positive sequence.

Part-2 : Unbalanced System

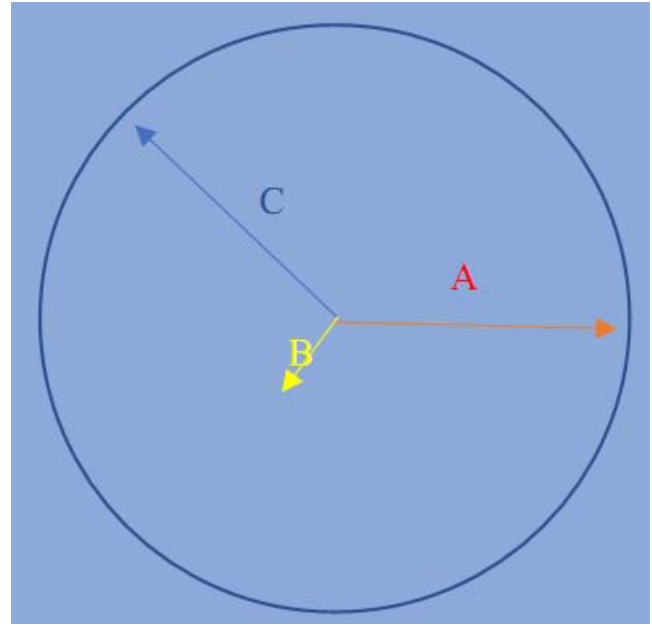
In the previous part of this paper we have analysed a balanced system and found that for a balanced system the resultant is 100% positive sequence.

Now let's take the example of an unbalanced system.

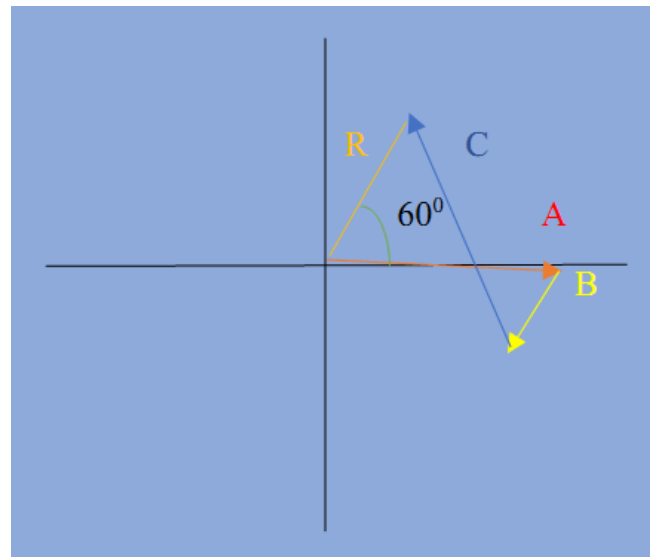
$$I_A = 5 \angle 0^\circ$$

$$I_B = 2 \angle -120^\circ$$

$$I_C = 5 \angle 120^\circ$$



Zero sequence component $I_0 = I_{A0} = 1/3(I_A + I_B + I_C)$
Now let's add the three phasors.



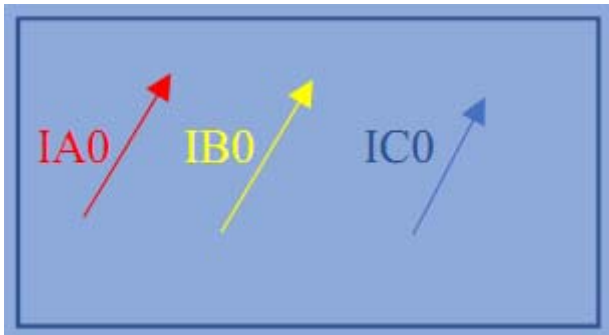
When we add the 3 phasors we get a resultant R which is at an angle of 60° to the reference with a magnitude of 3Amps

$$R = 3 \angle 60^\circ$$

$$\text{So } I_{A0} = 1/3(3 \angle 60^\circ) = 1 \angle 60^\circ$$

So the A phase zero sequence current is $1 \angle 60^\circ$
similarly we can transform the other phase. The zero

sequence components of all phases will have a magnitude of 1Amps and angle of 60°

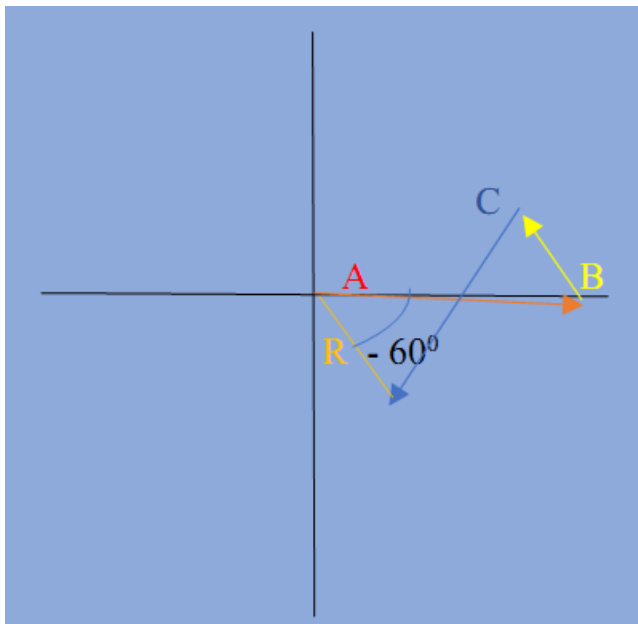


Zero sequence components

Now let's find the negative sequence components

Negative sequence component $I_2 = I_{A2} = 1/3(I_A + a^2 I_B + a I_C)$

So let's add the phasor I_A with I_B (phase shifted by 240°) and I_C (phase shifted by 120°)



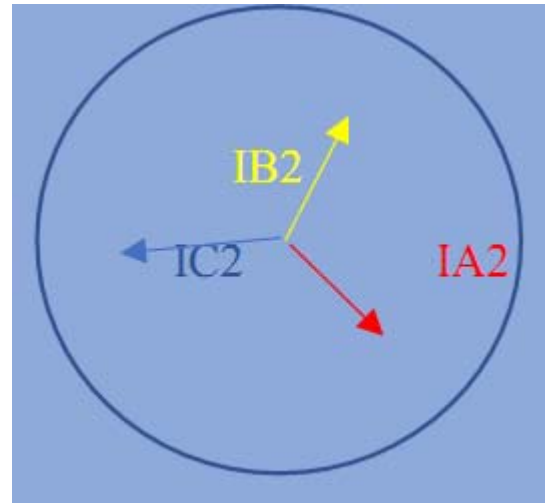
When we add the 3 phasors we get a resultant R which is at an angle of -60° to the reference with a magnitude of 3Amps

$$R = 3A \angle -60^\circ$$

$$\text{So } I_{A2} = 1/3(3 \angle -60^\circ) = 1 \angle -60^\circ$$

So the A phase negative sequence current is $1 \angle -$

60° similarly we can transform the other phase. The zero sequence components of all phases will have a magnitude of 1Amps and angle of 60° lagging angle.



Negative sequence components

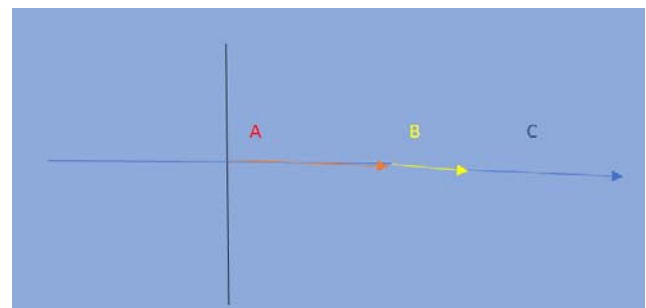
Now the negative sequence components are 60° degrees lagging the phase components. We also notice that the following points for negative sequence components

1. Phase sequence is reversed compared to phase current.
2. They are all equal in magnitude
3. They are having a phase difference of 120° .

Now let's find the positive sequence components

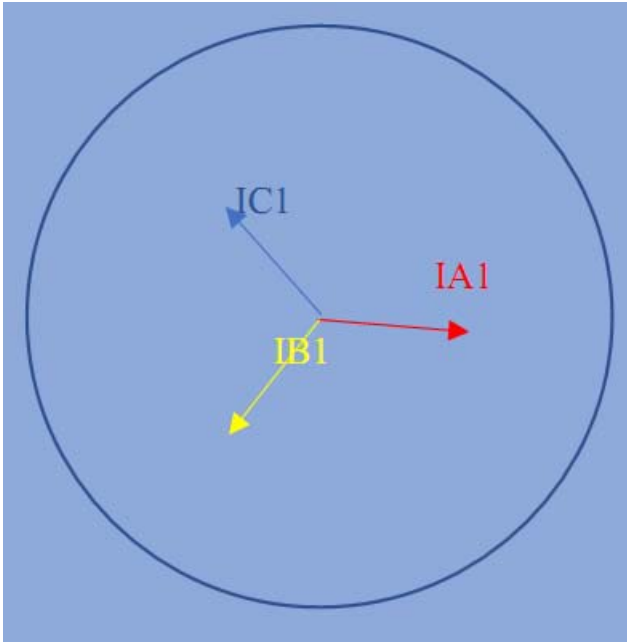
Positive sequence component $I_1 = I_{A1} = 1/3(I_A + a I_B + a^2 I_C)$

So let's add the phasor I_A with I_B (phase shifted by 120°) and I_C (phase shifted by 240°)



Now if we add the three phases we get the resultant $R = 12A \angle 0^\circ$.

$$\text{SO } I_{A1} = 1/3(12 \angle 0^\circ) = 4A \angle 60^\circ$$



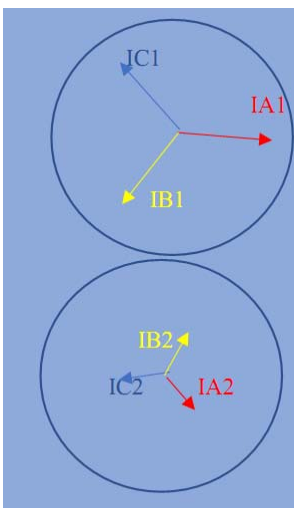
Positive sequence components

We notice that the following points for positive sequence components

1. Phase sequence is same compared to phase current.
2. They are all equal in magnitude
3. They are having a phase difference of 120° .

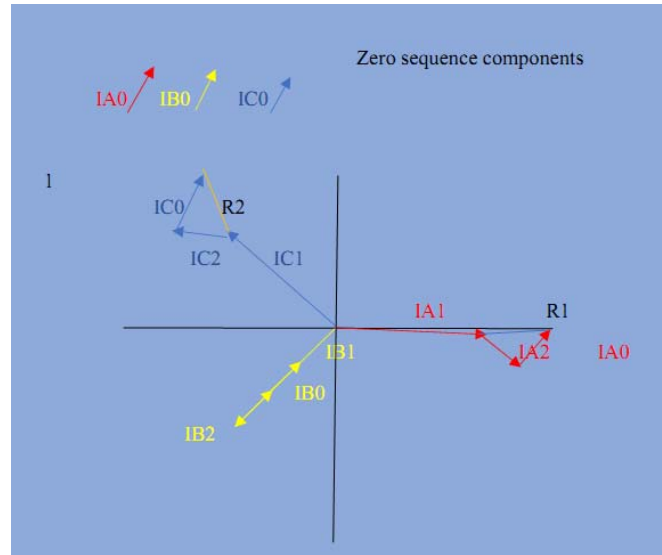
For an unbalanced system the magnitude of positive sequence is less compared to a balanced system

For getting our system values we can add our positive sequence, negative sequence and zero sequence values.



Positive sequence components

Negative sequence components



We are doing the summation by keeping the positive, negative and zero sequence components end to end.

So let's take the A phase

$$\begin{aligned} I_A &= I_{A1} + I_{A2} + I_{A0} \\ &= I_{A1} + R_1 \\ &= (4\angle 0^\circ) + (1\angle 0^\circ) = 5A\angle 0^\circ \end{aligned}$$

Now for B phase when we keep the components end to end we notice that negative and zero sequence components are in opposite phase to the positive sequence components.

$$\begin{aligned} I_B &= I_{B1} - I_{B2} - I_{B0} \\ &= 2A\angle -120^\circ \end{aligned}$$

Similarly for C phase

$$\begin{aligned} I_C &= I_{C1} + I_{C2} + I_{C3} \\ &= I_{C1} + R_2 \\ &= 5A\angle 120^\circ \end{aligned}$$

Now we have verified the math.

Voltage Stability Improvement and Loss Minimization by Optimal Placement of STATCOM using Teaching- Learning Based Optimization Technique

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Abstract. - In the modern power system voltage instability is the most prevalent issue which occurs continually and mandates the system operator to find the remedy in order to have the efficient and reliable operation of equipment connected to the system. This literature emphasizes on the voltage instability issue of power systems and also an approach which can overcome the problem whenever the system is subjected to an aforementioned problem which is usually accomplished by deploying compensation device of suitable size. In this paper, teaching learning-based optimization technique is used to find the appropriate size of the compensatory device, whenever the voltage violation occurs due to the increased demand for active power as well as reactive power in the system. dv/dq index is preferred to find the location of compensatory device allocation. In this literature, STATCOM is used as a compensatory device and this approach is validated for IEEE 30 bus system on the MATLAB platform.

Keywords:- STATCOM, voltage stability, optimal location, TLBO, loss minimization.

