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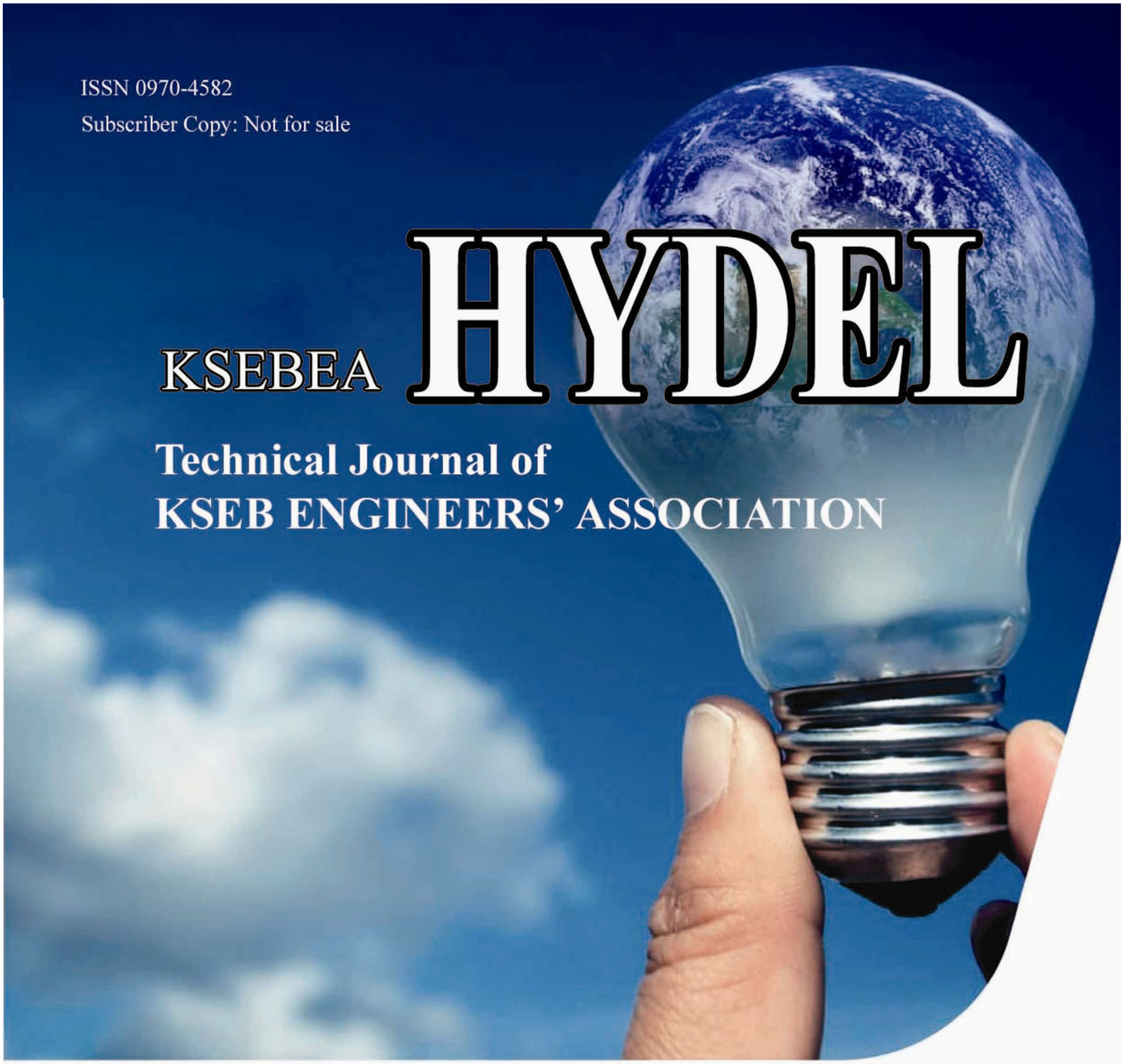

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Editorial...

An **electricity grid** is a most complex interconnection of various power system components and it can be thought of as the largest machine in the world, when considered as a single entity. Among the desired characteristics of a grid such as Safety, Robustness, Reliability, Stability, Resilience, Visibility to the power system operator, Power Quality for all the customers fed from the grid etc., Grid Resilience play a very important role in the serviceability of the grid.

Grid resilience refers to the ability of power system to recover quickly following a disaster or more generally, to the ability of anticipating extra-ordinary, high-impact, low-probability events; rapidly recovering from those disruptive events and absorbing lessons for adapting its operation; and make structural modifications to prevent or mitigate the impact of similar events in the future. Adaptation thus refers to long-term planning and operational measures taken to reduce the vulnerability to external sudden shocks.

Due to climate change issues, the weather disaster plays havoc with electric power distribution and causes a catastrophic situation resulting in power outages affecting thousands and crores of customers. With increasing dependence on electricity for most daily activities including life saving equipment and vital services like transportation, water supply, health care, communications, emergency services etc. are affected and an urgent need exists to enhance the resilience of our nation's electricity delivery infrastructure to reduce the impact from natural disasters and climate change events on quality of life, sustained economic activity and national security. Resilience includes the ability to withstand and recover from deliberate attacks, accidents or naturally occurring threats or incidents involving man-made disasters.

Renewable Energy Sources (RESs) will displace energy produced by conventional plants, but their ability to displace conventional generation capacity shall be very limited. Micro-grids, with appropriate enabling technologies will facilitate the paradigm shift required in delivering resilience and security of supply from redundancy in assets. Preventive control measures to achieve more intelligent operation through corrective control actions also shall be supported by micro-grids with the aid of a host of enabling technologies including Information and Communication Technology (ICT).

Micro-grids can disconnect from the traditional grid, operate autonomously, and help mitigate grid disturbances, serve as a grid resource for faster system response and recovery, and hence strengthen grid resilience. Thus the micro-grids are self-healing and self-organising miniature grids capable of flaw-less operation and deliver power to the designated areas in a catastrophe.

Resilience is a multi-dimensional dynamic concept with several intrinsic complexities. However, it needs to be quantified for evaluating the effectiveness of the strategies aimed at achieving resilience and to make amendments thereupon. Resilience is quantified based on the degree of robustness to initial shock to the power grid, the functionality achieved during the event or post-event recovery duration.

The resilience assessment method should be capable of quantifying the frequency and duration of customer disconnections due to severe disasters and also the number of customers disconnected.

Networks and Components hardening measures can be undertaken to achieve high resilience. Hardening measures include converting the overhead Distribution and Transmission lines underground; upgrading poles and structures with stronger and more robust materials; Elevating Sub-stations; Relocating facilities to areas less prone to extreme weather; Relocating transmission lines to areas less affected by deterring weather and by creating redundant transmission line routes to provide operational flexibility, as they offer ability to bypass damaged lines which contribute to prevention of cascading failures.

The grid can be made smarter as a smart grid provides the system operators with monitoring and control assets for dealing with unfolding disaster in a timely and efficient way, thus saving the grid from a collapse or catastrophe. Smart intervention strategies can be Distributed Energy Systems & Decentralised Control, Micro-grid Implementation, Deployment of Advanced Grid Visualisation and Situational Awareness Systems, Adoption of faster Disaster Response System and Risk Management etc.

Co-existence of large interconnected traditional grids and smaller balancing areas, with distributed and decentralised control, that could be operated as micro-grids, if need be, contribute to the robustness of the grid and it increases operational flexibility and grid security. In extreme emergencies, the micro-grid can function in an islanded fashion to power the essential loads in a hospital, military base or such other critical areas within the immediate neighbourhood of the micro-grid, thereby ensuring seamless support for the operation of the designated area achieving 100% reliability.

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HOUSEHOLD ELECTRICITY CONSUMPTION VERSUS INCOME – A CASE STUDY OF KERALA

Dr E Mohammed Shereef

Deputy Chief Engineer, KSEBL

Abstract

This paper investigates the relationship between income and electricity consumption in Kerala. The fundamental principle is that energy consumption at the household level is a key indicator of standard of living. The residential electricity consumption in the state is witnessing a rapid and consistent growth. As the residential consumers enjoy subsidised tariff, they may not take adequate attention to avoid wastage of electricity. The study of relationship between income and residential electricity demand is significant as it helps to better understand the implications of various welfare policies. The study conducted among the domestic consumers established that household income is a major determinant of electricity demand. It is also established that the domestic consumers are also willing to reduce their electricity consumption further, which is a strong indication that there exists a scope for electricity conservation

Key words

Residential consumers, Standard of living, Determinants of electricity, Electricity demand, Household income, Electricity conservation.

Introduction

The household consumption of electricity is widely viewed as enhancing standard of living. In Kerala the residential consumption grew from 1073.17 MU in 1987-88 to 7705.86 MU in 2011-12. The share of domestic consumption during this period increased from 29.59 % to 47.62 %. Today the residential consumers have become as the largest consumer sector. The residential electricity demand modelling has an important role in tariff determination as well as in evolving measures for electricity conservation. The average price of electricity has been increasing over the years and hence its impact on different income groups has remained a concern. So, the relationship between electricity demand and income remains to be a major interest for scholars, policy makers and regulators.

Review of Literature

The relationship between electricity consumption and income has been studied in the literature and among policy analysts for quite some time. Many UN and World Bank documents, like Sanghvi and Barnes (2001), Dzioubinski and Chipman (1999), Barnes (1995), and Goldemberg and Johansson (1995), as well as other literature, identified the relationship between energy consumption and standard of living. Electricity is a critical element that plays a vital and positive role in the socio-economic development and human welfare of any country (Gupta and Sahu, 2009). It is also a fact that proper reforms in the power sector acts as a catalyst in realizing various social and economic goals. Ibrahim etal (2002) in their study revealed that the household electricity consumption in Kerala increases with income and family size. Sharma etal (2002) stated that the rapid increase in the consumption of electricity in the residential sector of Kerala aggravates the energy crisis in the State. The role of economic and non-economic factors in the determination of residential electricity demand was investigated by Forster (2010) and found that the demand for electricity is based on the overall number of family members, their age differentials, income etc. Reghu and Reddy (2012) in a study conducted in Andhra Pradesh revealed that high cost power is procured to meet the fast growing consumption in the higher slabs where as the poor households are affected both by a disproportionate tariff burden and wide disparities in consumption.

Objectives

The objectives of this study are to

(i) examine whether electricity consumption increases with household income

(ii) examine whether significant relationship exist between monthly income and consumption,

(iii) know whether domestic consumers are willing to reduce electricity consumption

Methodology

A survey was undertaken among the domestic consumers of KSEBL. The questionnaire for collecting the primary data contained two sections. The first section contained items pertaining to the demographics of the respondents. Sample items include age, education, number of family members, income etc. The other part elicited information pertaining to the bimonthly electricity consumption, billed amount, willingness to reduce electricity consumption etc. The willingness to reduce consumption was elicited on a five point scale that varied from strongly agree to strongly disagree. The data were collected from 1066 respondents of 156 Electrical Sections in Kerala covering all the districts.

Results and discussion

For the analysis, the respondents are grouped in to four groups based on the monthly income as shown in Table 1.

Table 1

Distribution of Households on the basis of Monthly Income

Monthly family income	Income Group	No. of households	Percentage
Up to Rs.5,000	IG-1	447	41.9
Rs.5,001 to Rs.20,000	IG-2	332	31.1
Rs.20,001 to Rs.50,000	IG-3	198	18.6
Above Rs.50,000	IG-4	89	8.4
Total	1066		100.0

The low income group (IG-1) households constitute around 42 % and the high income group (IG-4) households constitute around 8 % of the total households. An attempt was made to categorize the monthly consumption into four groups so as to analyze the impact of income on consumption. The details are presented in Table 2.

Table 2

Data regarding Income and Consumption

Income Group	Consumption Group				
	Up to 40 Units	41-80 Units	`81-200 Units	Above 200 Units	Total
IG-1	283	129	34	1	**447**
IG-2	51	136	128	17	**332**
IG-3	7	34	122	35	**198**
IG-4	0	6	61	22	**89**
Total	**341**	**305**	**345**	**75**	**1066**

It can be seen from the above table that the consumption of domestic consumers increases with an increase in income level. The percentage of households coming in the four consumption groups in four income categories is shown in Figure.1

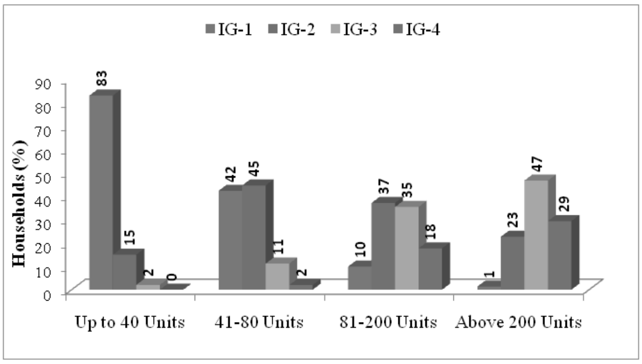

Figure.1 Households in different income and consumption groups

It can thus be observed that, in low consumption group (up to 40 units), 83 % of the households are in the low income group (IG-1) whereas there is no household in high income group (IG-4). Similarly, it can thus be noticed that, in high consumption group (above 200 units), 76 % of the households are in the high income groups (IG-3&IG-4) whereas only 1 % of the household are in the low income group (IG-1). This establishes the fact that consumption increases as the income increase. This is in line with the earlier studies of Ibrahim, et al (2002), Ramachandran and Anita (2005), Forster (2010), and Olaleye (2012).

To know whether there is any significant association between the income and consumption, Pearson Chi-Square test was conducted and the result is shown in Table. 3. The hypothesis formulated for testing the association is as under:

H_0: There is no association between the household income and electricity consumption.

Table 3

Chi-square Test

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	565.579	9	0.000

The test result shows that there is a strong association between the household income and the electricity consumption at 1% level of significance. The results thus indicate the existence of a significant relation between monthly income and consumption. The inference that could be traced is that electricity demand is income elastic and hence income and electricity consumption moves together. Therefore the income is a major determinant of household consumption and the electricity demand is income elastic. Earlier studies have also proved this (Ramachandran and Anita, 2005; and Olaleye, 2012).