1 Introduction

The rapid increase in modernization and the standard of living are somehow the major cause of the drastic increase in load demand and the problem of voltage versatility and losses in the transmission line. To mitigate this issue Power Electronics based devices named as FACTS are effectively used for loss minimization and to improve voltage stability and power flow control [1]. FACTS devices are quite expensive and their place implementation and size calculation is a cru-

cial factor [1]. To solve these FACTS optimization problems there are numerous methods like classical, technical, heuristic and mixed techniques but all these methods have some disadvantages besides all the advantages.

Classical methods have a computational limit as the size increases while the results of technical methods are not a global optimum. Heuristics techniques are able to calibrate the optimum results with fewer complexities used in [2].

These techniques are population-based and derived from human behavior or natural phenomena and have better convergence and also able to converge problems which have a non-continuous and not differentiable objective function, so they are more flexible than other methods and possess the capability to work beyond the limits of continuity and differentiability of a function used in [3].

Mixed methods are addressed as the FACTS optimization issue with technical as well as heuristic methods. The problem of optimal allocation of FACTS devices is solved by applying technical methods and subsequently, the settings of FACTS devices are optimized with classical or heuristic methods to alleviate the computational efforts with global optimal results as used in [4][5].

In this paper, STATCOM is employed as a compensatory device and to find the optimal location for STATCOM allocation dv/dq index method is used, which is very easy to calculate from the Jacobean matrix during load flow. TLBO is implemented in MATLAB coding for sizing and parameter setting of the STATCOM. N-R method is used for load flow

with STATCOM in order to optimize the objective function.

2. Placement and Sizing of Facts Devices

FACTS devices play an important role for stability enhancement and to improve the transmission capacity of the transmission line but these are very expensive and call for attention on the perspective some factors as an appropriate size of devices, size of FACTS device and location where the FACTS devices are to be deployed. These factors play a vital role in minimizing the installation cost of the FACTS device associated with the required reactive power compensation to improve the stability of the power system.

The optimal location for placement is necessary because of the fact that minimum no. of compensation devices are required at the optimal location [7]. In order to find out the optimal location for facts devices, the weakest bus of the system should be known because the location of weak buses is the best suitable location for the FACTS installation. dv/dq index method is used in this paper, this index contains the information about the voltage variations in each and every bus according to the load variation. The bus which shows the maximum deviation in the voltage profile with load changes are named as the weakest bus of that system. Sizing is an important factor in order to reduce the installation cost of FACTS devices. Expressions for the cost function of STATCOM is given below [6][8]:

$$C_{STATCOM} = 0.000375S^2 + 0.3041S + 162.4 \quad (\text{US\$/KVar}) \quad (1)$$

3 Problem Formulation

3.1 Objective Function

Objective function is the mathematical expression of objectives. FACTS devices are taken in use because of their multi-functionality. These devices are able to achieve more than single objective as:

3.1.1 First objective- Minimization of losses as in [9]

$$f_1 = \sum_{k=1}^{N_l} g_k [V_i^2 + V_j^2 - 2V_i V_j \cos(\delta_i - \delta_j)] \quad (2)$$

3.1.2 Second objective- minimization of the voltage deviation

$$f_2 = \sum_{j \in J_L} |V_j - V_{ref}|^2 \quad (3)$$

Final objective function

$$\text{Min}(F) = w_1 * \min(f_1) + w_2 * \min(f_2) \quad (4)$$

Here w_1 and w_2 are weight factors

4 Static Synchronous Compensator (STATCOM)

STATCOM classified under shunt connected FACTS devices. A coupling Transformer is used to affiliate the voltage source converter (VSC) with the transmission line.

STATCOM serves the purpose of supplying to or absorbing from depending upon the violation of line reactive power. Mode of operation of the STATCOM depends upon the variation in voltage of the line. When the terminal voltage falls off the lower limit STATCOM supplies reactive power and if the terminal voltage exceeds the upper limit STATCOM absorbs the reactive power from the line [11].

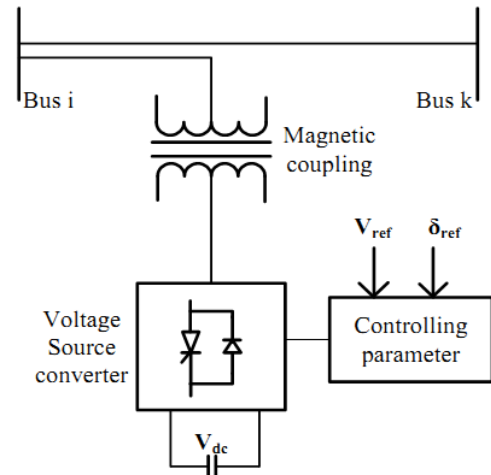


Fig. 1 Functional block diagram of STATCOM

STATCOM is a semiconductor device so its output is

limited to the defined maximum voltage and current rating.

The following real and reactive power equations are obtained for the converter placed at bus i as in [10][11].

$$P_{st} = V_i V_{st} y_{sh} \sin(\theta + \phi) - V_{st}^2 y_{sh} \sin(\phi) \quad (5)$$

$$Q_{st} = V_i V_{st} y_{sh} \cos(\theta - \phi) - V_i^2 y_{sh} \cos(\phi) \quad (6)$$

Here,

V_i = Grid voltage ; V_{st} = STATCOM voltage

From above equations we can say, reactive power injection is depend on phase angle (θ) and (θ) can be calculated from below equation [11], where Capacitor voltage V_c should be constant

$$V_c = \frac{V_i \sin(\theta + \phi)}{K \sin(\alpha) \sin(\frac{\gamma}{2})} \quad (7)$$

Here,

K = constant

(θ) = Phase angle and γ = width of DC voltage pulse on the capacitor

Real and reactive component of compensation current

can be expressed as in [11]:

$$I_p = I \cos(\frac{\pi}{2} - \theta)$$

$$I_q = \pm I \sin(\frac{\pi}{2} - \theta) \quad (8)$$

Where,

$$I = \pm \frac{V_i}{r} \sin \theta \quad (9)$$

(10)

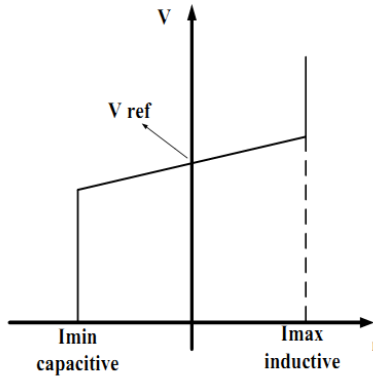


Fig. 2: V-I Characteristics for STATCOM

5 Teaching Learning Based Optimization (TLBO)

TLBO algorithm is inspired by classroom behavior or process of teaching and learning in the classroom. TLBO is population-based technique like PSO. The property which defines TLBO algorithm to be advantageous is the absence of user-defined or tuning parameter and makes it popular and very easy to be implemented. According to the classroom behavior, TLBO

algorithm involves two steps during implementation which are teaching and learning phase.

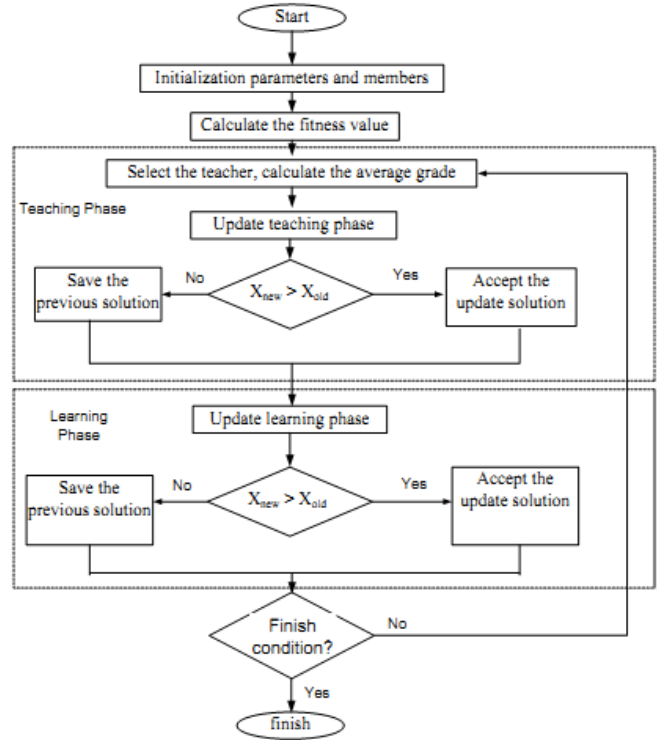


Fig. 3: Flow chart of TLBO

5.1 Teaching phase

Population is considered as learners having the same objectives as in a classroom. Best one among the all is treated as a teacher and all the learners start to shift towards teacher (this may be a local optimum or global optimum) in given space as shown in equations (11-12). This process works like a teacher teaches the students.

$$x_i^{new} = x_i + \text{Difference mean}_d \quad (11)$$

$$\text{Difference mean}_d = \text{rand}(M_d^{new} - TF * M_d) \quad (12)$$

Here, M_d

Here, M_d^{new} = new mean value

M_d = old mean value

TF = Teaching factor

5.2 Learning phase

After the teaching phase all learners are updated according to the above equations. In the learning phase,

each learner interacts with all others and the best solution will be considered as new learner or solution. If this is the global optimum for given space it will be final solution else it passes to the next iteration as in equations (13-14).

$$x_i^{new} = x_i^{new} + \text{rand}(x_i^{new} - x_j^{new}); \text{ if } f_i^{new} < f_j^{new} \quad (13)$$

$$x_i^{new} = x_i^{new} + \text{rand}(x_j^{new} - x_i^{new}); \text{ if } f_i^{new} > f_j^{new} \quad (14)$$

6 Results and Discussion

The proposed algorithm is written and results are validated in MATLAB with the consideration of the IEEE 30 bus system as a test system. The IEEE 30 bus system consisting of 5 generator buses, 24 load buses and one slack bus (bus no. 1). For better com-

pensation, the STATCOM is employed at the weakest among all buses. In this system, the 26th bus is found to be the weakest one and the task is accomplished by performing the dv/dq index method. Further to show the superiority of the proposed methodology over the existing system a comparison has been made which reflects, the proposed methodology to be beneficial over the existing system. For the comparison of power loss at distinct loads is taken into consideration as an attribute.

Table 1. Power loss comparison at different loading conditions.

From the above table, it is clear that with the proposed methodology power loss in the system is minimized with a substantial reduction at a higher value of loading.

Another comparison has been made considering the voltage profile at different loading conditions. With the implementation of the proposed methodology, it can be observed that enhancement in voltage profile is accomplished over the existing system.

Load (%)	Active power loss(MW)	
	Without STATCOM	With STATCOM
100	17.503	17.456
110	21.752	21.678
120	26.562	26.490
130	31.960	31.920

Table 2. Voltage Profile Comparison with Existing System

The observations show that with the implementation of proposed methodology the result obtained is satisfactory and hence ensures the assuagement of requisites of a compensator.

Bus no.	Base load		110% load		120% load		130% Load	
	Without STATCOM	With STATCOM	Without STATCOM	With STATCOM	Without STATCOM	With STATCOM	Without STATCOM	With STATCOM
1	1.060	1.060	1.060	1.060	1.060	1.060	1.060	1.060
2	1.043	1.043	1.043	1.043	1.043	1.043	1.043	1.043
3	1.027	1.028	1.025	1.026	1.022	1.023	1.018	1.019
4	1.020	1.021	1.017	1.018	1.0143	1.015	1.011	1.012
5	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
6	1.015	1.016	1.013	1.014	1.011	1.012	1.008	1.010
7	1.005	1.005	1.003	1.004	1.001	1.001	0.998	0.999
8	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
9	1.036	1.037	1.033	1.035	1.029	1.031	1.025	1.028
10	1.024	1.026	1.019	1.023	1.013	1.017	1.007	1.012
11	1.082	1.082	1.082	1.082	1.082	1.082	1.082	1.082
12	1.035	1.035	1.031	1.033	1.027	1.029	1.023	1.025
13	1.071	1.071	1.071	1.071	1.071	1.071	1.071	1.071
14	1.020	1.021	1.015	1.017	1.009	1.011	1.003	1.007
15	1.016	1.017	1.010	1.013	1.004	1.007	0.998	1.002
16	1.023	1.024	1.017	1.020	1.012	1.015	1.006	1.010
17	1.018	1.020	1.012	1.016	1.006	1.010	0.999	1.004
18	1.007	1.008	0.999	1.003	0.992	0.995	0.984	0.989
19	1.004	1.005	0.997	1.000	0.989	0.992	0.980	0.986
20	1.008	1.010	1.001	1.005	0.994	0.997	0.986	0.991
21	1.009	1.010	1.001	1.007	0.994	0.999	0.986	0.993
22	1.015	1.017	1.008	1.015	1.001	1.008	0.994	1.003
23	1.008	1.010	1.001	1.006	0.993	0.999	0.986	0.993
24	1.002	1.005	0.993	1.005	0.985	0.996	0.976	0.991
25	0.995	1.002	0.987	1.013	0.979	1.003	0.971	1.003
26	0.976	0.993	0.967	1.023	0.957	1.009	0.947	1.017
27	0.999	1.004	0.993	1.011	0.986	1.003	0.979	1.002
28	1.014	1.014	1.011	1.014	1.009	1.011	1.006	1.009
29	0.979	0.984	0.970	0.989	0.961	0.978	0.952	0.975
30	0.967	0.972	0.957	0.976	0.947	0.964	0.936	0.960

7 Conclusion

From the results obtained it can be observed that placement of STATCOM as FACTS device and application of TLBO algorithm have their own advantages on the perspective of various terms such as power loss minimization and voltage profile improvement. Although, from the results, it is clear that by minimizing the system power losses the proposed methodology has proven to be an economically efficient system. However, to get the precise economic efficiency of a device it is required to perform an operation because the installation cost of the FACTS device is also involved.

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Ivanpah Solar Thermal PowerPlant

Ivanpah Solar Electric Generating System situated in the Mojave Desert in California is the World's largest solar power plant. An engineering marvel in itself, Ivanpah uses over 3,00,000 mirrors (heliostats) to reflect heat and light from the Sun onto boilers atop three of the towers here. Each of these towers is 150 feet taller than the Statue of Liberty.



As water in the towers gets heated, steam is created and moves turbines. This produces enough clean and green electricity to power up 1,40,000 homes (about 392 megawatts).

From a distance, mirrors look like a lake in the middle of a desert which is about four times larger than the Central Park in the New York City. It can be seen from the International Space Station.

Solar thermal projects like Ivanpah are said to be more suited for India as we have plentiful land and Solar irradiation.

Innovations in Storage Battery Technology

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Battery research has been a priority in present day technology and structural development. The successful of a technology depends on the easiness in accessing the power and energy, especially through stored sources. The following three power supply and battery innovations that could change the way we energize our world.

Redox Flow Batteries

Vanadium Redox-flow batteries (VRFBs) is already in use to improve grid and large-scale energy storage. This form of battery was invented decades ago, but was only recently adopted as a viable option to lead the industrial battery charge.

VRFBs are appropriate for grid-scale usage, which means they store hundreds of megawatt-hours. For example, a wind farm or solar farm may use a VRFB to capture the excess energy created by these renewable energy sources during peak production times. The benefits of VRFBs compared to Li-on power cells are durability, scalability and longer discharge cycle. Vanadium-based Dedox-flow batteries also incur lower costs due to higher abundance of vanadium.

RFB works more like a reversible fuel cell: To discharge, the battery takes the chemical energy stored in liquid electrolytes and converts it into electrical current, reversing the process to charge. Other battery forms rely on charged electrodes, increasing fire risk. VRFBs are safer, especially when built around non-flammable materials.

This technology over comes the shorter discharge cycle; two hours or less. In the case of industrial Li-on batteries at grid-scale Like alkaline batteries.

Alkaline Solid-State Battery

Alkaline Solid-State Battery technology is invented by Michael Zimmerman. The advantages of this

technology includes safety, efficiency and sustainability. This research has made the further advancements under the leadership of Billy Joy at Ionic Materials.

Historically, consumers have relied on two kinds of batteries. Alkaline batteries which use zinc and manganese dioxide. However, they are not rechargeable. Later chargeable lithium ion batteries (Li-on) are introduced to over this shortfall.. A traditional Li-on battery, like what powers cell phones and electric vehicles, uses a liquid lithium electrolyte solution that carries ions. Li-on batteries can be unsafe. They can catch fire, especially if the liquid gets corrupted with another substance that creates a chemical reaction.

In a solid-state battery, the liquid is replaced with a plastic. The polymer is made of alkaline materials, which are far more abundant than lithium and cheaper to source and use. The polymer is naturally flame retardant, an important quality, and are rechargeable. They have the potential to be reformatted as large batteries for grid storage due to their efficiency. Drawbacks to this technology include weight/density issues and inadequate cycle amounts.

Sodium Solid State Battery

All-Solid-State, Sodium-based Battery has faster charging with an increased storage capacity and improved safety. Besides using sodium as the solid electrolyte, their material choices for other essential battery parts inhibit dendrite formation. Dendrites are electrolytic growths, looking like chemical vines, that cut battery life spans short. The technology uses a boron-based substance that would conduct the sodium ions. As an inorganic material, it will not catch fire while charging.

The research is in progress to improve the charge discharge to 1200 cycles, which is the current market standard.

Modeling and Simulation of Standalone Wind Energy Conversion System

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Abstract: With the current scenario of availability of deposits of conventional energy sources, it was only a matter of time before energy generation with renewable energy sources took charge. With renewable energy sources available in abundance, it has become possible to harness and use this energy extensively. One such energy source is Wind. This paper focuses on the modelling and simulation of standalone wind energy conversion system for small scale operations. The open-loop simulation is carried out in MATLAB Simulink. The system consists of Wind turbine Simulink model, DC generator and Full Bridge DC-DC converter followed by the load.

Keywords: Renewable, Wind Turbine, DC-DC Converter, DC Generator, Open loop.

INTRODUCTION

The conventional sources have always been at the forefront as far as electric power production is concerned. The only major hurdles are the emission of gases and the pollution of environment which eventually contribute to the global warming. Thus, the use of renewable sources for electric power generation has increased ferociously.

Renewable sources are clean sources, thus, it has an added advantage that emission of harmful gases are minimized to a greater extent. Also, these sources are available in abundance almost all the time. One such renewable source is wind energy. The fact that wind is a clean and inexhaustible source of energy and also that it is readily available in environment makes it a popular choice among the renewable sources. Since it does not pollute the environment during its operation, it has become one of the most desired energy systems for minimizing the environmental problems, both nationally and globally [1].

This paper focuses on modelling and development of standalone wind energy conversion system. The system is modelled for operating low and medium scale loads, basically residential loads, primarily in remote areas.

The block diagram of standalone wind energy system is shown in Fig.1. The system consists of wind turbine model, DC Generator, DC-DC converter and the load.

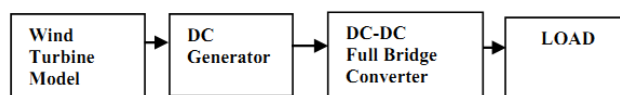


Fig.1 Block Diagram of open loop standalone wind energy conversion system

The output of the wind turbine model is coupled to the DC Generator. Thus, output from the Generator obtained is in DC form. This is fed to the Full Bridge DC-DC converter which is acting in boost mode, as the desired output required is higher. This output is then fed to the load. The simulation results for the system shown in Fig.1 are also shown.

WORKING PRINCIPLE OF WIND TURBINES

Wind turbines basically convert the dynamic energy of wind into mechanical power. This conversion of mechanical power into electrical energy can be achieved with the help of Generators. This conversion is achieved due to the sleek force that is hatched by rotor blades of turbine. As the wind gushes pass the blades, there is a nonconformity in the air pressure on

either sides of blade. This nonconformity across either sides of the blades gives rise to lifting and dragging action [2].

The gyration of rotor begins when the lifting force of blades is higher than the dragging force. The rotor is further coupled to the Generator with the help of a shaft. This shift from sleek force of the rotor blades to the gyration of generator gives rise to electricity. Higher is the gyration speed, higher is the electricity generated.

MATHEMATICAL MODELING OF WIND TURBINE

The modelling of the system is done keeping in mind the practical parameters as well as ideal conditions. The mechanical output power of turbine is expressed as "(1)",

$$P_m = C_p(\lambda, \beta) * \rho * A^2 * v^3_{\text{wind}}(1)$$

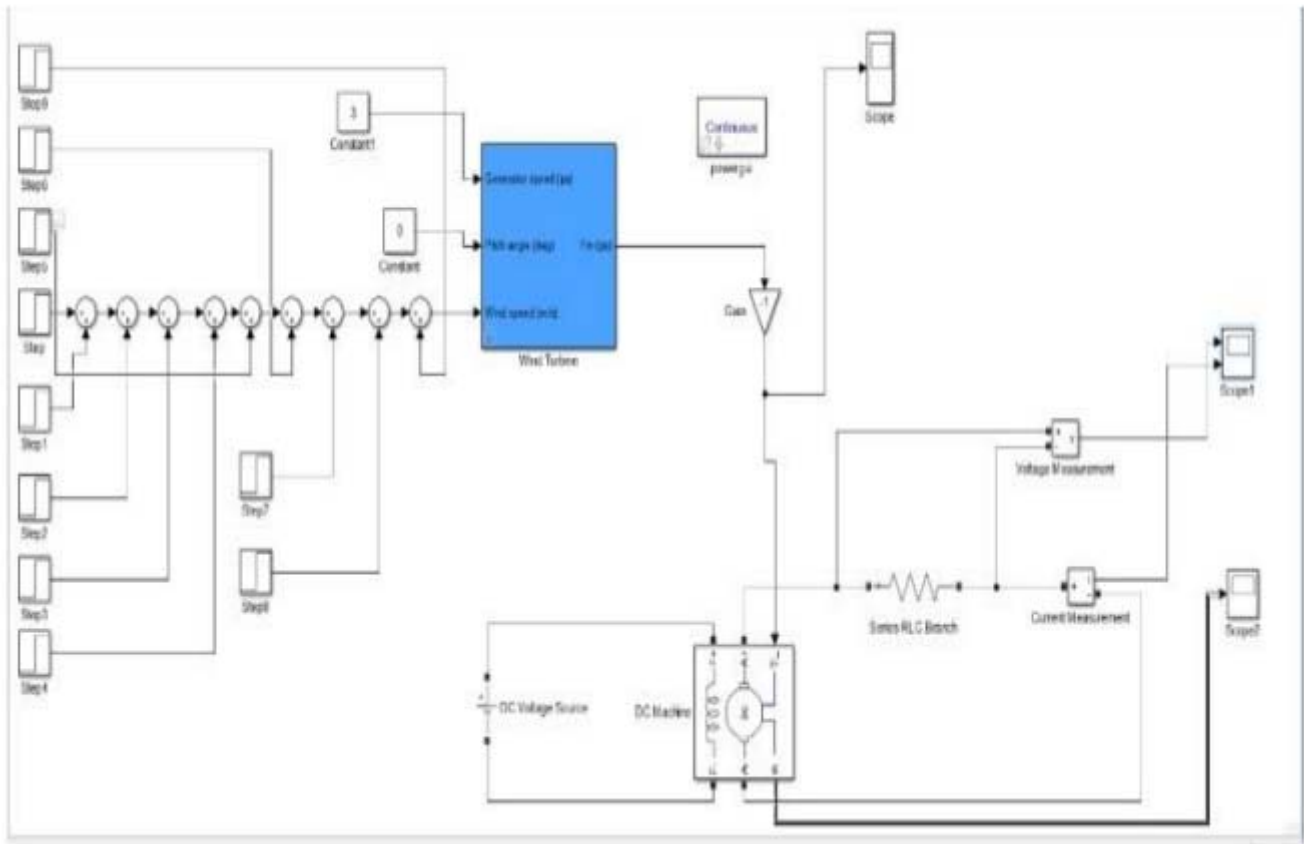


Fig 3: Matlab Model of Wind turbine and DC Generator

The output voltage and current of the entire system is monitored across the Load.

DC-DC Full Bridge Converter

The output of DC generator is then cascaded to the Full bridge converter. This converter is specifically used when we need a steep increase in voltage [5]. There are two operating stages in this converter:

- 1) DC to AC conversion
- 2) AC to DC conversion

DC to AC translation is possible with the help of IGBT switches which are inverting the voltage. The gate pulses are triggering the switches which are scheduled after a certain delay with respect to each other. This inverted voltage is then fed to the transformer. The transformer amplifies the voltage. The stepped up voltage is then fed to the rectifier circuit. The resulting wave is a

DC with ripples. In order to nullify this ripples, filter circuit is used [6]. The L and C values are so designed to negate the ripple in voltage and current.

The value of inductor is expressed as “(6)”

$$L = \frac{D \cdot V_{in}}{2 \cdot dI \cdot F_s} \quad (6)$$

The value of capacitor is expressed as “(7)”

$$C = \frac{dI}{(8 \cdot dV \cdot F_s)} \quad (7)$$

where ,

D - duty cycle,

F_s- switching frequency,

dI- ripple current (1% of inductor current),

dV-ripple voltage (1% of output voltage).

The value of inductor was 35mH and the value of capacitor was 470 microfarads.

The Matlab model of DC-DC Full Bridge Converter is shown in Fig.4.

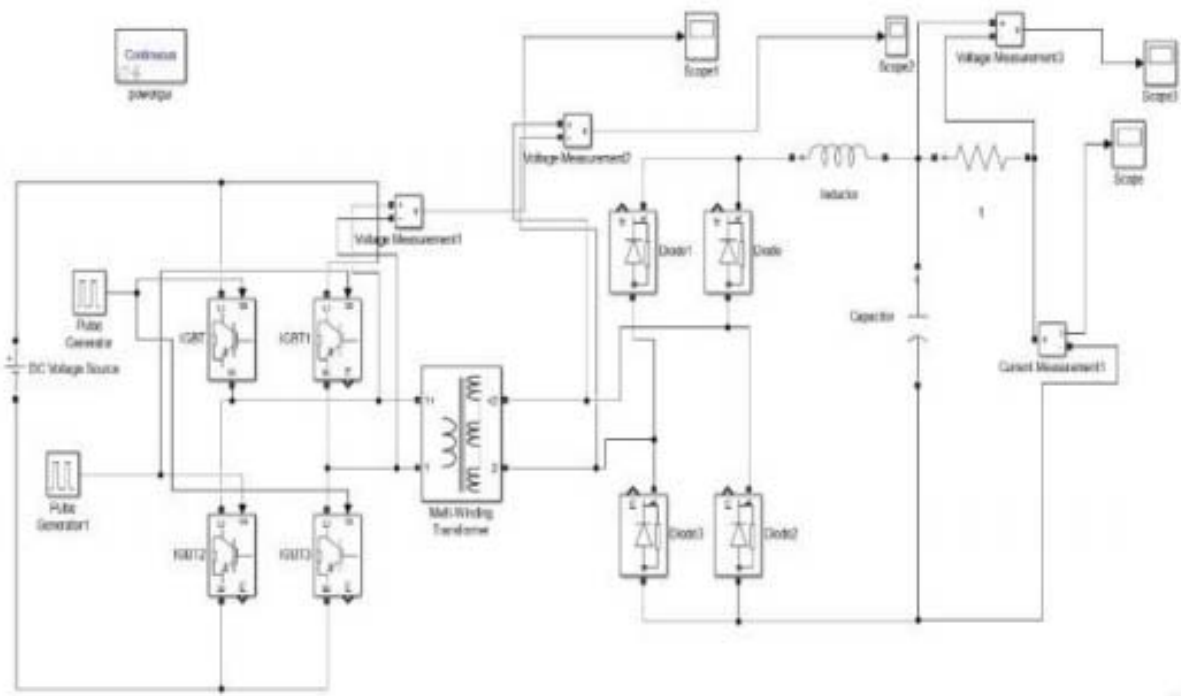


Fig 4: Matlab model of DC-DC Full Bridge Converter

DC-DC Full Bridge Converter consists of single phase inverter, step-up transformer and a rectifier.