It was also an objective of the study to find out whether the consumers are willing to reduce their monthly consumption. The income group wise opinion of the respondents is shown in Table 4.

Table 4

Willingness to reduce consumption (%)

Income Group	**Agree**	**No Opinion**	**Disagree**	**Total**
IG-1	63.3	20.6	16.1	100.0
IG-2	72.0	9.0	19.0	100.0
IG-3	72.2	7.6	20.2	100.0
IG-4	71.9	9.0	19.1	100.0
Total	**68.4**	**13.6**	**18.0**	**100.0**

In high income group, 71.9 % households agree that they can reduce their consumption where as it is 63.3 % in low income group. In low income group, 20.6 % consumers have no opinion regarding reducing consumption. This may be because of the lack of awareness of the low income group. The study revealed that majority of the consumers (68.4 %) is ready to reduce their consumption. However, 18 % expressed the doubt regarding reduction in consumption. This may be due to the fact that these consumers would have engaged in reducing the consumption of electricity to such extent that no further reduction is possible. This aspect, however, needs to be examined in detail, as this indication is not a healthy trend. As a small per cent of the consumers had no opinion, there is large scope for conserving electricity in households. The domestic sector is the largest consumer in the State and their consumption has to be reduced to the extent possible. This highlights the necessity of imparting proper awareness to domestic consumers for conservation of electricity.

Conclusion

The household electricity demand and per capita consumption increase as the household income increases. Also there exist a significant relationship between household income and electricity consumption. This indicates that electricity demand is income elastic. Similarly majority of the consumers are willing to reduce their electricity consumption further which shows the scope for electricity conservation among households. For achieving this, necessary awareness programs have to be conducted among the domestic consumers. Reduction in domestic consumption is beneficial to the utility. The result could be useful to evolve strategies to introduce suitable pricing policies as well as to reduce consumption in the residential sector.

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Ivanpah Solar Thermal Power Plant

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.

Automation in daily life

Dr P. S. Chandramohan
Former Principal, Govt. Engineering College

There was a time when human race depended only upon their muscle power. When we realized the natural phenomena and tried to utilize it, slowly we could ease our physical labour. We got enough time to relax, think and recreate. This paved the way for the development of art, science and technology.

When we could reliably pass on some of our physical labour to machines and mechanisms, automation found a place in daily life. The discovery of energy resources and the development of electricity generation as an industry pushed up the growth of automation. The automation in its early stages confined to simple things like pumping up water to a tank or setting up of an alarm clock has now spread in all sectors of our daily life. Reaching moon and mars or to predict thunderstorms and cyclones in advance and to take precautions to save human life have been made possible only because of the developments in automation.

'Automation' means 'do itself'. This is not possible without seeing, hearing and intelligence to take decisions. So artificially these things are to be fed to automatic systems. This is where we need the techniques from electrical and electronics engineering, computer science, communication engineering, sensor technology etc.

Let us examine a very simple case of an electric iron box. We set the temperature according to the type of cloth. A bi-metallic strip which expands or shrinks according to the temperature functions as the sensor as well as switch here. When the iron box reaches the set temperature, the strip opens the contact which cuts the electric current. Again when it is cooled, the strip makes contact and passes electricity. A similar arrangement – called thermostat – is there in refrigerator also. Only difference is that it breaks the contact when the refrigerator gets cooled to the set temperature and again contact is made when the temperature starts rising.

Now let us examine a little more complex system – washing machine. Programmed electronic chips control the functions here. Different functions include sensing weight of cloths filled, water temperature, mechanisms for bi-directional rotation, sensing water content of cloths in dryer and adjust speed of dryer accordingly etc. The electronic (microprocessor) chips are now-a-days equipped in a number of appliances like microwave ovens, ATM machines, cash registers in super markets, fuel control systems in automobiles, medical equipments, process control in industries etc.

We make use of automation not only to ease muscle power, but also to do work in places where human intervention is impossible. For example, robots are used in mines, localities near volcanoes etc. Robots are also used to fill fuel in nuclear reactors.

Many sensors have been developed to sense light, temperature, pressure, speed, flow, humidity, presence of living beings etc. We have also developed mechanisms to predict landslides and tsunamis in advance. Many automatic systems have also been developed that help physically challenged people. We have devices and mechanisms to avoid lightning hazards. Reliable security systems are now available for safety of homes/ buildings. Even though a costly affair today, the present technology is capable of watching our entire home and its premises from whichever part of the globe we are.

Today's electricity industry is very vast and complex in nature. The generation, transmission and distribution systems and its interconnections have become huge and complex in size grown from small local networks to wide-spread national and international networks. The tremendous growth in electricity industry is made possible only because of the growth in automation. In case of any emergency/ accident, the safety mechanisms must act within a fraction of a second. Otherwise, the financial losses can be huge in addition to the loss of very valuable lives. Not only for the emergency operations, but for the daily routine operations also the electricity industry essentially needs a lot of automation.

Power systems are to exist for ever (as far as mankind exists). Modern power systems are integrated to improve reliability, stability, quality of supply and for economic operation. At the same time integrated operation poses many challenges. Technological solutions exist for meeting challenges. Today the generation is of a heterogeneous mix of conventional and non-conventional sources. At the consumption side the loads are of diverse in nature and its composition varies from time to time. Power quality issues have become more important today. At the consumer end, the energy meters are no more mere measuring instruments alone. It helps the consumers to conserve energy and manage power utilization by displaying a number of useful data and information.

The power industry scenario has turned down from a stage of monopoly to that of competitions. To make cheap electricity available, we need desired interconnection of networks. For this electronic power exchanges and bidding are also needed. With the advancement of electronics, communication, I.T. etc., the power grid is becoming smarter day by day. With the new technologies leading to more automation, the power engineers may be relieved of number of operations; but may not be relieved of challenges. And challenges are to be realized as opportunities to strive for more perfection.

We shall come back to some other items in daily life.

It was not long back we stored records and data in bound volumes in a number of racks in huge buildings. To dig out any information from these, sometimes it needed hours or even days. Today, we do not require any considerable space at all for such huge storage because of the developments in computer, digital storage. We can retrieve the required data within seconds or sometimes within fraction of seconds by giving a search word.

It is not time to forget the fact that we were either taking carbon prints while typing or repeatedly writing to take multiple copies of lessons or other records. Today photocopy and scanning are in front of us at a very cheaper rate! Printing presses capable of making hundreds of copies per minute are so common. In factories, work of repeated nature and requiring muscle power are diverted to machines or robots. Many tools and machines are available to ease agricultural and gardening work. High rise buildings are common as the reach is not a problem at all because of lifts and escalators.

To make payment we need not wait in queues in banks and treasuries. It is possible with a mouse click sitting anywhere in front of a computer with NET connection. In whichever part of the world we are, we need not be tensed if we do not have cash with us. ATM card or credit card will do. Otherwise, net-banking or mobile banking is enough.

Earlier, researchers and students in higher studies used to wait for weeks after giving orders to get papers published outside their country. Today it will reach them within seconds through internet if the source (whether library or any publisher) is NET connected. If any payment is needed, that is also possible through online payment. We are able to watch classes of Professors in reputed universities, sitting home.

The letter correspondence through post office which required days are now mostly done through e-mail or Fax, instantly. The processes like getting application forms by sending requests enclosing payment receipts/ demand drafts after making payment in treasuries or banks suffering a long waiting are getting moved into our old memories. In most of the cases, online application with online payment of money is enough.

The developments in technology in the health sector have made diagnoses very speedy and accurate. Very complex and complicated surgeries are now-a-days mostly done with minimum blood loss and without any human error.

The communication revolution is materialized because of the integration of cell phone technology and satellite communication. Today, postal letters have become very less. Out of these, personal letters are rare to see! When we have easy, cheap and reliable mechanism to communicate instantly, who will go after a snailing mail service!? Today mobile phone is not a gadget to talk alone. To listen music, watch movies, send e-mail and to do bank transactions etc., this popular device is quite enough.

Imagine that we are trapped in a remote unknown place during night due to heavy rain or so. There is nothing to be panic. The GPS in the cell phone or GPS fitted in the vehicle will give us the location where we are and show how to come out and reach destination through the shortest and reliable route and also how far it is. What else needed!

Today, even our domestic kitchen is a show piece of modern automation. Gadgets to grind, powder, fry etc., fridge, electric cooker, cooking ranges, microwave oven, electric chimney, dish washer etc. are so common.

In short, does the automation make us lazy? To certain extent we may feel so; but it is not true. We have automation only to the extent to facilitate modern living. Compared to the earlier lifestyle, modern living comprises of a number of activities and it will continue to grow. The human race cannot have a 'go back'. "How could we live so far without these things!?" Such a question will be always asked by people. As human race develop, automation will also improve.

Automation never ends ……..

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.

SOLAR ENERGY PENETRATION IN KERALA: FACTS, ISSUES & SOLUTIONS

C. P. George

Deputy Chief Engineer, KSEBL

Introduction

The Indian ground mounted, utility scale solar power industry is growing at a furious pace in the last three years. From almost nil installed capacity prior to 2010, the total installed capacity of solar power is over 6000 MW in India now. An impressive achievement indeed.

In parallel, the rooftop solar sector has started accelerating too, especially in the last 24 months. 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. Significant load shedding and ceilings on power withdrawals during peak load periods have also made many of these units resort to diesel Gen-sets. The high cost of diesel based power and the decreasing costs of solar are making these rooftop solar an important solution for energy security and operational cost reductions.

While reliable data is hard to come for the rooftop sector, it is estimated that total rooftop solar additions in the last 3 years alone could top 400 MW. No mean achievement, given that the average rooftop installation would be in the range of 10 kW or less, implying that there have been over 40,000 rooftop solar installations, up from practically nothing before that…!!

All these augur well for this sector.

Rooftop solar power is being increasingly embraced by commercial, industrial and residential consumers in many states of India as a significant contributor to their energy mix because it combines

- On-site generation of power
- Utilising unused rooftop space
- Reasonable cost

Generating power on-site frees the consumer from being at the mercy of grid failures and even load shedding as the solar plant is not dependent on grid infrastructure to deliver its power to the load. In this sense a solar plant is similar to a diesel generator, but without the associated noise and emissions.

Rooftop space is often left unutilised in many establishments; installing a solar plant on the roof is a great way to derive additional value from your building.

Depending on the tariff regime, solar power may be cheaper than even grid power for some consumers; it is much cheaper than diesel power for all consumers, and offers the added advantage of fixing the cost of power for the next 25 years – a rooftop solar plant that delivers power at a "levelised cost" of Rs.9/kWh today will deliver power at the very same cost 25 years from now.

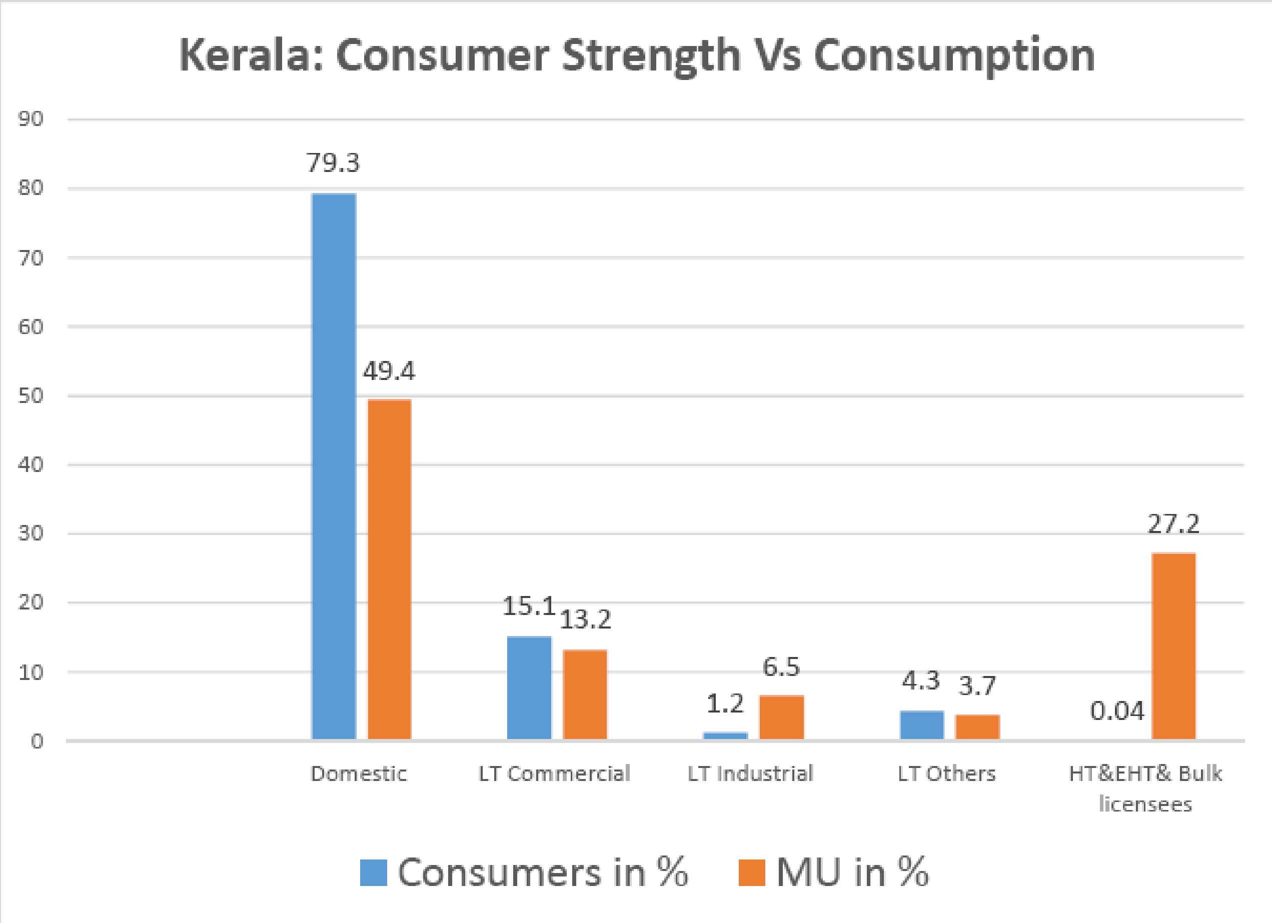
In addition, solar plants have no moving parts and are therefore very reliable, requiring minimal maintenance expenditure or downtime.