The above system is operated at 6.5V input which is stepped to the desired voltage at the load of 145V. The switching frequency is set at 10Khz while the operating duty cycle is 50%.

The obtained values of Inductor and Capacitor are 10.83mH and 62.5uF respectively.

OBSERVED RESULTS

The simulation of Wind Turbine Model and DC generator gave the following output for voltage and current waveforms are shown in fig.6.

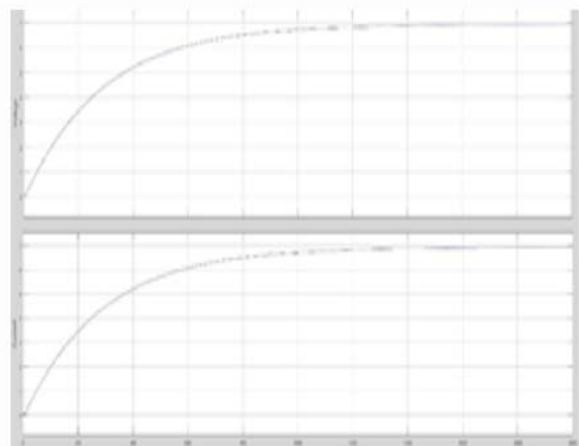


Fig.6

The obtained voltage was 24.12V and current obtained was also around 4.78A for a resistive load.

The simulation for Full Bridge Converter was also carried out. The Output DC voltage is shown in Fig.7 and Current waveform is shown in Fig.8.

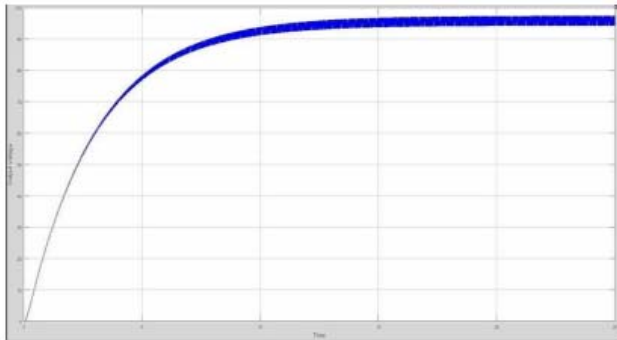


Fig.7

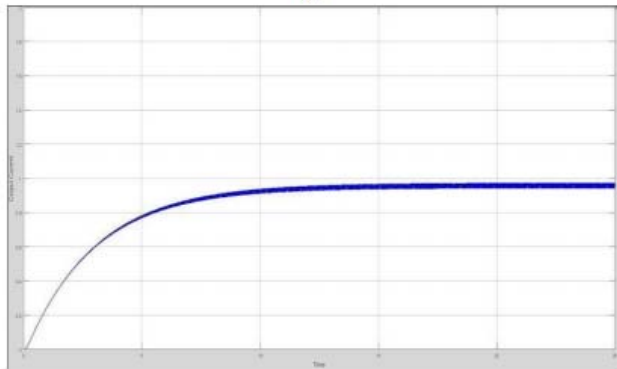


Fig.8

The output voltage of the entire system was observed to be around 94 DC and the current obtained was around 0.97A. Thus, the power delivered at the output is 91.18W.

CONCLUSION

The modelling and design of open loop standalone wind energy conversion system was discussed in this paper. The working principles of Wind Turbine systems, DC Generator was also briefly discussed. The need and working of Full Bridge DC-DC Converter was also discussed.

The aim of this project was to implement a compact Energy system which can be used to provide electricity in the remote areas where the electricity is scarcely available. The system was observed to deliver a power of 2.25KW which would be enough for

a lighting up a few houses in remote areas.

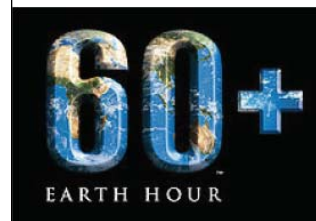
The simulation results for the system were also observed in this paper.

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Earth Hour

Earth Hour is a worldwide movement for the planet organized by the World Wide Fund for Nature (WWF). The event is held worldwide annually



encouraging individuals, communities, households and businesses to turn off their non-essential lights for one hour, from 8:30 to 9:30 p.m. on the last Saturday in March, as a symbol for their commitment to the

planet. It was famously started as a lights-off event in Sydney, Australia in 2007. Since then it has grown to engage more than 7000 cities and towns worldwide. Today, Earth Hour engages a massive mainstream community on a broad range of environmental issues. The one-hour event continues to remain the key driver of the now larger movement.

The FLOOD 2018 - an analysis based on data analytics

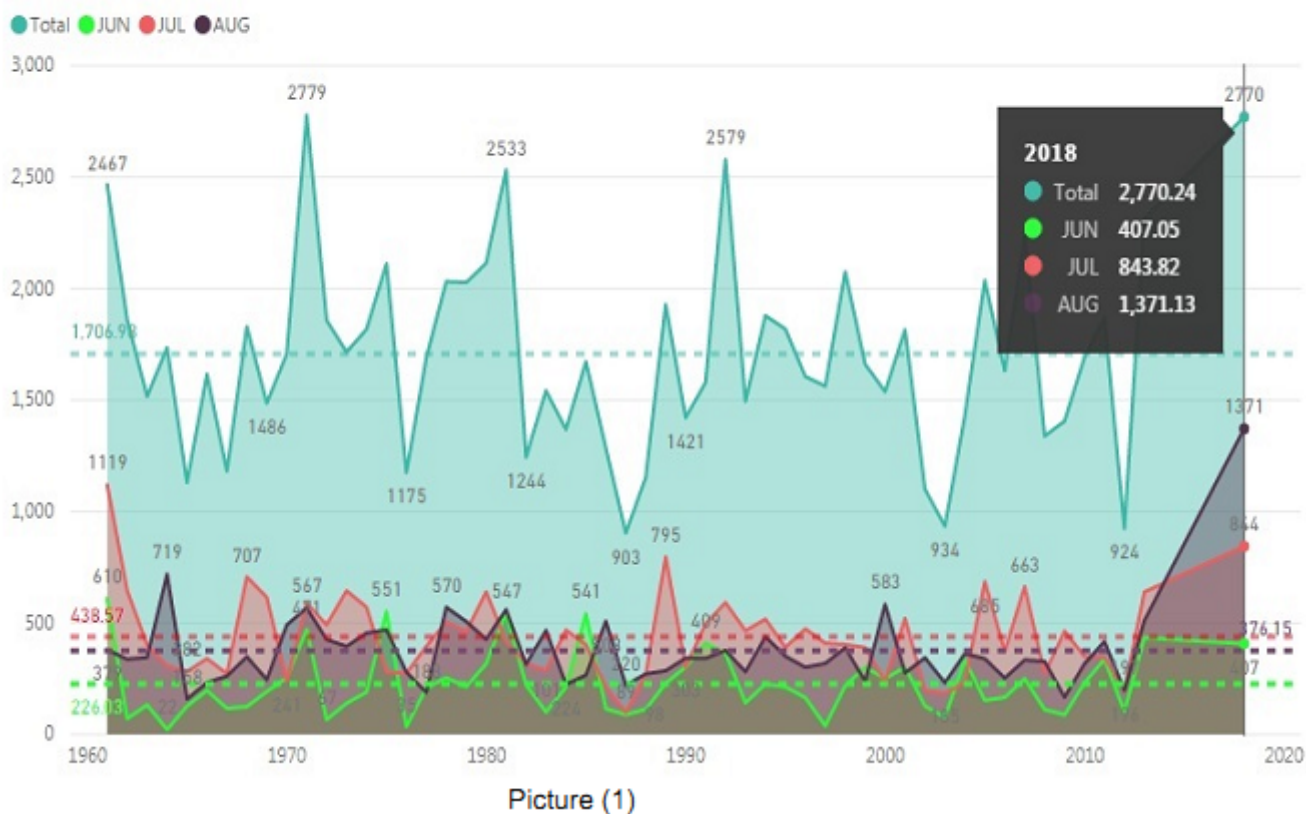
Er Shine Sebastian, Assistant Engineer, KSEB Ltd

It was a tough time for Keralites and departments in the previous year due to flood. The most wanted people for this tragedy was KSEBL in the view of press and media. So I thought of having an analysis based on analytics tools(Microsoft POWER BI is used for analysis). The software is having basic reporting and analytics techniques. Since it's a free version it has some limited functions compared to the full version. The first thing which we have to understand is that some places of kerala used to have flood during monsoon, especially in the low line area of Kuttanad and aluva Manapuram. I still recollect the situation in 2013 where my colleagues

house at Aluva was under water. So its not a new thing for us. Then what happened now?? Why everyone blame us?? I worked most of the time in Generating stations and having a very good understanding of Kerala DAMs and Hydrology. The data collected from WRIS, NLDC, SRLDC, SLDC are presented here for an academic purpose.

The analytics will give us the answers for our questions. Even the google sheets provide a lot of options to explore. You can also run various scripts to get accurate results. The reporting tool requires

Analysis of Idukki Inflow from 1960-2018



In which year we have received the maximum inflow for August month?

historical data. This technique is known as data warehousing. Nothing but a warehouse of data. The most important thing is that no data in this will be deleted and usually has a time stamp. The data analytics and reporting is need of the hour and India is the best in this. I have seen that WR-IS has good collection of data and hence these sites are used for academic purpose.

If we study the data of Idukki reservoir for the past few years we can understand what happened during flood 2018.

For Eg: what is the average inflow of water in to Idukki reservoir during various months of monsoon (The dotted lines)?

Analysis:

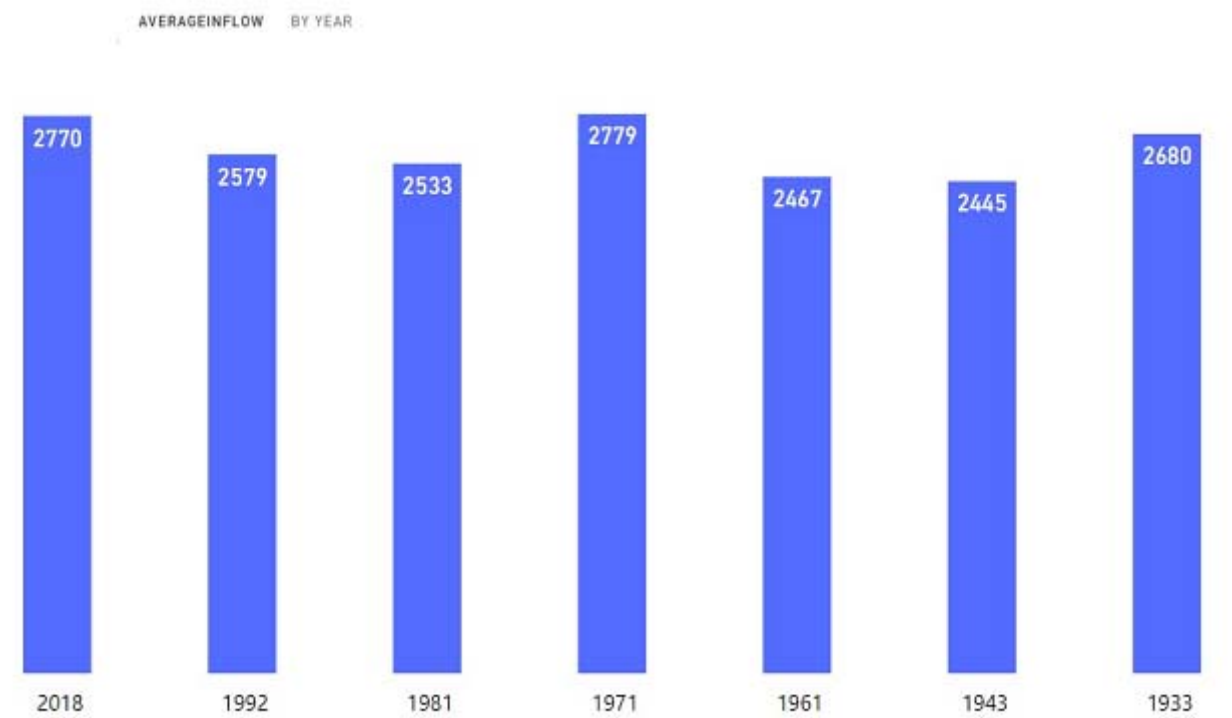
This is been shown in the picture 1 and it is For June - 226MCM, July- 438MCM, August - 376MCM. Now if we compare these values with inflow received in 2018, the results will give us what happened during flood???

Analysis:

We can see during 2018 we have received maximum inflow in the august month. So the graphical representation will always help us to have a clear picture on various issues.