In spite of all these advantages, the roof top solar generating plant is not that popular with the consumers of Kerala and the level of penetration is not anywhere near the desirable level.

Here I am trying to explore the issues that put constraints in penetration of rooftop Solar power in Kerala and provide the critical inputs that you would require in understanding how rooftop solar can make a difference in Kerala Grid.

General Constraints & Consumer Pattern

While the advantages of rooftop solar power are undeniable, some natural constraints should be considered as well, such as solar power being generated only during daytime, or lack of sufficient rooftop space limiting the size of solar plant that can be installed.



The distribution of consumer pattern in Kerala grid do not help us to augment the natural growth of roof top solar due to following

1. 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

2. Harnessing solar energy with battery backup is the option for these consumers, but its viability with present tariff structure is a point of debate.

Per Unit Cost of Solar Energy in Kerala and its Viability.

1 kWp of panel will generate about 1,350-1,460 kWh (units) per year i.e., about 3.7 - 4 kWh per day.

This is broadly representative of output from rooftop PV plants in Kerala. It is an average calculated over a year. Generation on individual days at your location will vary based on meteorological conditions

Capacity Utilisation Factor (CUF)

= Actual energy from the plant (kWh)/Plant capacity (kWp) x 24 x 365 = (KWp x 4 x 365)/ (KWp x 24 x 365) = 16.7%

This means a capacity utilisation of 16% only can be obtained for a solar plant in Kerala.

A. Solar Plant without Battery backup

Cost of 1kWp Solar roof top plant = 100000.00

Loan cost per annum @ 10% interest: = 10000.00

Annual depreciation cost with 25 year useful life = 3600.00

Total investment cost per annum = 13600.00

Energy generated per annum from 1kWp Solar Plant = 4 x 365 = 1460 kWh

Investment Cost for a roof top solar plant without battery backup = 13600/1460 = Rs. 9.31 per kWh

[Note: The values are only indicative and need to be considered accordingly]

B. Solar Plant with Battery backup

Cost of 1kWp Solar roof top plant = 160000.00

Loan cost per annum @ 10% interest: = 16000.00

Cost of Battery system = 50000.00

Annual depreciation cost of battery with 5 yr. life = 10000.00

Annual depreciation cost of plant with 25 yr. life = 4000.00

Total investment Cost per annum = 30000.00

Investment Cost for a roof top solar plant without battery backup = 30000/1460 = Rs. 20.55 per kWh

[Note: The values are only indicative and need to be considered accordingly]

As such it is very clear that the roof top solar is not a viable natural business in Kerala with the present technology. To encourage the business, an environment need to be created with appropriate policies and relevant financial aids from the governments along with proper regulatory supports.

Creating Environment

1. Cost of Power from a grid-interactive

Average Grid Tariff for various Categories in Kerala	
Category	**Rs. Per Unit**
LT Domestic	3.76
LT IV Industrial,	5.96
LT V Agricultural	2.39
LT VI Non Domestic	7.56
LT VII Commercial	8.48
LT XI Pub lighting	3.60
HT- I Industrial	6.18
HT III Agriculture	5.50
EHT -66kV	5.94
EHT-110 kV	5.54
Railways	5.75

PV plant with battery backup works out to about Rs.20.50/kWh. It is a cost-effective alternative for energy consumers

a. Where diesel generators are frequently used (as diesel would cost about Rs. 50/litre and the cost of power from diesel would be more than Rs. 20/kWh if we consider the pilferage, evaporation etc). In such cases, even the grid interactive solar plants are viable options due to its advantage of operation without noise and emissions. Grid-interactive system works in conjunction with a battery backup to support the load even during a power failure. As such while framing and enforcing the policies and regulations these environmental aspects need to be considered.

b. For consumers who are charged with grid tariff higher than the levelised cost of solar power, roof top grid tied solar power is a viable option. According to Kerala Grid tariff (please refer table above), for the commercial and non-domestic categories, the roof top solar can be considered as a viable option. But the main issue is the reliability of the grid supply. The domestic loads and public lighting loads are practically best suited to receive energy from a roof top plant and it is a viable option if the grid tariff is comparable. The domestic category consists of 80% of the total number consumers and consumes 50% of the total energy. The average grid tariff for domestic category is highly subsidised and hence not viable. As such the present structure of the grid tariff acts as a demotivating factor for the penetration of roof top solar plants in Kerala.

2. Reliable supply of grid power

As already stated, maximum possible capacity utilisation of a solar plant is 16% @ 4 units per kWp per day. At present the harvesting of solar energy shall be viable and comparable with prevailing grid tariff only in case of grid tied solar plants which are without battery backup. These grid tied rooftop systems are primarily designed to supply the generated power to the grid and also power the load. These systems will NOT generate power during a power failure as the inverter shuts down the system to stop sending power into the grid and avoids the risk of electrocuting utility personnel who are working to repair the grid. Thus reliable supply of grid is the basic prerequisite for ensuring better penetration of the roof top grid tied solar plant by increasing the financial viability and focus should be on increasing the reliability of the existing grid power of KSEBL

3. Government Policies and Regulatory Supports

a. Capital subsidy by government agencies including MNRE: The capital subsidy by the government agencies shall reduce the capital investment cost and appropriate reduction in per unit cost of solar energy make the roof top solar more viable. For example, 30% capital subsidy reduce the investment cost from Rs.9.31/kWh to Rs.6.51/kWh. But it is observed that the tedious procedures in getting the subsidy made this option less attractive.

b. Preferential tariff ('preferential tariff' means the tariff fixed by the Appropriate Commission for sale of energy, from a generating station using renewable energy sources, to a distribution licensee) and Renewable Energy Certificate (1REC=1MWH) for meeting RPO ('renewable purchase obligation' sub-section (1) of section 86 of the Act, for the obligated entity to purchase electricity from renewable energy sources mandated by the SERCs for the distribution licensee) are supposed to provide additional revenue from the sale of solar energy and make the roof top energy generation more attractive.

For Kerala, the KSERC is yet to make a regulation for preferential tariff for solar energy though we have a mandatory 0.25% RPO requirement for every distribution licensee and open access consumers.

As per the current market information, the Solar REC is regularly being marketed at the floor price of Rs.3.50 per unit in the power exchanges. But the point of concern is lowest percentage of market clearing. Only around 3% of the solar REC available in the power exchanges are being cleared in the market now. This need to be improved to a satisfactory level by appropriate policies and regulatory intervention including making the appropriate percentage RPO mandatory for every distribution licensees and the open access consumer.

Conclusion

Better solar energy penetration requires appropriate environment for its generation and utilisation. Focus on following points shall surely improve the present environment and need attention of the policy makers on priority basis.

1. A grid tariff that motivate the consumers, especially the domestic, non- domestic and commercial consumers to opt for solar energy from roof top solar plant.
2. A reliable supply of grid power to make the solar energy viable and cheap without a battery backup. This means systematic investment in transmission and distribution system.
3. Framing and enforcing policies and regulations that control emissions and noise levels from diesel generators and appropriate schemes to replace them with interactive roof top solar plants.
4. Government policy support with transparent and simple procedures for investment subsidy shall make per unit cost on solar energy competitive at consumer point. Even with present level of investment subsidy, the solar energy from grid tied solar plants are viable for nondomestic and commercial consumers.
5. Appropriate regulatory support from KSERC is the most important aspect to ensure viability of the solar energy. This include
   a. The mandatory RPO requirement for licensees and open access consumers
   b. The regulation for preferential tariff or feed in tariff for solar energy.

(*At present we do not have a preferential tariff for renewable energy and this regulation is the need of the hour*).

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.

Space charge effect on Polymeric insulation under High voltage DC application A review

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HVDC power transmission is becoming more and more popular because of the ability to transport bulk amount of power over long distances with lower capital cost, lower line losses and easy power connection and lower losses than AC. Polymeric materials are taking the place of conventionally used oil filled and oil impregnated paper cables used in power transmission. Among them polyethylene (PE) is widely used in HV cables. Space charge effect has been identified as one of the major components of electrical ageing process in polymeric material such as XLPE. Several studies have been carried out to understand the electric field and space charge distribution of polymeric materials under both AC and DC voltage condition[1-2]. The presence of space charge at the trapping sites such as crystalline/ amorphous interfaces may produce regions of high electrical stress, leading to breakdown insulation when used in HV applications [3].

When insulating materials are used in DC conditions it is important to consider heat generated by the steady current flowing through the insulation and the local high electric field set up as a result of space charge accumulation. [4] The accumulation of space charge within the insulating material is a great threat to the reliability of operation especially under DC voltage conditions. Electric field in an insulation system is decided by its permittivity for AC, but its conductivity/space charge for DC. Space charge in a polymeric material is very sensitive to various factors such as the physical and chemical structures of the insulating polymer, additives, electrode conditions, aging, applied field, temperature and so on[5-6].Therefore design of HVDC cables is more complicated than AC. It has been shown that space charge distribution plays an important role in dielectric aging through electrical tree initiation and finally leads to breakdown of polymeric insulators.[7-8] .

DC insulation in service is subjected to DC voltage, its polarity reversal, AC voltage, impulse and switching surges super imposed on DC. Hence it experiences a complicated space charge effects and it is very difficult to estimate the actual electric field and space charge distribution. These factors limit the use of polymeric material as insulation for high voltage DC cables [9].Electric field distribution E due to the presence of space charge can be estimated using Poisson's equation

$$\frac{dE}{dx} = \frac{\rho(x)}{\varepsilon_0 \varepsilon_r} \qquad (1)$$

where Á (x) is the charge density at x , μ_0 is the vacuum permittivity and μ_r is the permittivity of the material. The total field is the resultant of the applied field and the space charge field.

Measurement techniques

Evolution of space charge measurement techniques has been described by Lewiner[10] Several non-destructive testing methods such as laser-intensity-modulation-method (LIMM) , the thermal step (TS) method , the pressure wave propagation (PWP) or laser-induced pressure pulse (LIPP) method, and pulsed-electro-acoustic (PEA) method have been reported. [11-12]. The Pulsed Electro-Acoustic (PEA) method for space charge measurement is particularly suitable for investigating electrical properties such as injection, trapping and transport of electrical charges [13] because measurements can be easily performed under applied voltage and in volt off conditions. Figure 1 shows principle of PEA measurement.

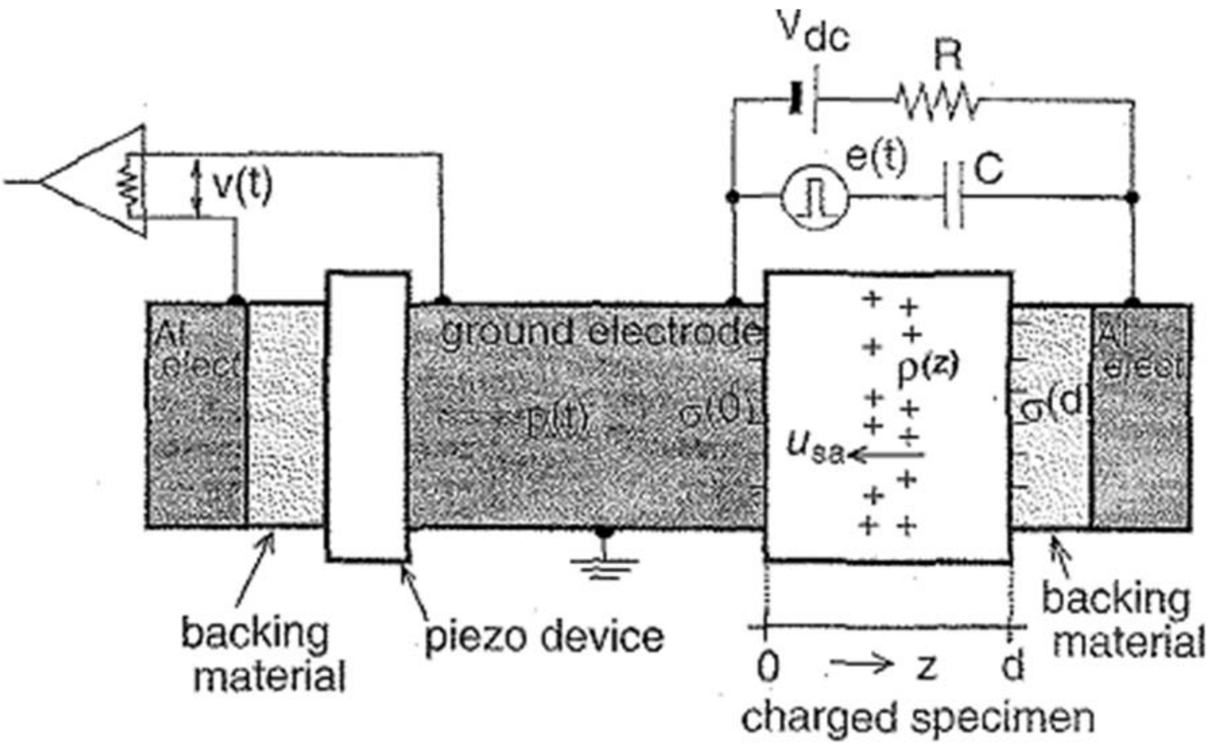

Fig 1.PEA space charge measurement system [14]

The principle of the pulsed electro-acoustic method is based on the Coulomb force law. When a pulsed electric field is applied to a sample, it induces a perturbation force on each charge. This force causes the charge to move slightly. This movement launches an acoustic wave which originates from the charged bulk. The acoustic signal is detected by a piezoelectric transducer mounted on one of the electrodes. The space charge profile information contained in the acoustic signal is extracted and calibrated through the use of a digital signal processing .

Factors affecting space charge formation

It is well known that the charge formation in the bulk is determined by several factors such as physical structure, additives, electrode material, applied stress and temperature [15]. In practical underground cable system operating temperature is not constant. Studies conducted on LDPE it was found that the space charge density was dependent on the temperature. At lower temperatures the charge density was considerable and was attributed to injection of charges from the electrodes. Above 55 °C it was much smaller, and the authors attributed the decrease to increased mobility of the charges within the polymer matrix[16].Investigations have shown that cross linking, melting, softening and permeation processes in polymers also can result in space charge build up[17]. Insulating grade XLPE used in HVAC cables typically contains additives, cross-linking agents, and other compounds that increase the ability of the material to withstand electrical stresses. Space charge in XLPE mainly consists of two parts. One is the trapped or mobile carriers injected from electrodes known as homo charges [18]. The other is charges formed due to the ionization and migration of the organic and inorganic impurities under electrical stress, referred as hetero or bulk space charge [19].

Polyethylene (typically 15-40 percent crystalline) consists of spherulites surrounded by amorphous regions. The spherulite size, which can significantly influence the mechanical and electrical properties of the material, depends on the processing temperatures and the cooling rates. It has been reported that the amorphous interspherulite regions in polyethylene are the preferred trapping locations of charge-carrying species. Water plays an important role in the formation and transport of space charge in polyethylene [20-21]. The accumulation of space charge at defect centers such as carbonyl groups formed by oxidation, can initiate local heating in a small region around the defect center, and can lead to breakdown of polymeric material[22] .Choo etal studied the effect of space charge dynamics of XLPE extruded cable under different temperature gradient and polarity reversal and concluded that injection and transportation of charges increases with increase in temperature gradient across the insulation [23]. The mobility of charge carriers, its distribution and depth of charge traps can give information on space charge dynamics of insulating materials. It is not possible to directly measure or calculate charge carrier mobility and trap depth. An estimation of these quantities can be obtained from depolarization characteristics [24-25]. In commonly used characterization for extruded HVDC cables includes measurements of leakage current and space charge distribution. The apparent conductivity obtained from leakage current shows good agreement with the conductivities that was evaluated from the time evolution of space charge from voltage application until steady-state [26].

The formation of space charge at the interface, electrode/polymer interface or polymer/polymer interface is more critical compared to that in the bulk because most electrical failures occur at the interfaces. Charge transportation in the material is influenced by the presence of traps and trapping characteristics. In addition, due to broken bonds and chain folds at the surfaces of the materials the traps originated from the surface play an important role in forming charges.[16]. Ionization of impurities in the insulating material...... It should be noted that water vapor, even at concentrations as low as 50 ppm, promotes the ionization of impurities and of cross-linking by-products in polyethylene [27]. Physical structure of polyethylene is complicated and it consists of lamellar and spherules structure .The chain branching depends upon the manufacturing process. The space charge accumulation in LDPE is strongly affected by the density or crystallinity [28].

Figure 2 shows the space charge distribution in LDPE (density 0.92gm/cm3) and LDPE doped with 0.3wt% antioxidants under dc field of 50MV/m at room temperature. Injected positive space charge is enhanced by antioxidant [28].

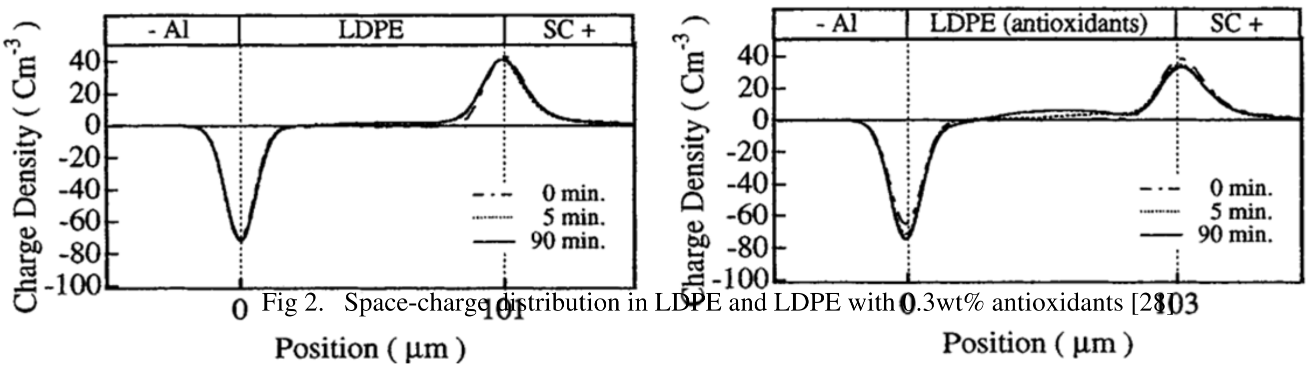

Fig 2. Space-charge distribution in LDPE and LDPE with 0.3wt% antioxidants [28]

Space charge dynamics in LDPE film at the applied fields between 25 to 125 kV/mm have been studied using PEA method and concluded that charge dynamics is determined by electrode material, applied electric field and its duration [29].

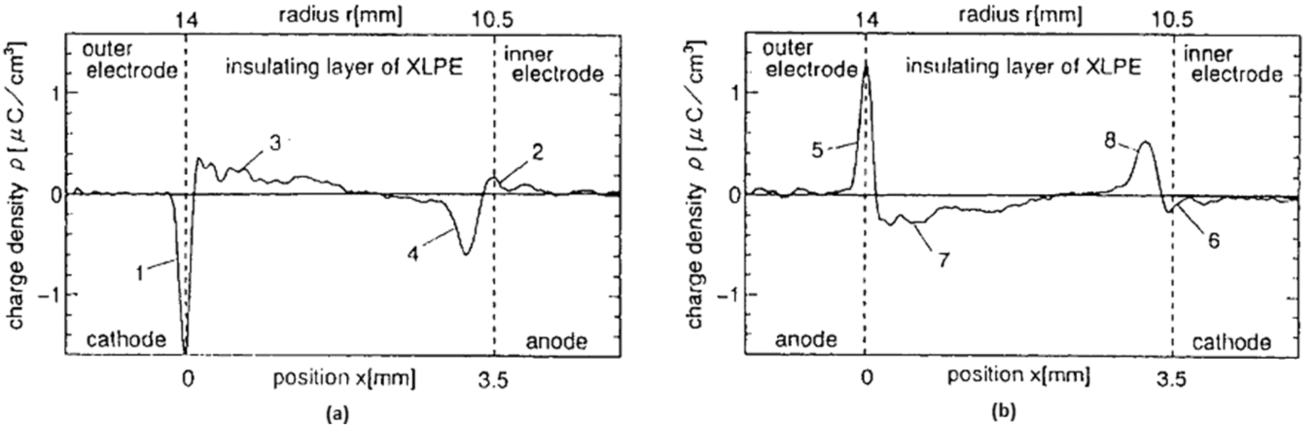

Fig 3.Polarity effect of dc voltage on space charge accumulation (a) +40 kV dc; (b) -40 kV DC. 1,2,5,6 : surface charge induced on electrodes.3,4,7,8: space charge accumulating in XLPE(30)

Figure 3 shows space charge accumulation under positive and negative DC voltage application. It is shown that there is no obvious difference in space charge distribution and charge density, except the inversion of profile on reversing the applied voltage. The space charge in crosslinked poly-ethylene (XLPE) power cable under the application of dc voltage and heat treatment is investigated by the PEA method[29] . It was noted that space charge decreases in the process of heat treatment and disappears in the insulation after heat treatment. This is because of the elimination and indistinctness of the interface between the crystalline and amorphous phases at high temperature, the density of local states, which acts as traps, will decrease[30]. Chong etal carried out studies on space charge dynamics in XLPE under DC field at temperatures ranging from 25C -90C. It was concluded that the testing temperature has effects on space charge dynamics such as enhancement of ionic dissociation of polar cross linked by-products, charge injection, charge mobility and electrical conductivity [31].

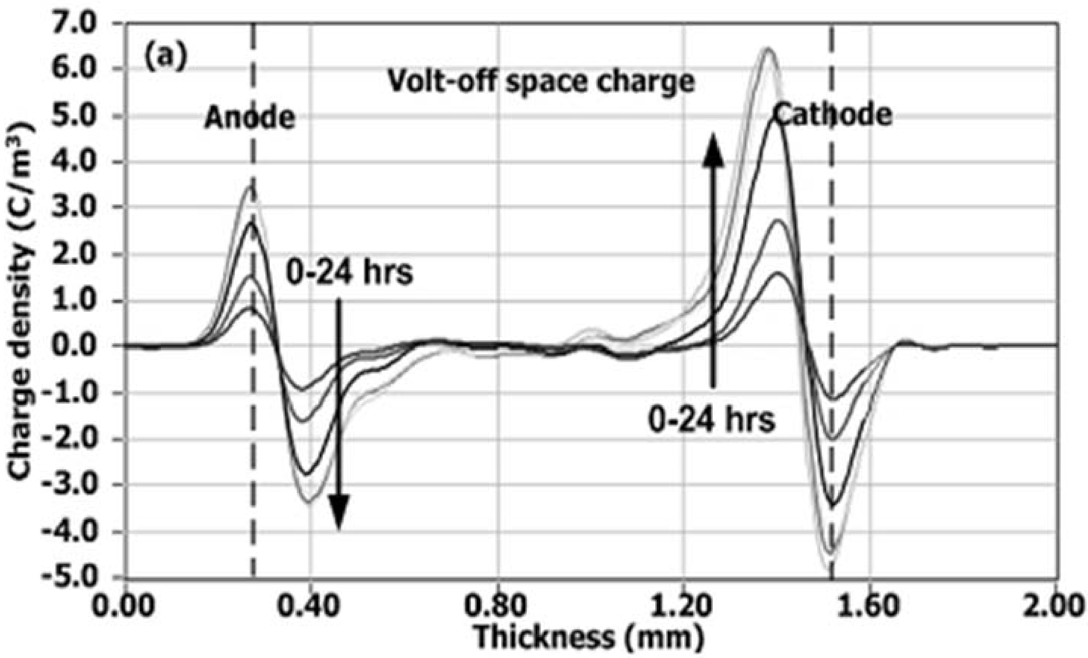

Fig 4.Decay of space charge in cable under short circuit at room temperature.[31]

Figure 4. shows volt-off space charge profile inXLPE cable insulation at various times. The volt-off profile shows the trapped charges, since this charges remains in the sample after the applied voltage has been removed.

The space charge dynamics in gamma-irradiated LDPE samples with and without antioxidant at low applied electric stresses have been studied using the PWP technique[32].The amount of charge formed for a given applied stress increased with the dose absorbed by the material and samples without antioxidant shows significant positive charge in the region close to the cathode after being electrically stressed. The change in space charge characteristics can be attributed to the changes in the trapping characteristics of the irradiated sample through oxidation at the sample.

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.

REACTIVE POWER COMPENSATION AND ITS APPLICATION IN HARMONIC RICH ENVIRONMENT

Johny P.A

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1. Introduction

Majority of loads in a power system are inductive. These loads draw reactive power from the source and the power factor will be lagging. The effect is full MW capacity of the source cannot be utilized for supplying active power to the load and the voltage of the system also is adversely affected. One of the solution for the improvement of power factor, improving voltage of the system and for the maximum utilization of the power source for the supply of active power requirement of the load is compensating the reactive power requirement of the load by implementing reactive power compensation by capacitor banks. Extreme care to be taken when the capacitors are connected to the buses having harmonics. This article is intended to give a brief overview of the subject and hence, complicated mathematical expressions and theories are purposely avoided.

Harmonics

Now a days almost all the loads connected to the power system are completely or partly non-linear. E.g. variable speed drive, electronic ballasts, computers, printers, scanners, electronic fan regulators, and other electronics equipment. The only perfect linear load available is the incandescent lamps and heaters (not controlled by electronics devices). Transformers and other equipment utilizing magnetic materials also draws nonlinear currents due to saturation of the magnetic materials. The current drawn by these nonlinear loads will not be purely sinusoidal.

The current wave shape will be distorted sine wave. If we analyse these distorted waves (Fourier Analysis) we can find it contains a number of sine wave components with different frequencies (multiples of supply frequency) i.e. 50Hz (1 x 50), 100Hz (2 x 50), 150Hz (3 x 50), 200Hz (4 x 50), 250Hz (5 x 50) etc. These current wave components are called fundamental (harmonic order-1), 2^{nd} harmonic, 3^{rd} harmonic, 4^{th} harmonics, 5^{th} harmonics etc. That means a distorted current wave is a combination of different sinusoidal current wave having different frequencies (combination of fundamental and harmonic current components). Each harmonics will have its own frequency, current, voltage, impedances etc. and behave as a separate power system and the net effect will be the super imposed effect of these component power systems.

These fundamental and harmonic components flows through the power system/network impedance. As the impedance is a function of frequency, each harmonic current will have different impedance (which is proportional to the frequency) and produce different voltage drops and i.e. voltage drop in the power system/network impedance will also follow the same wave shape of the distorted current wave. In effect the bus voltage will also be distorted and voltage harmonics will be generated. If the power system is very strong (the fault level is very high), the source impedance will be very small and hence the voltage drop also very small and hence the voltage distortion also negligible and vice versa.

Parallel Resonance between Capacitor Banks & Power System

Power system source reactance is inductive. When a shunt capacitor is connected to the power system it will resonate at some frequency. The parallel resonating frequency can be found out by a frequency scan. i.e. varying the frequency from 1 Hz to a very high (say 2.5kHz) in the impedance calculation (by simulation), or manually calculated. If there is a harmonics of that order of resonance frequency present in the system under consideration, it will get amplified and the capacitor banks may be damaged. Hence, when connecting capacitor banks to improve power factor or to compensate the reactive power requirements or for voltage support in a harmonic rich environment, extreme care is to be taken, as there will be a risk for the resonance between the capacitors and the source impedance and failure of the capacitor banks.