Heaviest Inflow

Now the average inflow in to idukki for the period of 1960 to 2019(Data up to September) is calculated and drilled down to see the top few years.(Picture 2



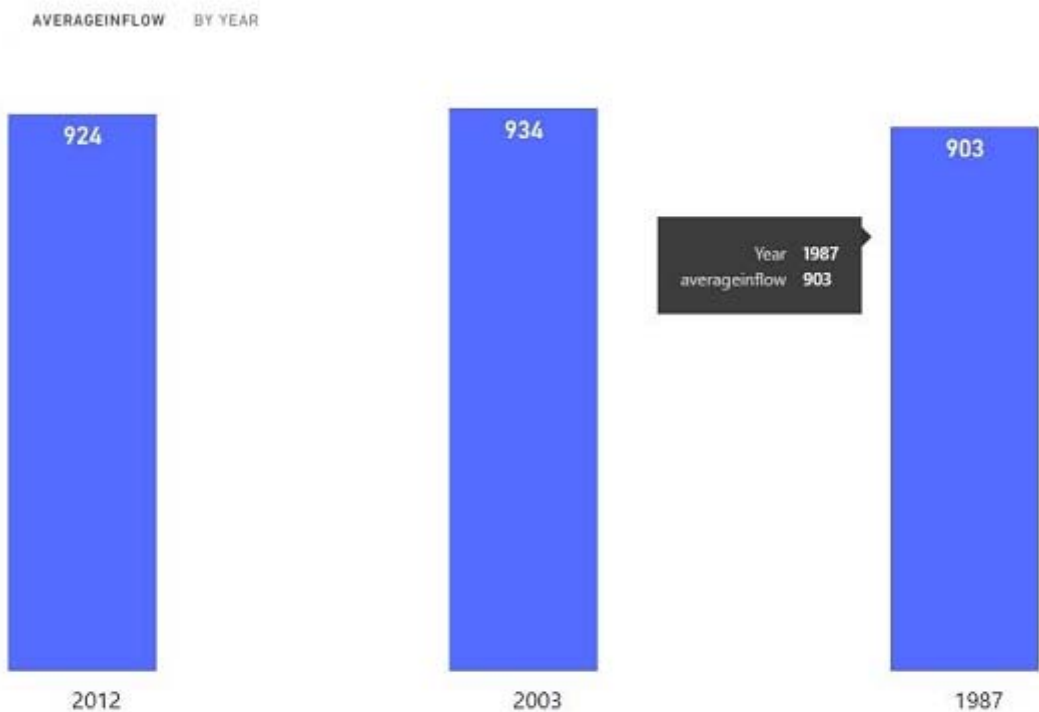
Picture(2)

Analysis:

It is seen that strong inflow (2500MCM and above) in to the dam used to occur in a period of 10 years between 1933 and 1943 and 1961,1971 and 1981 etc.

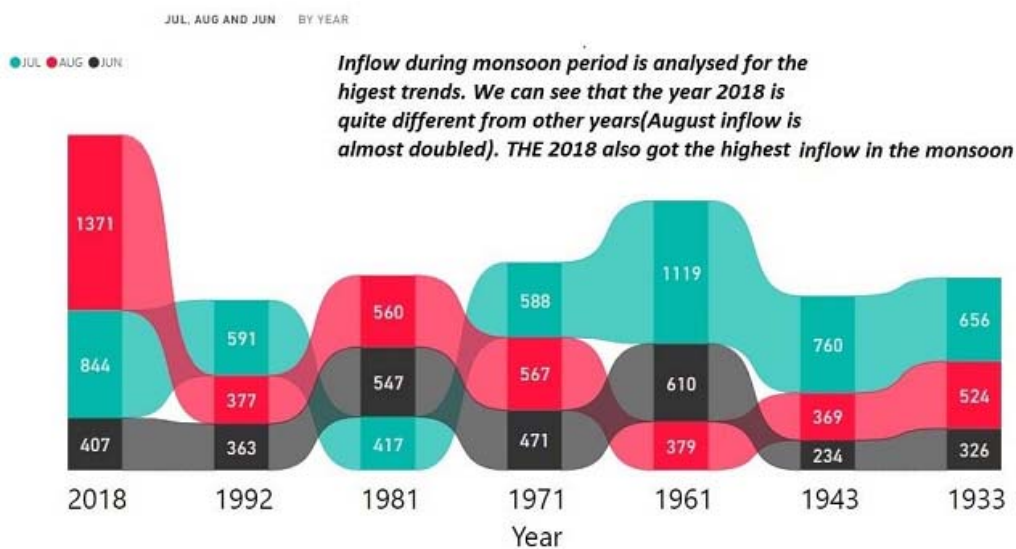
Worst Inflow

Moreover the worst inflow in to idukki reservoir happened in the year 2012,2003 and 1987(around 900 MCM) as shown below.



Picture (3)

Considering these aspects we will go back to our previous analysis- **‘What happened in 2018?’**. So I have taken a new graph which is known as ‘Ribbon’



Picture (4)

Inflow for each month is shown in the picture(4). It clearly says what happened during the peak of monsoon. **The reason for heavy inflow during 2018 is due to heavy rains and no dams in kerala generated floods. Here the discussion is for constructing more reservoirs like IDUKKI.** This is only the second time (first being 1981) we received heavy inflow during august month. **If this happened in July or June then we would have had the cushion for accommodating this massive in flow. But dangerously it happened in the month of august. That too 360 percentage above the average inflow (376 MCM).**

Rule Curve

So coming to the next level of analysis to handle such a situation, we need to consider rule curve. Rule curve shall be there for all dams and this curve will have information about its operational capability.

After the derivation of initial rule curves for different purposes, the operation analysis

is carried out for the reservoir and the rule curves are fine-tuned till the performance of the system could be improved. Finally derived rule curves are the operation rule curves which will be used to guide the operation of reservoir in actual field conditions. At any time, the reservoir is operated according to the prevalent water level and the elevation of different rule curve levels for the corresponding time. Let us assume that a reservoir is meant to serve for water supply (highest priority), irrigation (next priority), and hydropower (least priority). For these purposes, three operating rule curves are prepared, say curve 'W' for water supply, Curve 'I' for irrigation, and curve 'H' for hydropower. In addition to these, one upper rule curve, say curve 'U' is prepared.

The typical procedure for rule curve based operation is given in following steps:

- At any time step, if the present water level in the reservoir exceeds level 'U', then spill is made from the reservoir and the water level is brought to Level 'U'.
- If the present reservoir level falls below level 'U' but exceeds level 'H', full supply is made for meeting all demands from the reservoir but no spill is made.
- If the present reservoir level falls below level 'H' but exceeds level 'I', then supply for the hydropower

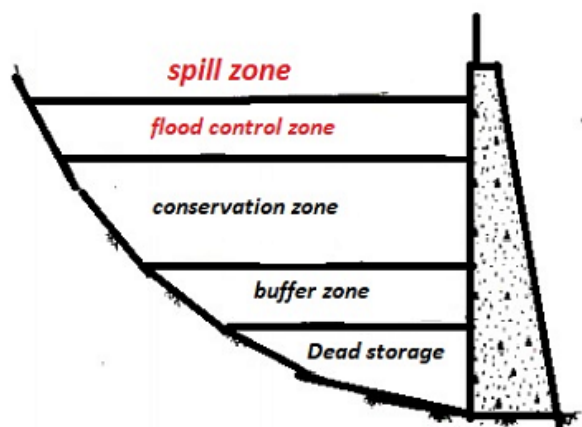
generation is curtailed (say, by 25%) while full demands of irrigation and water supply are made from the reservoir.

- If the present reservoir level falls below level 'I' but exceeds level 'W', then supply for the irrigation is curtailed (say, by 25%) while minimum demands for hydropower (if any) and full water supply demands are made from the reservoir.

- If the present reservoir level falls below level 'W', then release (full or partial) is made only for water supply demands and no release is made for irrigation or hydropower demands.

I have seen this typical pattern in all our dams and especially in Irrigation purpose dams like Chimmony Peechi etc. Here in peechi there is a different penstock for drinking water purpose alone, this level is much below the irrigation and hydro outlets. So our interest is basically for fixing the upper level for flood absorption i.e flood control zone.

Flood Control Zone



Reservoir zones for various purpose

Picture (5)

The normal operation policy is to release as much as possible when the reservoir is in the spill zone, to release as much as possible without causing flood damages to downstream when the reservoir is in flood control zone, and to bring the reservoir to the top of the conservation zone at the earliest possible time. The release from the conservation zone is governed by the requirements of water for various purposes intended to be met by the

stored water and the day-to-day releases may be adjusted based on the inflow anticipated and future requirements up to the end of operating horizons. When the amount of water is anticipated to be short compared to demand, releases may be curtailed. Limits of various zones may vary with time. **So the time is the most important thing. As I said earlier if this inflow happened in June then the situation would have been normal.**

Let's see what is the level of Idukki on 1st of august 2018.

Level on 01-08-2018					
Reservoir Name	FRL (m)	Current Level (m)	Reservoir Live Capacity at FRL (BCM)	Current Storage (BCM)	Live CURRENT YEAR
Idukki Reservoir	732.43	730.246	1.46	1.338	91.64
STORAGE AS % OF LIVE CAPACITY AT FRL					
LAST YEAR			LAST 10 YEARS AVERAGE		
23.84			41.3		

As on august 1st 2018 the reservoir had 91.64% water compared to the last year average of 23.84 and last 10 year average of 41.3%. This data was taken from WRIS.

Here in 2018 we received the heaviest inflow in the month of august for the first time after the commissioning of idukki. That means our reservoir was supposed to have a cushion to meet the flood control zone. At least this could have been decided if we have some of the analytical tools so that the trend of inflow will decide the operational rule curve. If we look at the inflow vs average inflow during similar years, we can see that 2018 almost match with 1961 and 1971 (picture 4). Moreover the inflow received during 2018 is almost the double of average inflow for these month (This is been shown in the picture 1 and it is For June - 226MCM, July- 438MCM, August - 376MCM). **So what we could have done is that , to create flood cushion to meet double of average inflow for august month i.e $2 \times 376 = 752$ MCM.** If the dam was lowered by 752MCM or half the live storage then we could have easily absorb 725 MCM of 1371 MCM (total inflow for august) and the impact in the periyar

region could have been set to NULL. **This would have made keralites to build 10 more idukki dams to protect kerala from floods.**

But unfortunately we missed this opportunity. But if we analyse the situation of 1961 with 2018 , I can surely say that Idukki HEP and this reservoir has saved People of Kerala. I have worked in Neriamangalam which is at panamkuttu. The panamkuttu is the confluence of Muthirapuzha and Periyar. During 1961 flood, the switch yard structures were damaged at neriamangalam. Even I heard from then SEO, that during 1992 flood the bridge was water topped and he could hardly reach office. **But in 2018 year , we could run all the machine safely and that's just because of Idukki Reservoir. This is the only power house which has the best design to meet the flood discharge of both the rivers. Moreover we had managed 2018 better than 1961 and 1992.** So my point is that Idukki reservoir and idukki power house saved keralaites. Idukki Power house discharged close to 10 MCM daily in to moovatupuzha river and thus diverted some flood water in to the inter basin. This is

a good concept and we could have done similar things in Chalakkudy and Idamalayar. But unfortunately we have no gates to control the flood water in to idamalyar. All we have is some pipes at wachumaram and it got stuck due to debris. So lets hope that we will have this inter-basin control to minimise the flood issues at chalakkudy.

CHALAKUDY THE WORST EFFECTED AREA IN FLOOD 2018

In my experience chalakkudy was devastated in flood 2018. The reason is pretty simple, poringalkuthu dam has no flood cushion. It has only 30 MCM storage and received almost 10 times of this water in 3 days as per CWC report. We had a proposal for Poringalkuthu Right bank dam with 500 MCM storage. If this dam was there then chalakkudy would have been saved. Moreover Tamil Nadu has all their major dams in chalakkudy river(Nirar, lower nirar, parambikulam, thunacadavu, upper sholayar) in our area. All these dams were constructed after Poringalkuthu Dam and constructed with the support of PAP agreement. During flood 2018, water from Parambikulam ,thunacadavu and upper sholayar flood discharged in to our poringalkuthu and we end up with no option but to take all the surge. The dam was overtopped for more than 24 hours but still not seen any study report in this front. So flowing analysis is made after collecting data from WRIS.

- **Design flood discharge of Sholayar and Parambikulam is 1820 and 1687 cumecs respectively. Thunacadavu has a flood discharge of 500, means poringalkuthu shall have flood discharge capacity of 4007 cumecs and more to divert the flood water. But unfortunately the dam has only 2265 cumecs flood discharge capacity. The 1742 cumecs water will definitely has to take some other path and hence dam overtopped.**
- **The wachumaram diversion is supposed to carry the excess water from poringalkuthu reservoir in to Idamalayar.** But this diversion was blocked completely due to accumulation of logs and other debris. So the chance of diverting the flood water in to Idamalayar has ceased. There is no gates to control the flood water in this inter-basin project(**the best example is periayar and moovatupuzha using IHEP**).
- All the dams in the upstream of poringalkuthu(upper and lower Sholayar, Parambikulam and Thunacadavu) discharged flood water in to this gravity dam. The dam withstood a similar issues earlier too. The coordination with TAMIL NADU authorities is need of the hour since Right bank project is not yet envisaged.
- Also PRB Scheme will play a major role in the flood management since it will be the biggest single generating station recommended so far in Chalakudy River. Moreover this Dam can impound 523MCM water. The CWC recommended a new dam in the upstream of poringalkuthu for flood management. Hence this old proposal may be revisited rigorously for the people of KERALA.
- The report of CWC says that Parambikulam has released more water in to chalakkudy river(poringal dam) which is more than their inflow!! These issues can be mitigated only with integration of data.

Conclude:

The reason for heavy inflow during 2018 or flood in other terms is due to heavy rains and no dams in kerala generated floods. Here the discussion is for constructing more reservoirs like IDUKKI and use data analytics and other reporting techniques for better operations.