Capacitor Banks with Damping / Current Limiting Reactors

When capacitors are switched on to the system a very high inrush current will flow through the capacitors. It will be in the order of kilo-Amps and will be many times higher than the rated current of the capacitor banks. Even though it will be for very short time, this will also damage the capacitor banks. In order to avoid this sudden increase of inrush current normally a reactor will be connected in series to the capacitor banks. But this also may resonate to a particular frequency (harmonics) which may be present in the system causing failure of the capacitor banks.

De-tuned Capacitor Banks

It is always better to use de-tuned capacitor banks for reactive power compensation whether harmonics are present or not. De-tuned capacitor banks/De-tuned filter banks are not to mitigate/filter out the harmonics present in the system. It is to shift away the resonating / tuned point (de-tuning) to a lower frequency (harmonic order) which will not be existing (normally at harmonic order of 4.6 i.e. at 230Hz) so that there will be no risk of resonating/ amplifying the harmonics of order 5^{th} and higher present if any and safeguard the capacitor banks from failures. Normally the lowest harmonics of almost all the nonlinear loads will be the 5^{th} harmonics. That is the reason for selecting a de-tuning point of 4.6. If the de-tuned capacitor banks are to be used where 3^{rd} harmonics are expected (eg. Data Centres) then the detuning point may be 2.65 (133Hz). Even though de-tuned capacitor banks are not intended for harmonics filtration, de-tuned capacitor banks will filter out a small percentage of harmonics as it is tuned close to a harmonic order.

IEEE-519 (1992) Harmonics Limits and its Compliance.

The international standard IEEE-519 (1992) recommends the allowable limits of the harmonics. The table 10.3 attached below shows the limits of the individual and total current distortion limits. As per IEEE 519 the limit is specified based on Total Demand Distortion (TDD) instead of Total Harmonic Distortion of current (THD I). THD (I) is based on the fundamental (50 Hz) component of current at the instant of measurement. The TDD is based on the average Maximum Demands (MD) of current recorded for a period of one year (Average of 12 current MDs). That means the highest THD(I) may be recorded at a very low load and the impact of this highest THD(I) on the system will be not very much noticeable. On the other hand highest TDD is based on the average of Max. Demands and this will reflect the real impact on the system. The THD (I) and TDD will be the same when the current at the highest THD(I) and the average of the Max. Demand current are the same.

Also, as the adverse effect of Total Harmonics Distortion on the power system depends upon the source impedance of the power source, that is its fault level, IEEE-519 specifies the limits based on Short Circuit Ratio (SCR) ($Isc/_{IL}$). If the system is strong the SCR will be high i.e. source impedance will be less and hence, the voltage distortion on the supply voltage will be less and high current distortion can be allowed.

Tuned Harmonic Filters

If it is obligatory to maintain the limit of harmonics within the IEEE 519 limits or it is required to maintain a harmonics free system for any reason, we have to first evaluate whether the harmonic levels exceed that recommended in the IEEE-519. If it is found exceeded, we have to implement harmonic mitigation activities to reduce the harmonics distortion within the recommended TDD level. One of the method is using the tuned harmonic filters instead of normal capacitor banks or de-tuned capacitor banks for reactive power compensation.

Tuned harmonic filters are the shunt R L C (Resistor, Reactor & Capacitor) branches tuned to resonate (series) at a specific harmonic order which is to be filtered out. By tuning the series R L C branch, at the tuned frequency or harmonic order, the net impedance of the filter branch at the tuned frequency will be the lowest one. Hence, the harmonic current for which the filter is tuned will flow through the filter and will not flow to the supply source. The harmonic current will be there, but it will not make any bad effect to the supply system, as it is not going to the supply system.

One or more number of filter branches may be required depending on the number of harmonics (3^{rd}, 5^{th}, 7^{th} etc.) to be filtered. Double tuned filters can be used to filter two (2) numbers of harmonics e.g. 5^{th} & 7^{th} harmonics. Sometimes only one filter is sufficient to maintain the TDD level within the IEEE-519 level. If it is required to maintain close to the pure sinusoidal wave shape, a number of filter branches tuned to almost all the predominant harmonics may be required.

Active Harmonic Filters (AHF)

Harmonic filters can be either passive (RLC circuit) or active (power electronic devices) or hybrid (combination of passive and active filters). Active Harmonic Filters sense and measure the wave shape and the harmonic content, generate a current wave of shape/harmonic spectrum just opposite to the load harmonics pattern and supply the same to the system so that the current drawn from the source will be sinusoidal and no harmonics will be injected to the power system. This is achieved using power electronic components, no bulk capacitors or reactors are required. AHF can also deliver reactive power (currents) to compensate the load reactive power requirement. AHF can be used either as harmonic filters, or as reactive power compensators or combination of the two. In any case the current that can be handled will be limited to the current rating of the AHF.

Static Var Compensators (SVC)

Static Var Compensators (SVC) are another system for the reactive power compensation. SVCs can deliver Capacitive and Inductive reactive power requirements to the system.

Normal capacitor banks, de-tuned capacitor banks or tuned filter banks cannot be used for smooth variation of the reactive power requirements. It can either be switched ON or OFF or switched ON in steps only. Additionally it will take some switching time also for mechanically switched system. If the system requires very fast switching ON or OFF and a smooth compensation of the reactive power (i.e. from 0 MVAr to say 600MVAr) we have to use Static Var Compensators (SVCs). SVC System consists of Thyristor Controlled Reactors (TCRs), Thyristor Switched Capacitor (TSCs) Banks, Harmonic filters, SVC Power Transformers, AC & DC Auxiliary system, SVC Protection & SVC Controllers, SVC Station Building etc.

Thyristor Switched Capacitor (TSC) banks and Thyristor Controlled Reactors (TCR) will be switched ON simultaneously. If the MVAr magnitudes of both TSC and TCR equal then the reactive power compensated will be zero (0). Capacitor banks (TSCs) can be switched ON only, by thyristors, but Reactors (TCRs) can be used to vary its inductive reactive power from zero (0) to its full rating by the controlled switching of the thyristors. The sum of the capacitive bank (-MVAr) and the variable / controlled inductive reactive power (+MVAr) will be the reactive power delivered to the system. E.g. the sum of -100 MVAr of capacitor banks (TSC or Filters) and the +99 MVAr of TCR is -1 MVAr of capacitive reactive power delivered to the system.

As the thyristor controlled current of the TCR is highly distorted and high harmonic contents will be injected to the system in addition to the existing or background harmonics. To tackle this issue some of the capacitor banks will be used as tuned harmonic filters. The sum of the MVAr ratings of TSCs and Harmonic Filters will be the total Capacitive MVAr rating and the sum of the Inductive MVAr rating of TCRs will be the total Inductive rating of the SVC system. One typical SVC rating is 380kV, -600MVAr (Capacitive) & +200MVAr (Inductive).

STATCOM (Static Synchronous Compensator)

Synchronous condensers are synchronous machines connected to the system and when over excited it will work as a synchronous condenser and supplying reactive power to the system. STATCOM is the electronic version of the Synchronous Condenser. STATCOM is a Voltage Source Converter (VSC) system using IGBT electronic components. VSC is connected to the supply bus of voltage V1 in series with a inductor and converted to DC and the DC is again inverted to AC voltage V2. The frequency of the V1 and V2 will be the same, but the magnitude of V2 is adjustable by the STATCOM controller. If the V1 & V2 are equal no current will flow through the STATCOM and hence, no reactive power delivery to the system. If V2 is less than V1 a current will flow from the bus to the STATCOM through the inductor and the STATCOM will behave as a reactor. When V2 is higher than V1, current will flow from STATCOM to the bus through the inductor, but it will be in the opposite direction. Previously it was lagging, now it will be leading the voltage (behave like a capacitor) and reactive power will be delivered to the bus. Normally the reactive power rating of both inductive and capacitive will be same for STATCOM. Typical rating is 132kV, -150MVAr (capacitive) & +150MVAr (Inductive).

The voltage wave form of the inverted voltage V2 is almost sinusoidal, hence, a small amount of high frequency (high harmonic order) only will be present and sometimes even no harmonic filter will be required. No big capacitor banks & reactors are required and modular designs are available hence, minimum space is required and the capacity of the STATCOM can be increased by adding additional modules. If the STATCOM is proposed at locations where harmonics are existing, additional function as Active Harmonics Filters (AHF) may be required.

Dynamic Reactive Power Compensation (DRPC)

All the above methods of reactive power compensations is normally operating to compensate the reactive power requirement at steady state of the power system (system in static state). But during fault condition, especially just after clearing a fault the system will be in dynamic condition. It will take some time to become the system steady state. To maintain proper system voltage during this period, high amount of reactive power compensation is required within milliseconds especially where high inductive load will remain on the system after the fault clearing. The Dynamic Reactive Power Compensation (DRPC) system is the same design of SVC and STATCOM but its controllers are designed to operate the SVC or STATCOM only during the dynamic conditions within milliseconds, say within about 20 ms and during the steady state condition, DRPC will not deliver any or deliver very minimum reactive power to the system and the entire capacity will be reserved to utilize the reactive power required during dynamic condition.

Conclusion

Present HV, MV or LV electrical network is polluted with harmonics due to high usage of power electronic devices. Various methods are available to compensate the reactive power requirements. De-tuned capacitor banks shall be used whether harmonics is existing or not. But if the harmonic level is exceeding the limit specified by the IEEE-519 standard, suitable harmonic filters, passive or active type, shall be provided. Extreme care to be taken, when installing reactive power compensating devices / harmonic filters, as there will be chances for the resonance between the capacitors and the source impedance and failure of the capacitor banks.

Table 1- Voltage distortion limit

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
V≤ 1.0 kV	5.0	8.0
1 kv< V ≤ kV	3.0	5.0
69 kv < V ≤ 161 kV	1.5	2.5
161 kV < V	1.0	1.5*

* High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Table 10-3- Current Distortion Limits for Genaral Distribution Systems (120 V Through 69000V)

	Maximum Harmonic Current Distribution in Percent of *I*L					
	Individual Harmonic Order (Odd Harmonics)					
***I*sc / *I*L**	**< 11**	**11≤ *h* < 17**	**17 ≤ *h* < 23**	**23 ≤ *h* < 35**	**35 ≤ *h***	**TDD**
< 20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1/0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, eg., half-wave converters, are not allowed.

* All power generation equipment is limited to these values of current distortion, regardless of actual *I*sc / *I*L

where

*I*sc = maximum short-circuit current at PCC

*I*L = maximum demand load current (fundamental frequency component) at PCC.

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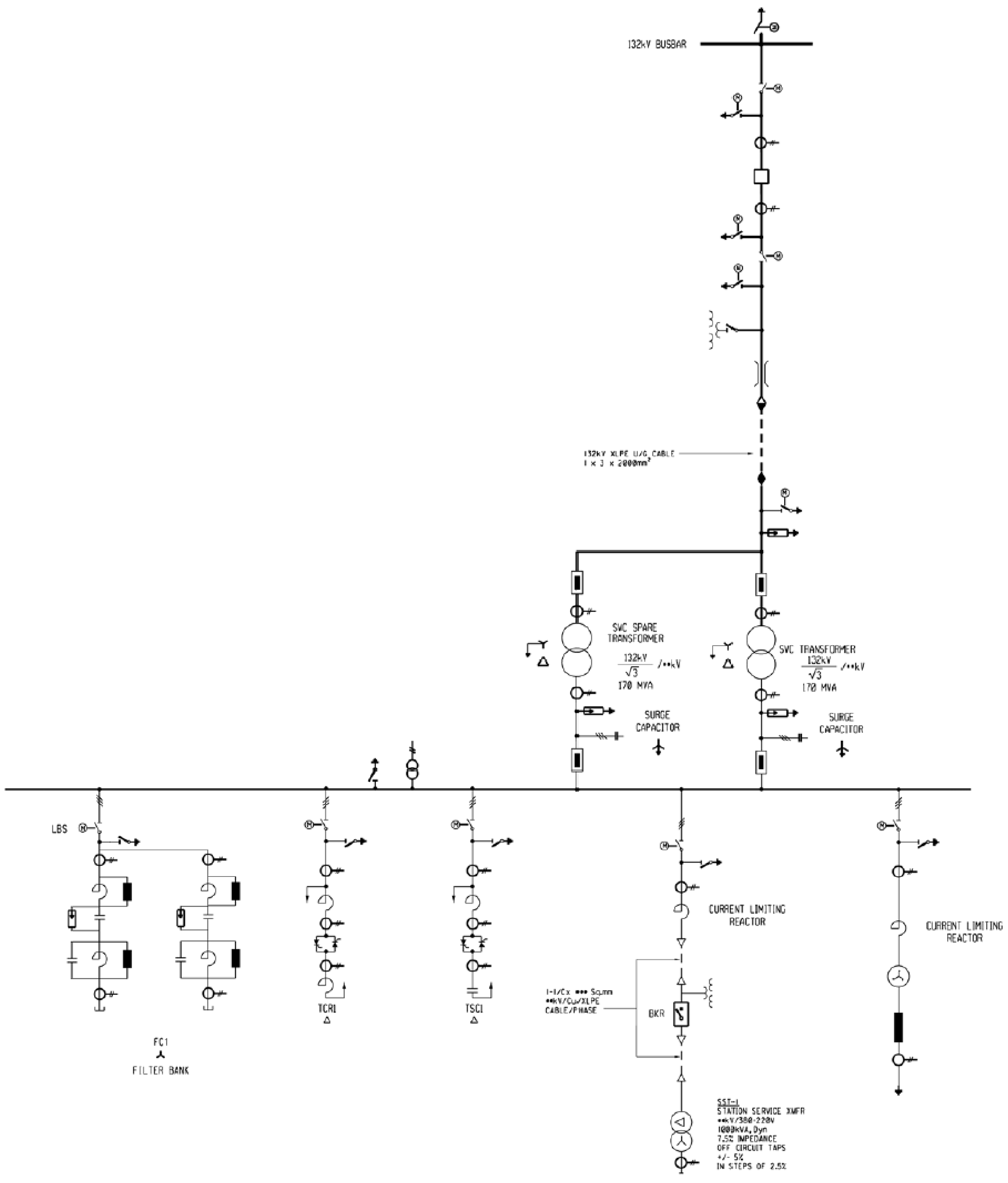
Energy Efficiency

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.