Role Of Energy Management In Climate Change And National Development

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Introduction

This is a world of competition. History teaches that whoever command larger energy could stand tall among the competitors and lead the world. Regions in the world were colonized by nations who commanded larger energy. Oldest reference about energy is related to the Sun. The Rig Veda declares that “Surya is the Soul, both of the moving and unmoving beings”. Civilizations were evolved to higher levels based on efficient use of energy. Higher generation and better management of energy constitutes the main criteria to win over competitors. This line of thinking took man to the present day practice of generation and consumption of electricity, choosing various sources of energy such as fossil fuel, Uranium, Renewables etc

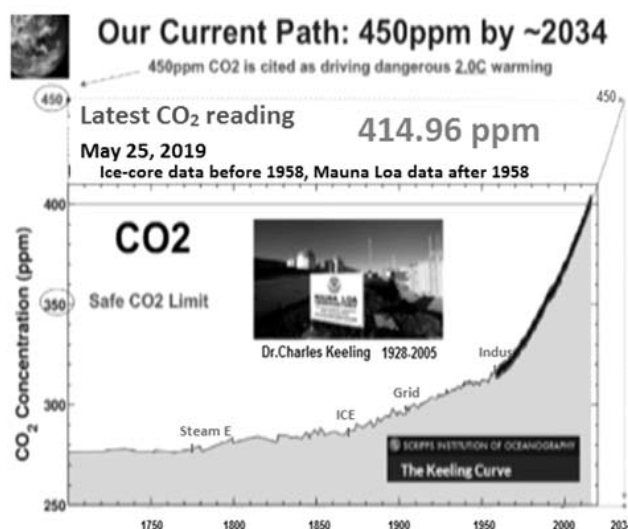
Energy and civilization

Progress of civilization, in the present day definition, has an intrinsic relationship with GDP. There is a correlation between energy generation and GDP of a nation. To raise GDP every nation tries every possible means to generate maximum energy. In this wild run for energy, nations turned to fossil fuels and Uranium. Incidentally, fossil fuels and Uranium are limited¹ in availability.

Climate change and industrialization

Climate change agreement ParisCOP21 was the result of the realisation of a precarious level of carbon pollution as per the Keeling Curve shown in Fig 1. Findings of Dr.Keeling lead to the study of historic CO₂ concentration. CO₂ concentration increased fast from 260 ppm after 1750 (Industrial Revolution). Note the gradual rise in carbon pollution from use of steam engine (1770), IC engine (1870) and electric motor (1890). It gets faster with the invention of electricity grid. The abnormal rise after 1960 is due to global

competitive mode of industrialisation. It was 315 ppm in 1960. It crosses 414.96 ppm on 25.5.2019 and moving towards 450 ppm when temperature would rise by 2 degree from the pre- industrial period.



Rise of earth's temperature causes unpredictable and violent climate mishaps - rise of ocean temperature, melting of ice, rise of sea level, heat waves, extreme weather events like hurricane, heavy rainfall, floods and landslides. Scientists predict catastrophe after 1.5 Degree C rise.

“The science is telling us that if we go above 1.5°C, we could experience an ‘extinction tsunami’ resulting in the collapse of many key ecosystems” The Paris summit reached a consensus to curtail a global rise in temperature to 2°C while trying to achieve a more ambitious target of 1.5°C by 2100. The agreement calls for carbon neutrality after 2050 and reducing the use of fossil fuels in favour of renewables.

Since 1980, greenhouse gas emissions have doubled, raising average global temperatures by at least 0.7 degrees Celsius – with climate change already impacting nature from the level of ecosystems to that of genetics². There is a campaign ‘Global Deal for Nature’³ spearheaded by the NGO, One Earth. Aim is to get back to the level of CO₂ concentration of pre-industrial period.

India’s mitigation strategies

India’s action plan emphasized⁴ striking a balance between emission reduction and sustainable development. India voluntarily pledged⁵ its “Intended Nationally Determined Contribution” (INDC) to UN in 2015 according to which India has to reduce emission intensity of GDP by 30-35% by 2030 from the 2005 level. Mitigation strategies are enumerated in the pledge. India has an ambitious programme for renewable generation. It aims to add 175 GW renewable capacity by 2022, and 500 GW by 2030.

Power System Planning

PLF of thermal plants declines from 75% in 2011 to 60% in 2018. It will decline further when more renewables are added to the grid. An acute shortage⁶ of coal is imminent. There will be sharp increase in grid tariff with the use of imported coal. Imported coal costs around Rs7100 per ton while Indian coal costs Rs2800 per ton. (2018). Resource nationalism will play havoc in future price of coal.

KSEBL’s contribution to climate change mitigation

Kerala has to raise renewable generation to support India’s ambitious programme. 70% of consumption in Kerala comes from fossil fuel source. Kerala has to revise the energy mix to enable supply of power at reasonable cost. This is to keep unit price of industrial products competitive.

Kerala has a rooftop solar potential of 30000 MW as estimated⁷ by WISE, a consultant engaged by KSEBL. According to Dr. Kalam, Kerala can become energy independent by exploiting rooftop potential 16 years. He said it in 2014. With a vibrant rooftop solar policy Kerala can raise solar generation fast enough. Doubt, the proposed Kerala Power Policy 2019 will accomplish the target. KSEBL has to change its

business model⁸ in line with the changes in global energy sector. Accommodate the technology disruptions in energy sector.

Conclusion

Energy is a primary input to industry. It is unfortunate the vested interests argue in favour of depleting fossil resource. Let us not get trapped in the ditch that is dug on the path to industrialisation. There is no greater threat to our security, to our economic growth, to the survival of future generations than Climate Change. Let our policy of industrialisation stick to mitigation of climate change. Let us transfer the gift we received from our forefathers to future generations.

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A NOVEL METHOD FOR HOME ENERGY MANAGEMENT SYSTEM WITH EFFICIENT LOAD SHIFTING

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Abstract—In the era of energy crisis, we are facing issues of rising the energy costs and carbon footprint. So the efficient use of energy is becoming an important aspect in the world. The energy management system allows us to monitor, manage and preserve the amount of energy consumed and helps to use the energy in a more efficient way. Thus the customer is able to control the appliances when he or she is away from the house. Here an energy management and production strategy is presented. The main objective of the work is to decrease the electricity bill and to maintain a green environment. In this system each home is able to produce its own energy at free of cost. For this we are introducing a strategy for producing the electricity from waste water by means of a microbial fuel cell. The electricity is stored in a storage system and during the peak hours this energy is used which enables us to reduce the energy cost. The system provides a provision for shifting the starting time of delay tolerant home appliances from peak hours to off peak hours. This reduces the peak load and cost of electricity. Technological advancement is the new revolution that the 21st century is facing now. One such revolutionary technology is the Internet of Things (IoT).

Internet of Things (IoT) is a world-wide network connecting all the smart objects together. It is the way in which all things are enabled to talk with each other. The emerging technologies of Internet of Things (IoT) are used to monitor and manage the energy consumption. The customer is able to view the power consumption of each device and the overall power consumption. This allows the customers to understand the contribution of each device towards the overall elec-

tricity bill they receive. The system allows the facility for online bill generation and online bill payment.

Keywords- Internet of Things; microbial fuel cell; peak load; energy consumption

I. INTRODUCTION

Energy is an essential aspect of today's modern life. As the energy consumption is increasing day by day, the natural resources are depleting gradually. In developing nation like India, about 49% of total energy is utilized in industries. The primary objective of energy management is to provide services with less cost and environmental effect. The rise in home energy consumption is due to increasing population and implementation of smart appliances. In order to minimise the energy utilisation in home it is necessary to go for an energy management system which helps to control the electricity bill and to maintain the sustainability. Thus the consumer is able to monitor, control and conserve the energy consumption. To retain a sustainable society is one of the most important challenges of the 21st century. An IoT based energy management system is an effective solution to face this challenge. The proper use of energy enables us to reduce the energy cost, decreases global emissions and reduces carbon footprint at a large scale.

The existing system has several drawbacks such as the problems related with data storage, organisation and analysis. To overcome these drawbacks Internet of Things (IoT) is included in the system. IoT provides a pervasive measuring platform to monitor, control and conserve the energy consumption of each device. This real time data enables the users to achieve

the necessary information about the energy consumption of each appliance in the home and allows them to take appropriate decision to minimise the electricity price. The use of IoT helps the consumer to control the household appliances remotely. That is they can ON/OFF the devices through a computer or a mobile phone.

Increase in the economic growth leads to a rapid growth in the energy demand. Since the main source of energy is the fossil fuels, the resource is depleting day by day thus increasing the fuel cost and results in an increase in energy cost. As fossil fuels is burnt, the concentration of green house gases in the atmosphere increases leading to an imbalance in the environmental conditions. So we are trying to find an alternative source of energy. The proposing work describes a method of producing electricity from the waste water by means of a microbial fuel cell. This energy can be used during the peak hour in order to reduce the electricity bill. The electricity cost can be further reduced by decreasing the peak load. This can be achieved by shifting the starting time of delay tolerant appliances from peak hour to off peak hour.

II. IoT BASED ENERGY MANAGEMENT SYSTEM

The Internet of Things (IoT) is a system of interconnected computing devices, that are provided with distinctive identifiers. This allows the consumers to connect and control the devices remotely and automatically without any human intrusion. The objects are connected with one another through a network allowing a large amount of automation and control without any human interaction.

The basic requirements of the system are:

- The controller should collect the data about the energy consumption of each device.
- The system should be scalable so that the data can be collected and analyzed easily.
- The system should be secure to guarantee the protection of the communication of system.
- The communication should be private to prevent illegal users from interfering over the data. The energy management system is essential because it enables us to:

- Reduce costs – this is becoming increasingly significant as energy costs rise. Higher demand for energy increases fuel cost which in turn increases the energy costs.

- Reduce carbon emissions and the environmental damage that they cause – burning of fossil fuels causes carbon emission

- Reduce risk – by reducing your demand for energy and by controlling it so as to make it more predictable.

III. SYSTEM IMPLEMENTATION

The overall system consists of two sections: energy production and energy management. The energy production section generates electricity from the waste water by using a fuel cell.

The energy management section performs monitoring and controlling the energy consumption and billing the electricity utilization.



Fig 1 : Energy production system

The block diagram for the energy production system is shown in fig.1. The main part of the system is a microbial fuel cell. The microbial fuel cell has three parts: anode, cathode and a proton exchange membrane (PEM). Microbial fuel cell is a device that converts chemical energy directly into electrical energy. This conversion is performed with the help of microbes present in the waste water.

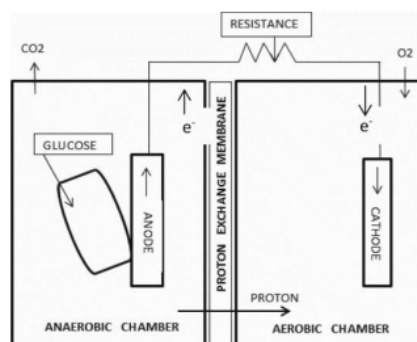


Fig 2: Microbial fuel cell

The microorganisms present in the anodic chamber are provided with a sympathetic substrate which is degraded in the absence of air to discharge electrons which are carried from the anode to the cathode through the external resistor and the protons produced are selectively passed through the exchange membrane. The output of the fuel cell is fed to a dc to dc converter to boost up its output voltage. The output is stored in a storage system and is supplied to the load only during the peak hour. This plays an essential role in the reduction of energy cost.

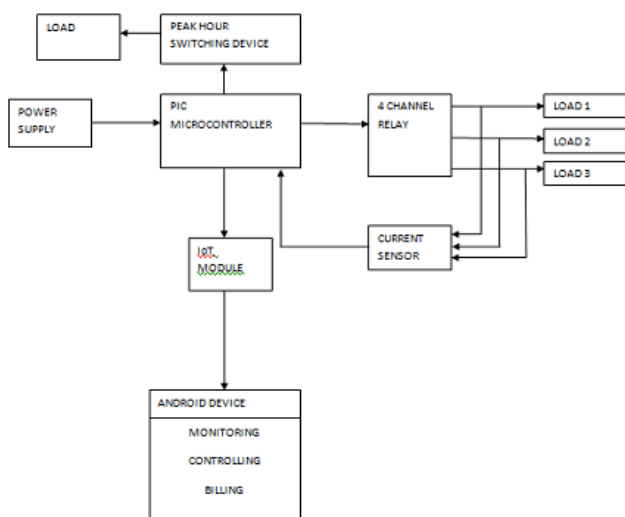


Fig 3: Energy management system

The block diagram for the energy management system is shown in Fig 3. The controller used here is PIC16F877A. The current sensor is used to sense the current through each load and the data is sent to the PIC controller for calculating the power consumption. ACS 712 is the current sensor used here. It works based on hall effect and calculates current upto 20 A.

Hall effect is the generation of a potential difference across an electrical conductor, when an electric current flows through it.

The four channel relay is used to ON/OFF the devices. The power consumption details and the status

of each load is transmitted by the IoT module ESP8266. It is a self controlled system on chip in which TCP/IP protocol stack is included that can give any microcontroller access to the WiFi network. These data are stored on a cloud server and is displayed on the mobile phone. Also an option for paying the electricity bill is provided in the app. The system is capable of performing load shifting, that is the delay tolerant devices shifts the starting time from peak hour to off peak hour. This helps to reduce the peak load and the electricity bill. The peak hour switching device which is a relay that is used for this purpose. The status of each device can be viewed on the mobile phone. The device controlling and billing function can be performed through a mobile phone.

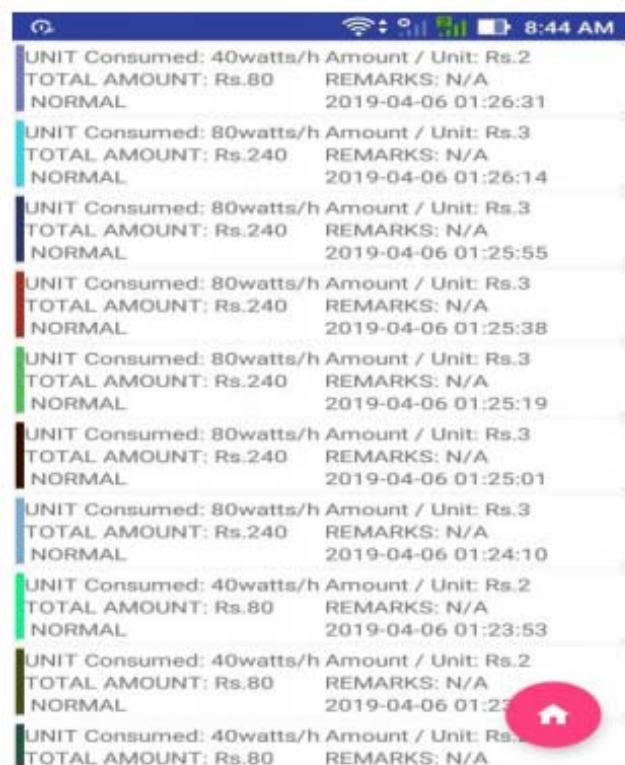
IV. RESULT

In the device automation section, the status of each device whether it is ON/OFF can be known and also it is possible to change the state of the device. The user is able to ON/OFF the device when he/she is away from the home.



Fig 4 Remote control of devices

These data are displayed on a mobile phone and more devices can be added in this setup. This helps the consumer to turn off the unused devices remotely.



UNIT Consumed	Amount / Unit	TOTAL AMOUNT	REMARKS	Timestamp
40watts/h	Rs.2	Rs.80	N/A	2019-04-06 01:26:31
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:26:14
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:25:55
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:25:38
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:25:19
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:25:01
80watts/h	Rs.3	Rs.240	N/A	2019-04-06 01:24:10
40watts/h	Rs.2	Rs.80	N/A	2019-04-06 01:23:53
40watts/h	Rs.2	Rs.80	N/A	2019-04-06 01:23:53

Fig 5: Bill payment

The power consumed and the amount of electricity bill is displayed on the mobile phone.

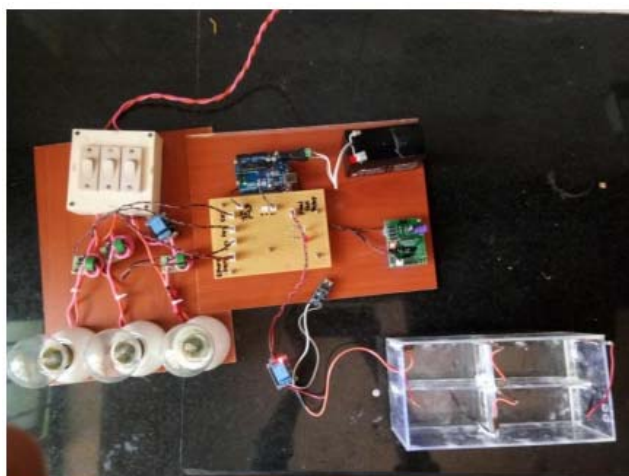


Fig 6: Hardware

The entire hardware is shown in fig 6. The loads are controlled via IoT. The fuel cell produces energy and is used during the peak hour.

V CONCLUSION

In this paper an energy management system that aims to reduce the electricity bill is described. The system provides the facility for controlling the devices remotely and online bill payment. This allows us to reduce the energy cost by a considerable amount. The ability of the system to shift the starting time of the delay tolerant devices from the peak hour to off peak hour decreases the electricity bill further. The use of fuel cell enables us to conserve energy. The Internet of Things (IoT) is the core technology used for this purpose. It provides a computing platform to monitor and control the devices.

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DEVICE NUMBERS AND THEIR NOMENCLATURE			
2	Time Delay Starting or closing relay	62	Time-delay stopping or opening relay
3	Checking or interlocking relay	63	Liquid or Gas pressure, Level or Flow relay
21	Distance relay	64	Ground Protection relay
25	Check synchronizing relay	67	AC Directional over current relay
27	Undervoltage relay	68	Blocking relay
29	Isolating Contactor	74	Alarm relay
30	Annunciator relay	76	D.C. Over current relay
32	Directional power (Reverse power) relay	78	Phase angle measuring or out of step relay
37	Under current or Under power relay	79	AC Auto reclose relay
40	Field failure (loss of excitation) relay	80	Monitoring loss of DC supply
46	Negative phase sequence relay	81	Frequency relay
47	Phase-sequence Voltage relay	81U	Under frequency
49	Machine or Transformer Thermal relay	81O	Over frequency relay
50	Instantaneous Overcurrent relay	83	Automatic selective control or transfer relay
51	A.C. Time Over current relay	85	Carrier or pilot wire receive relay
52a	Circuit breaker Auxiliary Switch "Normally open" ('a' contact)	86	Locking out relay (Tripping relay)
52b	Circuit breaker Auxiliary Switch "Normally close" ('b' contact)	87	Differential relay
55	Power Factor relay	87G	Generator differential relay
56	Field Application relay	87GT	Overall differential relay
59	Over voltage relay	87U	UAT differential relay
60	Voltage balance relay	87NT	Restricted earth fault relay
61	Current balance relay	95	Trip circuit supervision relay
		99	Overflux relay
		186A	Auto reclose lockout relay
		186B	Auto reclose lockout relay

CODE OF PRACTICE - LEAD IDENTIFICATION (CONTROL WIRING - PROTECTION & METERING CIRCUITS)			
A series	C.T secondaries for special protection; A1, A2, A3 etc. (Distance /Differential / REF Protection)	H series	LT AC supply; H1, H2, H3 etc
B series	C.T secondary for Bus bar protection; B1, B2, B3 etc.	J series	Main DC incoming; J1 (+ve) J2 (-ve) etc.
C series	C.T Secondary for protection circuits; C1, C2, C3 etc. (Back up Protection Over Current & Earth Fault)	K series	Controls, closing, tripping; K1, K2, K3 etc.
D series	C.T secondaries for metering circuits; D1, D2, D3 etc.	L series	Alarm indication and annunciation; L1, L2, L3 etc
E series	Potential Transformer secondaries; E1, E2, E3 etc. (For protection and metering)	P series	DC Supply for Bus Bar Protection and LBB protection Circuit.

Reduced Graphene Oxide/Polyaniline Composite Characterization for Better Performance Supercapacitor Electrodes

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Abstract—The arrival of novel organic and inorganic nanomaterials in recent years, particularly nanostructured carbons, conducting polymers, and metal oxides, has enabled the fabrication of various energy devices with enhanced performance. A conventional method is utilized for the preparation of reduced graphene oxide/polyaniline (rGO/PANI) composite, where ammonium persulfate (APS) is added to the acidic solution of graphene oxide (GO) and aniline monomer and further reduced using hydrazine. Here in-situ polymerization is conducted to polymerize the aniline monomer. An investigation is carried out by varying the amount of GO while keeping amount of aniline constant to obtain the best composition. The characterizations reveal the structural property, purity of the composite, the vibrational and rotational characteristics and further shows proper loading of PANI on rGO. As investigated earlier rGO/PANI composite then to have an energy density of about 13.9 Wh kg⁻¹ and specific capacitance around 600 Fg⁻¹. Therefore electrodes made out of rGO/PANI composite can be considered as a promising milestone for the fabrication of low cost, better performance supercapacitor.

Keywords—*Reduced Graphene Oxide, Polyaniline. Supercapacitor Energy density.*

I. INTRODUCTION

Energy storage plays a significant role in today's lifestyle. There are different type of electric energy storage devices that are based on non faradaic or faradaic charging/discharging at electrode/electrolyte interface, which means ion adsorption or redox reac-

tion takes place at the electrodes to store electric energy[1,2]. Batteries have high energy density but low power density, hence supercapacitor act as a complement to them providing high power density, whereas their energy density is lower than that of batteries. Hence many researchers are thereby trying to improve the energy density of supercapacitor keeping the power density high. Overcoming the obstacle of low energy density is by developing new electrode materials for supercapacitors. Based on these research supercapacitors can be classified into three categories according to their charge storing mechanism: electric double-layer capacitors (EDLCs), pseudocapacitors, and hybrid capacitors.

EDLCs are mostly referred to as supercapacitors or ultracapacitors as they electrostatically store the charge by using reversible adsorption of the electrolyte ions onto electrochemically stable, high-surface-area carbonaceous electrodes as shown in figure. 1. In pseudocapacitors fast redox reactions occurs during the charge/discharge process at the electrode surface made of pseudocapacitive materials, hence they show battery like behavior in the charge/discharge process. Compared to EDLCs they have slow charge/discharge rate but high capacitance. The major pseudocapacitive materials are transition metal oxides and conducting polymer. Hybrid supercapacitor combines the advantages of both EDLCs and pseudocapacitors providing high energy density and power density.

EDLCs utilize the charge storing mechanism of carbon based electrode material. Graphene, a car-

bon material that is one-atom-thick two-dimensional (2D) densely packed into a hexagonal structure, has risen as a novel class of potential materials attractive for electrochemical capacitors (ECs). Use of graphene as a supercapacitor electrode material has become the focus of a significant amount of scientific research in the field of energy storage because of its unique combination of features such as superb electrical conductivity, corrosion resistance in aqueous electrolytes, highly modifiable nanostructures, long cycle life, and large theoretical specific surface area of over $2600 \text{ m}^2 \text{ g}^{-1}$ [3-7]. If the entire specific surface area is fully utilized graphene is capable of achieving a capacitance of up to 550 F/g . An enhancement in the capacitance can be obtained by the use of graphene because of fast electron transfer rate during faradaic charge transfer like other conducting carbon materials. The in-plane C-C bond is one of the strongest bonds in materials and the out-of-plane p bond, which contributes to a delocalized network of electrons, is responsible for the electron conduction of graphene and provides the weak interaction among graphene layers or between graphene and substrate [8-10].

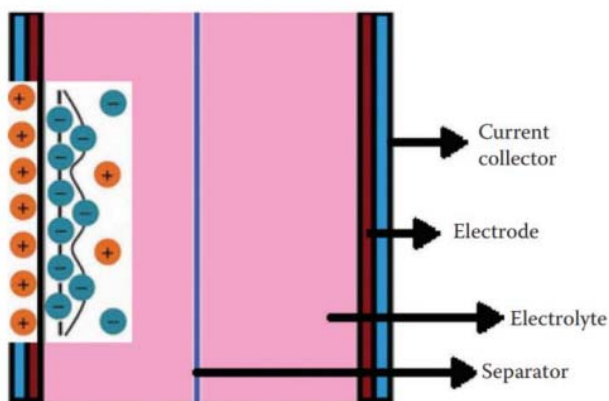


Fig. 1. Basic arrangement of an EDLC cell.[21]

Transition metal oxides are an attractive options as electrode material due to high specific capacitance and low resistance, which leads to making it easier to construct high energy and power supercapacitors. The commonly used metal oxides are nickel oxide (NiO), ruthenium dioxide (RuO_2), manganese oxide (MnO_2), iridium oxide (IrO_2). The lower cost of production and use of a milder electrolyte make them a feasible

alternative. Transition metals possess multiple oxidation states and it is this property that gains them favor for capacitive application [11,12]. Ruthenium IV Oxide was the first material to exhibit this property and it has specific capacitance of 720 to 1340 F/g in water. Limited occurrence and high costs inhibit further exploration of the material [11]. Taking the case of conducting polymers reduction-oxidation process is used to store and release charge. Conducting polymers (CPs), like Poly(3,4-ethylenedioxythiophene) (PEDOT), polypyrrole (Ppy) and polyaniline (PANi), have attracted great interests in energy storage, sensors and electrochromic devices since the discovery in 1960 [13]. Conducting polymers based devices (CP Device) show high specific capacitance compared with electrochemical double-layer supercapacitors, and have faster kinetics than most inorganic batteries, which can narrow the gap between inorganic batteries and carbon based capacitors, indicating the high potential of conducting polymers in energy storage [14]. In conducting polymers reduction-oxidation process is used to store and release charge. If oxidation occurs also known as doping, ions are been transferred to the polymer back bone. If reduction occurs also known as de-doping, in that case ions are released back into the solution Polyaniline (PANi) generates most attention among the conducting polymers because it has the highest specific capacitance due to multi-redox reactions, good electronic properties due to protonation, and low cost for its infinite abundance [15]. In addition, it has better thermal stability, high environment stability, high conductivity and can be easily synthesized by chemical or electrochemical methods, resulting in powder or thin film [13]. Polyaniline (PANI) composited with graphene is considered as a superior material for supercapacitor application due to its large theoretical pseudocapacitance [16]. However, such composites mostly suffer from the poor long-term stability due to the degradation caused by the swelling and shrinking of PANI molecules. To avoid this limitation, combining PANI with carbon materials has proved to reinforce the stability of PANI as well as maximize the capacitance value.

Combinations of conducting polymers and graphene composites are highly considered because, they have

high conductivity and more active electrochemical sites which make them most suitable for electrochemical reactions required for electrode composition. In this experiment, nanostructured PANI are composited with different compositions of reduced graphene oxide and used as electrode materials of supercapacitors

II. EXPERIMENTAL

A. Materials

Graphite flakes and aniline were purchased from Sigma Aldrich. They were used in the experiment without further purification. Ammonium persulfate (APS), sulphuric acid and hydrochloric acid were supplied by local chemical suppliers. All reactions were carried out in deionized (DI) water.