TYPICAL SVC/DRPC SYSTEM

Multiagent Based Adaptive Protection in Smart Grids

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Integration of intermittent renewable energy sources link wind, solar leads to the mal-operation of existing protective relays in the power system. In order to avoid these issues, the relays are to be changed into adaptive relays in which intelligence must be added to change the relay setting according to distributed generation penetration. The adaptive relaying can be made into reality in smart grid environment by multiagent system which is a solution strategy for mal-function of relays is suggested in this paper.

Keywords—Adaptive relays; Distributed generation; Smart grids; Multiagent system.

I. Introduction

India has the third largest energy demand in the world and its carbon emission is much higher than any other countries. The electricity generation and transmission efficiency in India is low compared to other countries [1]. The government of India is increasingly interested in adopting innovative technology including smart grids to avoid sustaining energy shortage, transmission losses etc. The smart grid can be defined as widely distributed energy delivery network characterized by a two way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances. It can also be defined as electricity delivery system from point of generation to point of consumption integrated with communication and information technology [2]. The monitoring and controlling ability of the existing electrical grids is substantially improved by the introduction of smart grid. The electrical grids become interactive by the addition of monitoring and controlling capabilities. Distributed Generation (DG) including renewable energy sources is an integral part in smart grid. The advantage of distributed generation is given in [3]. Low capital investment, local use of generated power by the load, absence of any high voltage transmission system, etc. lead to flourishing of decentralized generation. Advancement of technology with renewable energy sources, gradual reduction in cost, ease of operation and maintainability, etc., all go in favour of distributed Generation as source of green power. Many of the DG sources are intermittent in nature which causes the mal-operation of the conventional protective relays, stability and security issues etc.

II. Maloperation Of Relays

A. Overcurrent Relays

The setting of over current relay is usually done at the time of the installation only. The short circuit capacity as well as maximum, minimum load current is changing by the addition of intermittent generating sources, load etc. Hence the setting must be based on varying system conditions. The load impedance, source impedance and source voltage are tracked in real time to find out maximum and minimum fault currents. This information is used to modify the relay settings continuously. This will increase the reliability and accuracy of the over current relay [4].

B. Differential Relays

The addition of renewable sources causes the variation in differential current, restraining current and through fault current which causes the unnecessary operation of differential relay. The differential and restraining current is to be updated by the addition of the DG sources and the slope of the biased differential relay can be suitably changed.

C. *Distance Relays*

The voltage at the relay location is a function of the Z_S/Z_L (source impedance (Z_S) to load impedance (Z_L)) ratio. The higher this ratio, the smaller is the voltage fed to the pressure coil, results in the mal-operation of distance relay. The Z_S/Z_L ratio is calculated in real time and compensation voltage is applied to the pressure coil in order to avoid the mal-operation of the differential relay [5].

III. Adaptive Protection

The concepts of adaptive relays evolved in 1980s, which can self adjust the relay settings according to any changes in the operating conditions. Adaptive Relaying means protective settings should be automatically adjusted to make the relays more attuned to prevailing system conditions [6].There are different types of adaptive protection like adaptive over current protection, adaptive transformer differential protection and adaptive distance protection. Recently increasingly more distributed generators (DGs), being connected to the grid, the implementation of DG can create difficulties for the existing power system protection schemes and cause protection devices to mal-operate. Adaptive relaying can be a solution to these problems [3].

IV. Agent Based Substation Automation

Currently power system operation, control, automation and monitoring is based on Supervisory Control and Data Acquisition (SCADA) system. A central master station located at main control centre gathers information from a number of Remote Terminal Units (RTU), which are usually located at substation. Besides the acceptable performance and reliability of the SCADA system, it has certain disadvantages, particularly in the area of flexibility and open access to the information of the entire system. Recently several manufacturers have introduced Intelligent Electronic Devices (IED) that perform various functions in power system such as protection, control and monitoring. Recent technologies like Ethernet Local Area Networks (LAN) in substations are used to connect various IEDs and control systems and allow access to data from other systems including databases and Enterprise Resource planning (ERP) systems, and from outside locations

The developments in information and communication technology and wide area computer networks made it possible to include the information of large area into the power system protection. The adaptive protection in wide area system requires faster data transfer between relays, information processing and speedy computation of relay settings. Normal communication protocol cannot be used in multiagent based adaptive protection because the data are transmitted in text format and unreliable communication transfer by web. The protocol used for electrical substation automation is IEC 61850.The protocol can run in TCP/IP networks or substation LAN with high speed switched Ethernet with operating time below four millisecond for protective relaying. Number of information models based on object oriented programming and communication services are already defined in IEC 61850, which results in the interoperation of (IEDs) from different manufacturer.

The wide area protection system can be made intelligent by Multi Agent System (MAS). The substation IEDs can be an agent and there is sharing of data between different agents. The MAS techniques and real time wide area communication is complex and multiagent, wide area network (WAN) based adaptive protection systems are in research stage.

V. Mult-Agent System

Distributed artificial intelligence (DAI) methods come under artificial intelligence group which has the ability to solve complex real system problems. The research in the field of DAI comes under three different areas

- Parallel AI
- Distributed Problem Solving (DPS)
- Multiagent Systems

Parallel AI includes classical AI techniques like neural, fuzzy, neuro-fuzzy etc. The main advantages of this method are increase in speed of operation and the ability to work on parallel threads to achieve at a global solution for a particular problem. In DPS method the problem is solved by sharing the knowledge and the resources. The flexibility of distributed solving method is less due to its inbuilt design strategies. In multiagent system each computing entity is referred to an agent. MAS can be defined as a network of individual agents that share knowledge and communicate with each other in order to solve a problem that is beyond the scope of a single agent. The flexibility of MAS is much greater than any other artificial intelligence method [7].

The multiagent system helps to solve the problems in the power system network in online manner. The intelligent agents in the network interact with each other to achieve the common goal by sharing their knowledge and information. MAS has reasoning ability and responding ability to the events in the environment.

A. Agents

An agent is a computer system which is situated in the environment and is capable of making decisions in the environment in order to meet its design objective [8]. The interaction between agent and the environment is Fig.1.

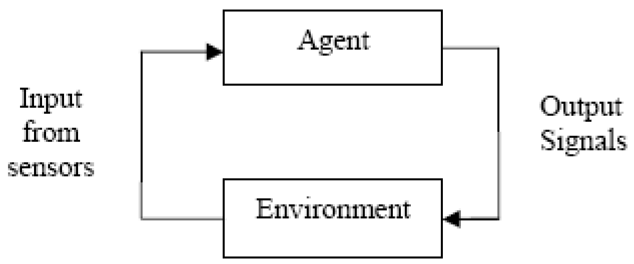

Fig.1. Agents Interact with Environment

It can also be defined as the software packages associated with equipments which is situated in some environment and can sense and react to the changes in the environment. Agent technology is one of the most interesting and the recent developments in the area of distributed artificial intelligence. It has a wide range of applications, with information management, intelligent user interfaces, personal assistants, internet commerce etc. An agent-based system has a lot of advantages compared with SCADA based monitoring and automation. Each function or task of the entire system, such as the management of a single IED or multiple IEDs, can be included as a separate agent, making the system simple and modular. Agents are loosely coupled and communicate through messages. The directory services helps to add new functions to an agent-based system for creating a new agent, which will then make it available to others in the environment.

A. Properties of Agent System [7]

The major properties of the agent are

- Adaptation

The ability of the agent to interact with the environment through sensors and actuators.

- Autonomy

Autonomy is defined as the ability of an agent to choose its action independently without external intervention by other agents in the network.

- Influential Capability

The ability of the agent to work cooperatively with other agents to achieve a common goal.

- Proactiveness

The ability of the agent to adapt to the changing environment is termed as proactiveness.

- Responsiveness

The ability of the agent to perceive the conditions of the environment and responds to it within a specific time interval with the changes in the environment.

- Social Behaviour

The ability of the agent to interact with the external sources to achieve a specific goal.

- Reactivity

The ability of the agent to react with any changes in the environment.

B. Hierarchy of Multiagent System [9]

In order to realize the function of different levels and make the structure of MAS clear, the whole MAS can be divided into three layers the bottom layer, the middle layer and the upper layer, as shown in Fig.2.

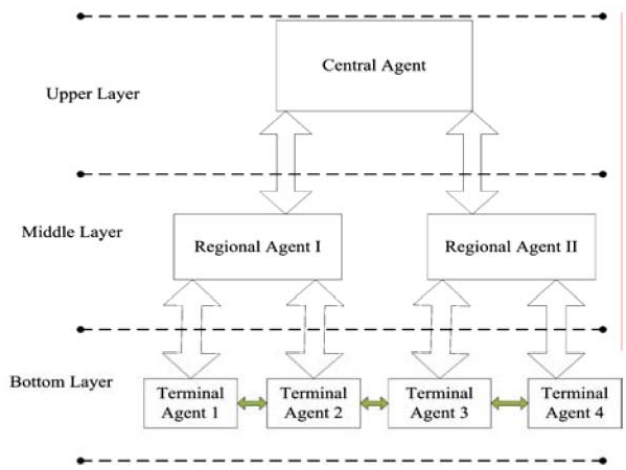

Fig.2. Hierarchy Chart of Agents

All the terminal agents that directly interact with the distribution system (including different DGs), make up the bottom layer. Regional agents that connect bottom layer and the upper layer make up the middle layer. The central agent gathers information of the entire system, and it forms the upper layer. Three layers play different roles. Agents are designed according to the functional requirements.

A. Advantages of Multiagent System [10]

MAS is an extension of the agent technology in which agents work together to achieve a common goal in decentralized manner. MAS can make intelligent decisions without human intervention. The major advantages of MAS technology are

- Increase in the speed and efficiency
- Improved reliability and robustness of the system
- Better scalability and flexibility
- Reduced cost
- Reusability
- Provides two way communication

B. Multiagent System Architecture

In team MAS architecture the agents in a team, work together to increase the overall performance of the group. rather than each working as individual agents (Fig.3). The interactions of the agents within a team can be quite arbitrary and the goals or the roles assigned to each of the agents can vary with time based on improvements resulting from the team performance [7].

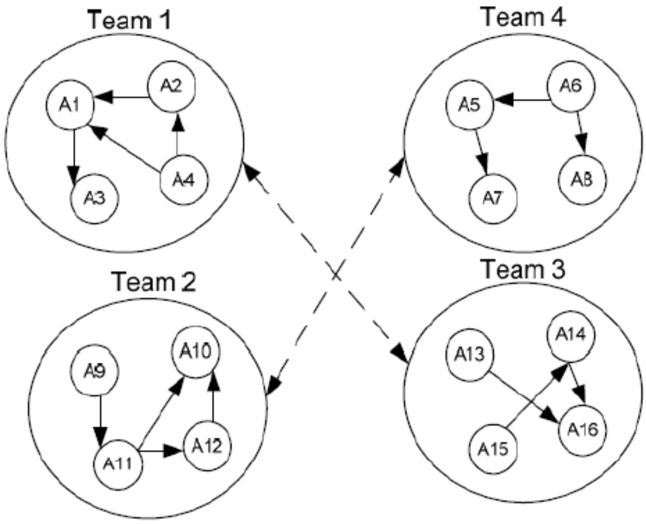

Fig.3. Team based Multiagent Architecture

A. Application of Multiagent System

Multi Agent System are used in wide range of engineering application specifically in power engineering, to construct reliable systems [11].

- Condition monitoring
- Power system restoration
- Market simulations
- System control and automation
- Protection
- Distributed energy resources scheduling
- Contingency analysis
- Control and management of energy in hybrid energy systems

Power system architecture is usually distributed and suited ideally to a multiagent system, which provides greater flexibility and reliability compared to a traditional system. Two types of agents have been used for the implementation of power system architecture.

- Simple Java-based agents – These agents are used to perform small tasks which do not require any intelligence or, it acts as an agent that wraps an existing system, where the intelligent functionality is included in the wrapped system. These agents are also used as the mobile agent due to its small size.
- Belief-Desire-Intention (BDI) agents- They are based on the concept of three mental states (beliefs, desires, and intentions) and will respond to any external situations and will performs actions to achieve a common goal. The flexibility makes them suitable for performing a wide range of system tasks, such as real-time control and online monitoring, alarm/event management etc.

VI. Multiagent System In Power System Protection

The adaptive protection is achieved by the cooperation between equipment agents, mobile agents, protector agents and reorganizer agents (Fig.4) [12].

A. Equipment Agents

- Line Agent – Calculate current value perodically.
- Bus Agent – Observe bus voltage and current.
- Current Transformer (CT) Agent- Measures CT current.
- Circuit Breaker (CB) Agent - observe circuit breaker condition (opened/closed).

B. Protector Agents

- Detector Agent - detect fault by calculation of current value, voltage value etc.
- Isolator Agent - trip CBs and isolate the fault section if a detector agent senses a fault.
- Isolator Reorganizer Agent - isolates the minimum zone after detector agent giving the signal.

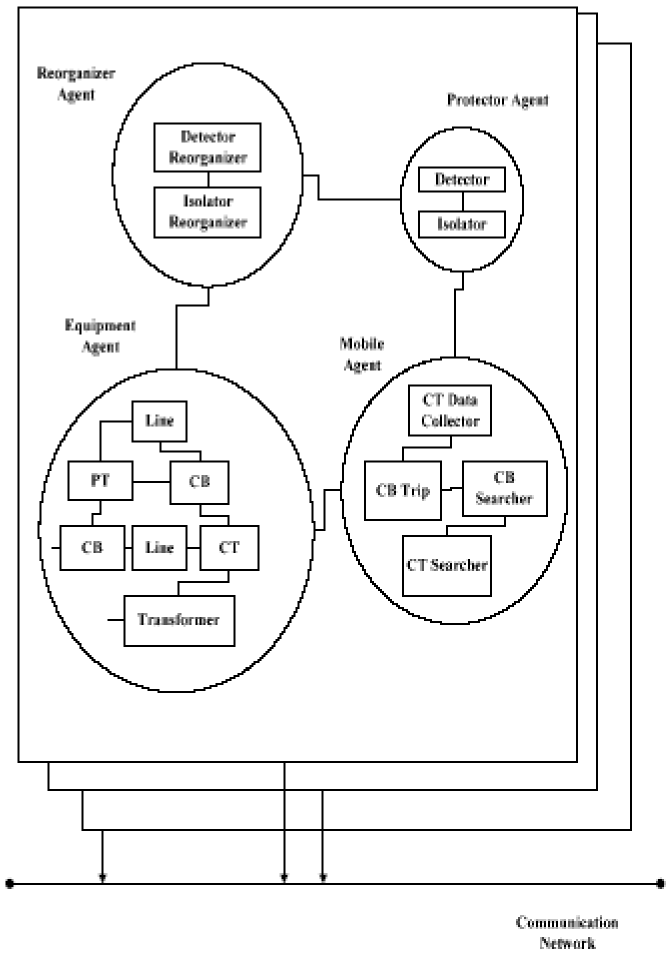

Fig.4. Different Agents in Multiagent based Power System Protection

A. Mobile Agents

- CT data collector agent - Transfer current data periodically from the CT agent to the detector agent
- PT Data Collector Agent - Transfer voltage data periodically from the PT agent to the line agent.
- Current Data Collector Agent - Transfer charging current data from the line agent to the detector agent
- CB Trip Agent - Transfer trip signal to the CB agent
 - Transfer trip order to the next CB agent in the given direction if a CB fails to operate.
- CT Searcher Agent - Search all the CT agents in the given direction and at a specific distance.

VII. Structure of Multiagent Based Adaptive Relaying Scheme

The structure of the Multiagent system is given in the Fig.5.

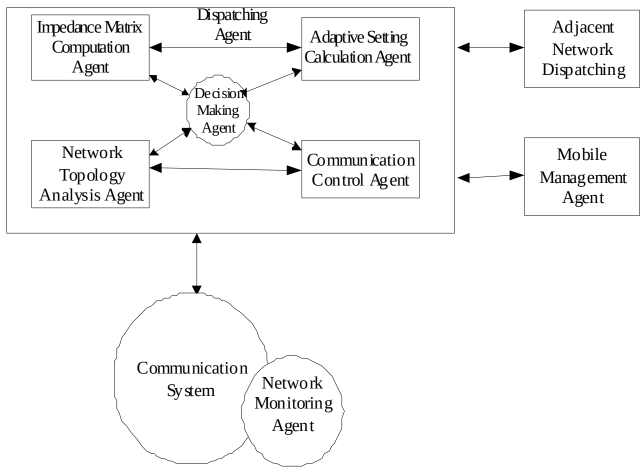

Fig.5. Mutiagent Structure for Adaptive Protection

- Communication Control Agent – Controls and handle communication messages according to their priorities.
- Network Topology Analysis Agent -Use graph theory and AI searching techniques to analyze and update the network topology when a contingency occurs in the system.
- Impedance Matrix Computation Agent – Calculates modified network impedance matrix by parallel computing method according to updated network topology in the presence of DGs, and send its equivalent matrix to the impedance matrix computation agents of adjacent networks in the system.
- Adaptive Setting Calculation Agent - Calculate adaptive settings of the relays by parallel computing methods according to the updated network impedance matrix.
- Relay Agent- Send real time data of IED and compare sensing data with the existing relay's setting, and decide whether the relay must be tripped or not.
- Mobile Management Agent - Manage and control the mobile agents in the system, and maintain their communication with other elements in the system.

- Network Monitoring Agent-Monitor the status of the communication network and evaluate its state in a continuous manner [13].

VIII. Implementation of Multagent System – Jade Software

JADE (Java Agent DEvelopment) is an open source Java based software used for the development of distributed multiagent applications which has been developed by TILAB (TelecomItalia LABoratories). JADE is a middleware software platform that provides a layer of separation between the software and the underlying operating system. In JADE platform, the underlying operating system is the java virtual machine. JADE provides a set of functions and classes to implement different agents in power system successfully. These functions simplify the process of sending and creating messages, as well as providing interfaces for standard behaviours, making the coding simpler for the developer and user, with maintaining the standards of Foundation for Intelligent Physical Agents (FIPA) [8,14].

IX. Conclusion

The protective relays in the substation mal-operates by the addition of intermittent renewable energy sources. The conventional relays are to be changed into adaptive relays, in which decision making capability is incorporated into the relays. Due to the economical and environmental concern, the grid is to be changed into smarter in which renewable energy sources is an integral part. In smart grid environment, the adaptive relaying technology can be by multiagent system in which software knowledge is associated with each element in the substation, generating station, transmission line etc.

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New method for Source Separation of Ground Borne Vibration Signals

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***Abstract*—the source separation of ground borne vibration signals is an exigent problem. The separation of a set of signals from a set of observed signal mixtures, without the information about the source signals or the mixing process is known as Blind Source Separation (BSS). BSS depends on the assumption that the source signals do not correlate with each other. A new BSS method WASOBI-DECONV is proposed for the separation of the convoluted ground borne signals. The performance of the proposed method is evaluated with real world data. The performance of WASOBI and the proposed WASOBI-DECONV is compared. The experiments shows that the proposed algorithm outperforms the WASOBI algorithm for the targeted signals**

Keywords- Ground Borne Vibration, Blind Source Separation, WASOBI, WASOBI-DECONV

Introduction

Vibrations are phenomenon which exists in many forms ranging from atomic level to tremors. This paper considers the problem of source separation of ground borne low level vibration signal. The framework can be used to separate multiple vibration propagates through the ground. The observed signals are mixed form of the vibration signals from the different sources. This can be considered as a 'blind case' as the sources and mixing sources are unknown [1]. Blind Source Separation (BSS) is a modern technique which recovers both the unknown sources and unknown mixing matrix systems from only measured mixtures of signals. [2]

Problem Formulation

The prediction of vibration propagation through soil is an intricate task, made difficult by the non-homogeneity of the vibration propagation medium (i.e. soil and/or rock). Ground vibration propagates through the soil or rock as waves, so that the amplitude generally decreases with distance from the source.[3,4] Convolute mixing arises due to time delays resulting from vibration propagation over the ground and the multipath generated by reflections from various layers of the earth. These factors make the source separation of ground borne vibration a complex task. The source separation problem of speech signals is well studied and a blistering topic of research during the last decade. But only few work appeared on the source separation of ground vibrations.

Ground borne Vibration as Convolution Model

The excitation of the ground surface generates body primary waves, P, and shear waves, S, additionally to Rayleigh surface waves, R. These waves propagate through different means and exhibit different behaviors. The Rayleigh waves are elliptically retrograde waves which propagate in normal direction to excitation source, not only in surface but also into the semi-space, with a high rate of attenuation in this last direction [5]. Rayleigh surface waves have lower geometric attenuation ratio than body waves and, therefore, they transport vibration energy to higher distances from the excitation source. In the ground, the P-wave speed is the highest, typically 400 to 800 m/s. The S-wave travel typically at 200 to 300 m/s. Of the total input energy, 67% radiates as R-waves, 26% as S-waves, and 7% P-waves [6].Due to the higher contribution to the energy transportation, as seen before, and the lower decaying rate, Rayleigh surface waves are that considered in the development of the superficial ground borne vibration propagation model due to the level of vibration considered is low and the measurement distance is only a few meters [3].

The "convolution model" proposed by Enders Robinson etal assumes that the recorded seismic signals $s(t)$ is the convolution of an earth-reflectivity function $e(t)$ and a seismic wavelet $w(t)$ from a point source, where t represents recording time. The convolution model approximates the earth by a linear system.[7]

According to this model, the seismic trace is given by:

$$s(t)=w(t) * e(t) + v(t) \quad (1)$$

where $v(t)$ is an additive noise. The de convolution is used to compute the earth's reflectivity given the seismic trace $s(t)$.

The convolution model of the seismic trace is widely accepted because it agrees well with the observed seismic traces. Though we are principally focus in R-waves, the effect of P-waves with multipath reflections cannot be ignored in some cases.

Apart from the single source convolution model, we consider multiple source-multiple sensor frameworks. So the observation at each sensor contains the convoluted and mixed signals from different sources. At the discrete time index t, a mixture of N source signals $s(t) = (s_1(t), \dots s_N(t))$ are received at an array of M sensors. The received signals are denoted $x(t)= (x_1(t), \dots x_M(t).)$, The basic model of convolutive mixtures can be given as follows.

$$x_m(t) = \sum_{n=1}^{N}\sum_{k=0}^{K-1} a_{mnk}\ s_n(t-k) + v_m(t) \quad (2)$$

where $Vm(t)$ is additive noise. The captured signal is a linear mixture of filtered versions of each of the source signals and a_{mnk} corresponding mixing filter coefficients and in practical case k > ∞

$$x(t) = \sum_{k=0}^{K-1} A_k\ s\ (t-k) + v\ (t) \quad (3)$$

A_k is an $M\ X\ N$ matrix which contains k^{th} filter coefficient and v(t) is the $M\ X\ 1$ noise vector. The de-convoluted and de-noised model, theoretically can be considered as the instantaneous model which is given as;

$$x(t) = A\ s(t) \quad (4)$$

The coefficients a_{ij} of matrix A are assumed different enough to make the matrix that they form invertible. Thus, there exists a matrix W with coefficients w_{ij} such that we can separate $s(t)$ as

$$y(t) = w \,.\, x(t) \quad (5)$$

where $y(t)$ is as close to $s(t)$ as possible. [8][9]

The separation of a set of signals from a set of observed signal mixtures, without the information about the source signals or the mixing process is known as Blind Source Separation (BSS). BSS depends on the assumption that the source signals do not correlate with each other i.e. the signals are statistically independent or de-correlated. [10] [11]

It is not easy to measure the distance of the buried vibration sources and the mixing system is unknown due to the non-homogeneity of earth crust. So we use the method of BSS. In the case of BSS no information is needed on the source positions or the mixing systems. The mixing and demixing matrix for only one channel is labeled for easy understanding. Co efficient of other channels can be written in similar way.

WEIGHTS-ADJUSTED SECOND-ORDER BLIND IDENTIFICATION (WASOBI)

Blind separation of sources with different spectra can be attained using second-order statistics. The second-order blind identification (SOBI) algorithm, proposed by Belouchrani etal [12], uses approximate joint diagonalization. The substantial improvement over SOBI can be attained when the joint diagonalization is transformed into a properly weighted nonlinear least squares problem. The optimal weight for weights-adjusted SOBI (WASOBI) algorithm is generated iteratively. Detailed discussion of the algorithm is available in [13]

DECONVOLUTION BASED ON POWER SPECTRAL SUBTRACTION

The observed vibration

$$x[t] = h[t] * s[t] + v[t] \quad (6)$$

where $h[t]$ is convolutional noise, $v[t]$ is additive noise on source signal $s[t]$

The additive noise is suppressed in the pre processing step as shown in the framework and the equation becomes

$$x[t] = h[t] * s[t] \qquad (7)$$

If the length of the impulse response is much greater than the analysis window size, the short time Fourier transform, STFT of the convoluted vibration can be written as

$$X(f,w) \approx S(f,w) * H(w)$$
$$= S(f,w)H(0,w) + \sum_{d=1}^{D-1} S(f-d,w)H(d,w) \qquad (8)$$

where f is the frame index, $H(w)$ is the STFT of the impulse response, $S(f,w)$ is the STFT of uncontaminated signal s, and $H(d,w)$ denotes the part of $H(w)$ corresponding to the frame delay d. That is, with a long impulse response, the channel distortion is no longer of a multiplicative nature in a linear spectral domain, but is rather convolutional [14]

The estimation of STFT of uncontaminated signal is discussed in[15] The Blind estimation of spectrum of impulse is detailed in[16]. The early reverberation is compensated by subtracting the cepstral mean of the signal.