B. Characterization and instrumentation FTIR spectroscopy was done using an FTIR instrument (Shimadzu). Powered XRD analysis were carried out by using a Rigaku miniflex 600 diffractometer using a generator voltage of 40 kV and a current of 15 mA. Raman spectroscopy study was carried out by Raman spectrometer, witec alpha 300.

C. GO/PANI preparation Add 7.71g of APS to 50ml HCl taken in a 250ml beaker and sonicate it for 5 minutes and pre-cool this solution by keeping it in an ice bath (solution B). Add 3ml aniline to 50ml HCl taken in a 250ml beaker and add various composition of graphene oxide to it (solution A). Add solution B to solution A through a burette kept in an ice bath (0-40

C) under constant magnetic stirring for 2 hrs and hence GO/PANI composite (solution C) is formed.

D). Reduced graphene oxide (rGO)/PANI preparation Kept solution C in a hot water bath of 980 C. Add 0.4ml hydrazine to this and stir it for 30 minutes. Wash and filter this solution and hence reduced graphene/PANI (rGO/PANI) solution is formed (solution D). Add 2.57g APS to 50ml HCl in a beaker (solution E) and keep it for sonication for 5 minutes. Solution E is added drop by drop with a dropper, to solution D kept in an ice bath under continuous magnetic stirring for 20min. The formed solution is finally washed several times using a centrifuge. Keep the solution for drying and hence rGO/PANI composite is formed.

E. Supercapacitor Electrode Arrangement The rGO/PANI composite formed is placed as a supercapacitor electrode along with current collectors, a separator dipped in electrolyte in a sieve lock arrangement as shown in Fig. 2. The supercapacitor is expected to deliver a capacitance of 600F/g.

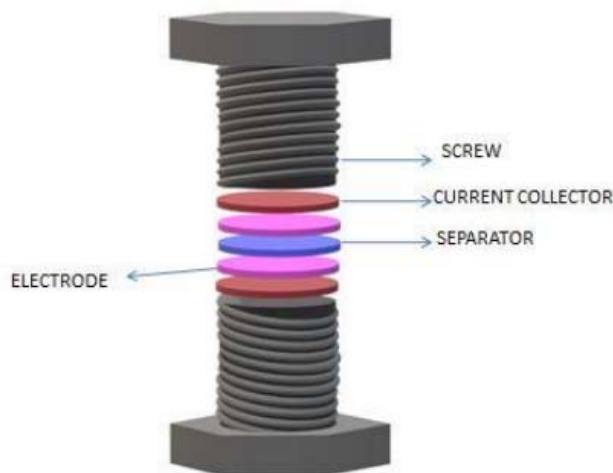


Fig. 2. Supercapacitor Arrangement.

III. RESULTS AND DISCUSSIONS

X-ray diffraction (XRD) measurements were done to analyze the structure of GO, RGO, PANI and rGO/PANI composites. The XRD patterns of GO, rGO, PANI and PANI/rGO are given in Fig. 3. A high reflection with peak at $2\theta = 13.1^\circ$ in the GO indicates the inter-layer spacing between GO layers [17]. A highly broad reflection peak was displayed at $2\theta = 24.6^\circ$, which can be interrelated to reduction in the interlayer spacing of rGO sample. At $2\theta = 25.60$ shows the greatest intense peak of pure PANI sample, which has some broad reflection peaks. Some crystalline order of bulk PANI samples are specified by these reflections. When rGO is mixed with PANI, the peaks of diffraction allocated to the interlayer distance between the sheets of rGO slowly shift to a lower angle region which depends on the increasing of the PANI loading.

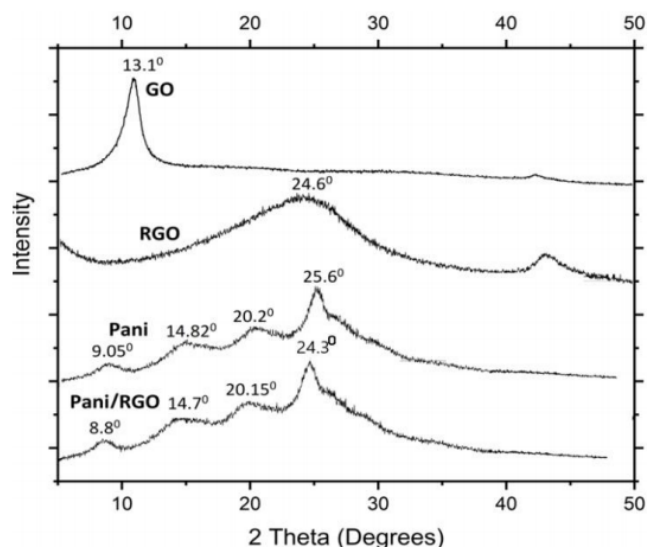


Fig. 3. XRD patterns of GO, rGO, PANI and rGO/PANI.

The FTIR patterns of GO, rGO, PANI and rGO/PANI are given in Fig. 4. The GO shows a broad absorption band at 3440 cm^{-1} indicating the stretching vibration of hydroxyl groups. The absorption peaks at 1631 cm^{-1} and 1384 cm^{-1} depicts the stretching vibration of aromatic C=C bond and the bending vibration of O-H groups, respectively [18]. The extra absorption peaks at 1733 cm^{-1} and 1118 cm^{-1} are related to the stretching vibrations of C=O and C-O groups respectively [19]. When GO is reduced to rGO, the peak intensities of oxygen rich functional groups and hydroxyl groups are reduced, which indicates the reduction of GO to rGO.

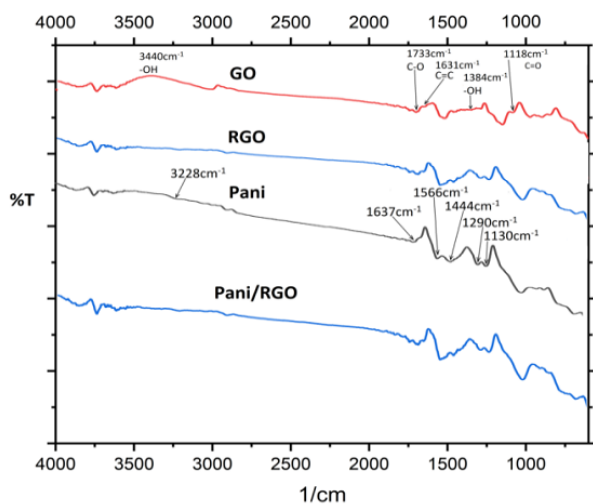


Fig. 4. FTIR patterns of GO, rGO, PANI and PANI/rGO.

The Raman spectra of GO, rGO, PANI and rGO/PANI are given in Fig. 5. Raman spectra of GO shows two distinctive Raman bands at 1342 cm^{-1} and 1581 cm^{-1} called D and G bands respectively [20]. When GO is reduced to rGO, the surface defects increases which leads to the increase in the D band intensity. When PANI was mixed with rGO, the G band shifts from 1591 cm^{-1} of rGO to 1577 cm^{-1} which proves the chemical bond formation between rGO and PANI chain.

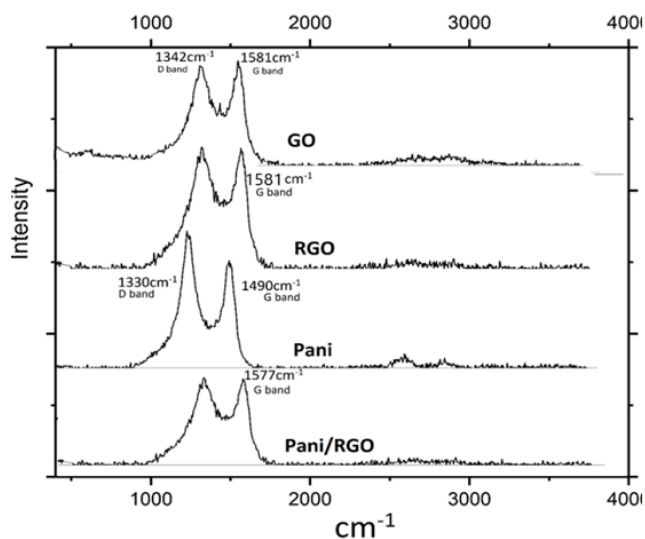


Fig. 5. Raman spectroscopy of GO, rGO, PANI and rGO/PANI

IV. CONCLUSION

Supercapacitors have the quality that makes them suited for a number of applications including being able to compliment the strengths of batteries, used in electric vehicles hybrid power systems and emergency power supplies. With carbon materials, a high specific surface area and rational pore distribution were achieved, even though their capacitances and energy density are still low. Conducting polymers show high specific capacitance, but the major challenges faced are their swelling and shrinking when charging and discharging, leading to short lifetime. This paper presents the material characterization of rGO/PANI composite used as an electrode material for pseudocapacitor.

The technique used for the proper coating rGO over PANI is in-situ polymerization. This makes the composite highly conductive and hence it can be used as a supercapacitor electrode delivering high capacitance upto 600F/g. Future work will include analyzing the supercapacitor performance using electrochemical workstation including cyclic voltammetric test and galvanostatic charge/discharge test and morphological study using SEM and TEM.

Acknowledgment

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Energy Efficiency

Efficient energy use is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses. Energy efficiency and renewable energy are said to be the *twin pillars* of sustainable energy policy and are high priorities in the sustainable energy hierarchy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Amazing Facts

- In the average home, 75% of the electricity used to power electronics is consumed while the products are turned off. The average desktop computer idles at 80 watts, while the average laptop idles at 20 watts.
- Enough sunlight reaches the earth's surface each minute to satisfy the world's energy demands for an entire year.
- Only 10% of the energy used by a traditional light bulb generates actual light. The other 90% of the energy creates heat.
- Google searches account for about 0.013% of the world's energy usage. This equals enough electricity to power 200,000 homes continuously. The energy it takes to conduct 100 searches on Google is the equivalent of a light bulb burning for 28 minutes.
- The first power plant - owned by Thomas Edison - opened in New York City in 1882.
- Thomas Edison invented more than 2,000 new products, including almost everything needed for us to use electricity in our homes: switches, fuses, sockets and meters.
- Benjamin Franklin didn't discover electricity, but he did prove that lightning is a form of electrical energy.
- A bolt of lightning can measure up to three million (3,000,000) volts, and it lasts less than one second!
- The word "electrocute" is a combination of the words electro and execute, meaning you were killed by electricity. So if you don't die, you were not electrocuted, you were shocked.
- Benjamin Harrison, the 23rd president of the US, was the first president to have electricity in the White House but he never touched any light switches because he was too scared of getting electrocuted.
- Huge amounts of renewable energy can be stored over a long period of time by using Pumped Storage Hydropower, where water is pumped up a hill with renewable electricity then sent back down the hill to generate on demand clean electricity at up to 80% efficiency.
- In 1963, Quebec government bought out all the private power companies and nationalized electricity. Today, 96% of Quebec's power is from hydroelectricity, and it has some of the cheapest electricity rates in North America while earning billions in revenue.
- Only 10% of energy in a light bulb is used to create light. Ninety percent of a light bulb's energy creates heat. Compact fluorescent light bulbs (CFLs), on the other hand, use about 80% less electricity than conventional bulbs and last up to 12 times as long.
- About 5,000 years ago, the energy people consumed for their survival averaged about 12,000 kilocalories per person each day. In AD 1400, each person was consuming about twice as much energy (26,000 kilocalories). After the Industrial Revolution, the demand almost tripled to an average of 77,000 kilocalories per person in 1875. By 1975, it had tripled again to 230,000 kilocalories per person.
- The world's biggest blackout occurred on August 14, 2004, when a massive power outage occurred across the northeastern U.S. and throughout Ontario, Canada, affecting 50 million people.

- In 2007, wind produced 1.3% of the electricity in the world. The world's largest wind farm is the Horse Hollow Wind Energy Center near Abilene, Texas. Covering 92 square miles, the center has more than 400 turbines that are 262 feet tall. They produce 735 megawatts of electricity
- Approximately 30% of energy used in buildings is used inefficiently or unnecessarily.
- In the last 50 years, atmospheric CO₂ has shot up to levels unprecedented in the previous 400,000 years. The man-made injection of CO₂ into the atmosphere is primarily from the burning of fossil fuels.
- The most powerful hydroelectric project in the world is China's Three Gorges Dam. The enormous power plant brings power to millions of Chinese villagers and will generate more than 22,000 megawatts from six generators.
- American hospitals are some of the most energy-intensive buildings on the planet.
- China has taken over the U.S. as both the world's largest CO₂ emitter and the world's largest energy consumer.
- Thomas Edison built the first power plant, and in 1882 his Pearl Street Power Station sent electricity to 85 buildings. People were initially afraid of electricity and parents would not let their children near the lights.
- English polymath Thomas Young (1773-1829) was the first to use the word "energy" in its current sense, replacing the traditional term *vis viva*, meaning "living force."
- More than 1/5 of the world's primary energy is used for transport, followed by industry, construction, and agriculture. Much is in the form of gasoline, of which nearly 792.5 million gallons is burned every day.
- A "watt" is a unit of power that measures the rate of producing or using energy. The term was named after Scottish engineer James Watt (1736-1819), who developed an improved steam engine. Watt measured his engine's performance in horsepower. One horsepower equaled 746 watts.
- Researchers note that energy is the key "to the advancement of civilization" and that energy is the catalyst that allows human societies to evolve.
- The word "energy" comes from the Greek *energeia*, meaning operation, activity.
- The world's oil reserves will last until 2052 and gas reserves will last until 2065.
- A hurricane releases 50 trillion to 200 trillion watts of heat energy. This is as much energy as a 10-megaton nuclear bomb exploding every 20 minutes.