Assuming that phases of different frames are non-correlated for simplification, the power spectrum of (8) can be approximated as [15]

$$\left|\tilde{X}(f,w)\right|^2 = \frac{|X(f,w)|^2}{|\bar{X}(f,w)|^2} \approx \left|\tilde{S}(f,w)\right|^2 + \frac{\sum_{d=1}^{D-1}\{|\tilde{S}(f-d,w)|^2|H(d,w)|^2\}}{|H(0,w)|^2} \qquad (9)$$

where $\left|\tilde{S}(f,w)\right|^2 = \frac{|S(f,w)|^2}{|\bar{S}(f,w)|^2}$, $\left|\tilde{X}(f,w)\right|^2$ is the power spectrum of convoluted of vibration after early reverberation suppression. and $\bar{S}(f,w)$ is the mean vector of $S(f,w)$ The power spectrum of unpolluted signals $\left|\hat{S}(f,w)\right|^2$ can be estimated as

$$\left|\hat{S}(f,w)\right|^2 \approx max\left\{\left|\tilde{X}(f,w)\right|^2 - \alpha \cdot \frac{\sum_{d=1}^{D-1}\{\left|\hat{S}(f-d,w)\right|^2|H(d,w)|^2\}}{|H(0,w)|^2}, \beta \cdot \left|\tilde{X}(f,w)\right|^2\right\} \qquad (10)$$

where a is the noise over estimation factor β, is the spectral floor parameter to avoid negative or under flow values, and $H(d,w)$, $d=o,...D-1$ is the STFT of the impulse response which is blindly estimated. D is the number of reverberation windows [16]

Proposed Method

In proposed framework the signal is preprocessed to obtain a noiseless, at least, theoretically, signal. The signal is subjected to de reverberation (de convolution) to an optimal level using power spectrum subtraction, a computationally efficient method [16] without affecting the direct signals. The signals are then source separated using WASOBI algorithm, which uses a second order statistics. [12] A general outline of the proposed method is given in the figure 1

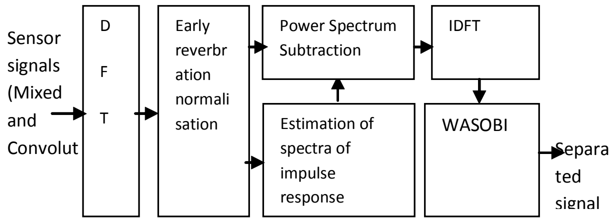


Figure 1: Multichannel Separation model using WASOBI-DECONV

The Experiment

The signal sources used for our study are four shakers which can produce low level stable vibrations. These sources can be modeled as point sources. The sensors are high sensitive accelerometers. The signals are amplified using a low noise amplifier and converted to digital signals using a 16 bit ADC. We used 20000 samples for the experiments in each case

The acquisition of the low level ground vibration is challenging as the outdoor field measurements are susceptible to weather condition and various noises hence rugged instruments are needed. The vibration signals from the sources-four shakers v1, v2, v3 and v4 are recorded in the ground at various distances. Both sensors and sources are buried in ground at a depth of 5 cm each. The airborne noise is considered negligible. The other types of noise include sensor noise and source noise. The amplitude damping and frequency attenuation are neglected as the distance is small. The captured signals are separated using the algorithms and performance is studied.[17] The experiment is detailed in our paper [18]

Performance Measures

Two widely used performance messures for evaluating the performance of separation namely Signal to Interference Ratio and performance Index of separability are used for the comparison

A. Signal to Interference Ratio

The ratio of the useful signal power to the interference power that determines the performance of the separating system. The SIR is defined as for each pair of signals (y_i, s_j) [20]

$$SIR\_S_{ij} = -10\log 10\left(\frac{\|y_i - s_j\|_2^2}{\|s_j\|_2^2}\right) \quad (11)$$

A. Performance index

The Performance Index (*PI*), defined by [21][20]:

$$PI = \frac{1}{n(n-1)}\sum_{i=1}^{n}\left\{\left(\sum_{k=1}^{n}\frac{|w_{ik}|}{max_j|w_{ij}|}-1\right)+\left(\sum_{k=1}^{n}\frac{|w_{ki}|}{max_j|w_{ji}|}-1\right)\right\} \quad (12)$$

Where *wij* is the $(i,j)^{th}$ element of the global system matrix *W*. The term max*j* |*wij*| is the maximum value along the i^{th} row of *W* and max*j* |*wji*| is the maximum value of the i^{th} column of *W*. When perfect separation is achieved *PI* is zero. In practice this is too optimistic.

The Result and Discussion

The performances of the both algorithm is compared in the following table. It shows that performance index of separability is improved atmost by 23 % and signal to interference ratio by 15.4 % asymptotically. A good separation is achieved in most cases. The tables 1 shows the Performance index of separability for various source –sensor distance for the two algorithms, table 2 shows variations of SIR and table 3 shows the SIR of most separated component. The plots show the performances of the two algorithms. It shows that the WASOBI-DECONV do better than that of the WASOBI algorithm for various source-sensor distances. The value of index of separability increases with source-sensor distance. The increase in value shows that the contamination of the signal increases with distance. This increase is nonlinear because of the heterogeneity of the propagation medium. A potential application of the method is to track lives buried in ground by capture and examine the noise as slight as shallow breathing, heartbeat, small voice made by the victim, sounds of the movements of limbs etc., which can results in ground borne vibrations (21)

Table: 1 Performance Index of separability

Source -Sensor Distance (in CM)	WASOBI	WASOBI-DECONV
20	0.17841	0.13429
40	0.16981	0.13738
60	0.208261	0.11957
80	0.180506	0.16982
100	0.186579	0.17786
120	0.182044	0.166571
140	0.303816	0.22686
160	0.260711	0.22686
180	0.25346	0.1616
200	0.315632	0.29028

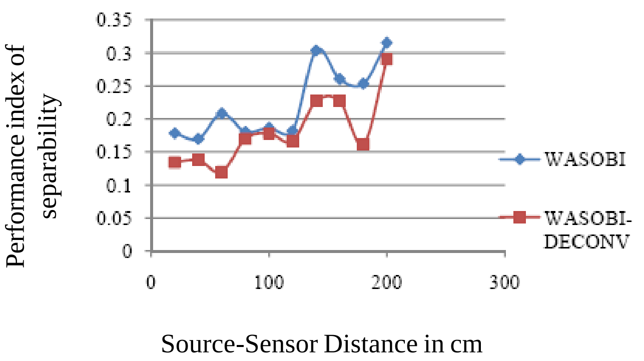


Figure 2: Plot of Performance index of separability

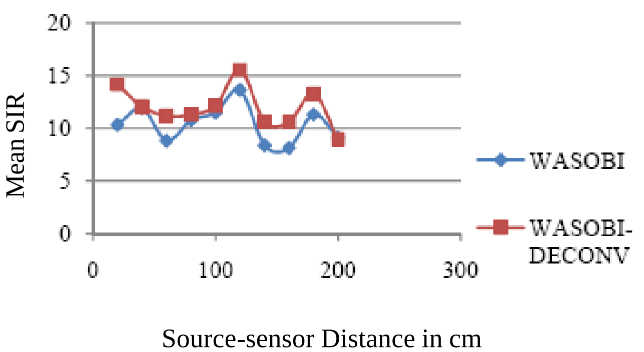
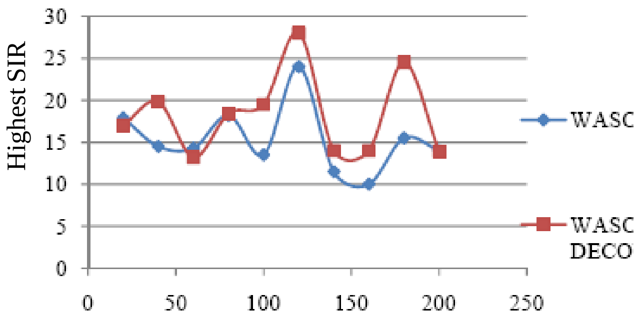


Figure 3 : Plot of mean SIR



Source -Sensor Distance (in cm)

Figure 4: Plot of Highest SIR

Table 2: Mean SIR

Source-Sensor Distance (in CM)	WASOBI	WASOBI-DECONV
20	10.3376	14.1779
40	11.8972	12.0697
60	8.8282	11.1998
80	10.7611	11.32
100	11.4974	12.1396
120	13.6467	15.55
140	8.3793	10.6195
160	8.1323	10.6195
180	11.3072	13.2862
200	9.11	8.9519

Table 3: Highest SIR

Source-Sensor Distance (in CM)	WASOBI	WASOBI-DECONV
20	17.9	17
40	14.5	19.8
60	14.3	13.2
80	18.2	18.4
100	13.5	19.5
120	24	28
140	11.5	14
160	10	14
180	15.5	24.5
200	14	13.9

Conclusion

In this paper a new method WASOBI-DECONV for the blind source separation of ground borne low level vibration signal is discussed. The performances of new method show that it outperforms the WASOBI in the considered cases. An adaptive multistage de-convolution may further improve the performance of the algorithm

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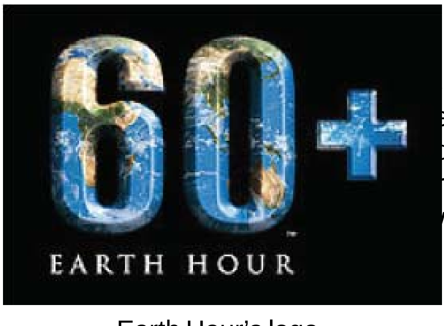
Earth Hour

Earth Hour

Earth Hour is a worldwide movement for the planet organized by the World Wide Fund for
worldwide annually encouraging individuals, communities,
off their non-essential lights for one hour, from 8:30 to 9:30
h, as a symbol for their commitment to the planet. It was
nt in Sydney, Australia in 2007. Since then it has grown to
d towns worldwide. Today, Earth Hour engages a massive
range of environmental issues. The one-hour event continues
larger movement.



Earth Hour's logo

FLOCCULATION: A COST AND ENERGY EFFICIENT ALTERNATIVE FOR BIOMASS HARVESTING METHOD FROM MICROALGAE - *Chlorella vulgaris*

Comparison study on chemical and natural coagulants

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Abstract - One of the major objectives of modern technology and environmental studies is to find cost and energy efficient methods for biomass and bioenergy production in order to reduce adverse implication on ecosystem. Renewable, carbon neutral, cost and energy efficient sources are necessary for environmental and economic sustainability. Microalgae are a promising new source of biomass that may complement agricultural crops. Harvesting micro algae using metal salts or moringa oliferais marginally less expensive than centrifugation, which is currently the most commonly used method for harvesting microalgae.

One of the major challenge in obtaining biomass from microalgae lies in harvesting, which requires the separation of a low amount of biomass consisting of small individual cells from a larger volume of culture medium. Flocculation is identified as a promising low cost and minimum energy consuming harvesting method.

The flocculation performance efficiency study of different flocculent salts were done while harvesting microalgae species chlorella vulgaris. Flocculation experiment using Zinc chloride and Zinc sulphate salts at different concentrations were carried out under different pH conditions. Comparison study was done between these two chemical coagulants and natural coagulant moringa olifera and conventional alum used in water treatment for settling of microalgae. The result showed that maximum efficiency was exhibited by Zinc chloride under acidic conditions. Effect of Zinc sulphate was not negligible but remained less at lower concentrations and non-uniform settling was found at higher concentrations. Moringa olifera also exhibited good efficiency close to Zinc chloride while alum showed comparatively less efficiency. Hence the present work revealed that Zinc chloride gave the maximum efficiency and can be substituted by moringa olifera to avoid contamination while harvesting of micro algal cells of ***chlorella vulgaris.***

Keywords: chlorella vulgaris, flocculation, centrifugation, moringa olifera.

1. INTRODUCTION

Oil-accumulating microalgae are a promising feedstock for biodiesel production[1], [2]Commercial microalgal biodiesel production is not economically feasible yet, mainly due to the high-energy inputs required for water pumping, mixing and for harvesting the microalgal biomass combined with large investment costs [3]. Harvesting in commercial microalgae production plants is generally done by centrifugation.

To minimize the energy consumption of harvesting microalgae, an integrated approach is needed [4]. Flocculation can be induced in different ways.

Coagulation flocculation processes could provide mass microalgae biomass recoveries at a very reasonable costs [5]. In this process, the selection of coagulant is crucial that the downstream processing of the biomass is not adversely affected by the coagulant contamination which then lead to the additional cost for biomass purification. It was reported that the major component of Alum and Acrylamide could lead to human health implications, such as involvement in Alzheimer's disease and the cause of cancers [5]. The use of natural coagulant would be an alternative in overcoming this possibility. Hence, the use of natural coagulants is expensive and utilize potential food supply. In this study, the investigation was performed to explore the potential of cheaper natural coagulant which is Moringa oleifera (MO).MO is known as a tropical plant which belongs to the family Moringaceae, a single family of shrubs. MO was reported to contain an active bio-coagulating compound. Several studies have been done on the performance of MO seeds as an alternative coagulant and assisting coagulant to the conventional chemical coagulant in water treatment [6]. In addition, [7]had correlated the flocculation effect observed with a peptide obtained in saline extract whereas [8], [9]purified and characterized a new lectin extracted in 0.15 M NaCl solution from MO seeds which was claimed to have flocculating activity. In this study, a laboratory investigation was carried out to determine the effects of chemical and natural coagulants at different dosage and pH on flocculation of suspended freshwater microalgae, Chlorella sp. with MO seed powder derivatives.

2. METHODS AND MATERIALS

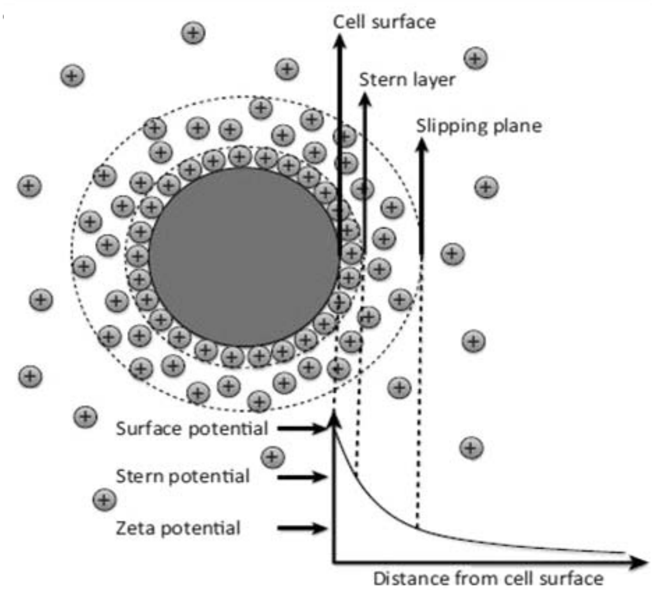
A. *Organism and culture medium*

Chlorella vulgaris species, obtained from National Environmental Engineering and Research Institute (NEERI), Nagpur, Maharashtra (India), was grown in sterile Tris Acetate Phosphate (TAP) medium. The filtered sterilized distilled water was enriched with required quantity of TAP medium containing (g L-1): Tris-HCl (2.42 g L-1), TAP salts [NH4Cl (0.375 g L-1), MgSO4. 7H2O (0.1 g L-1), CaCl2. 2H2O (0.05 g L-1)], phosphate buffer [K2HPO4.3H2O (0.0108 g L-1), KH2PO4.7H2O (0.0054 g L-1)], micronutrients [EDTA disodium salt (0.05 g L-1), ZnSO4.7H2O (0.022 g L-1), H3BO3 (0.0114 g L-1), MnCl2.4H2O (0.005 g L-1), CoCl2.6H2O (0.0016 g L-1), CuSO4.5H2O (0.00157 g L-1), (NH4)6Mo7O24. 4 H2O (0.0011 g L-1), FeSO4. 7 H2O (0.05 g L-1)] and Glacial acetic acid (1 ml L-1). The medium was adjusted to pH 8 and autoclaved at 1210 C for 20 min. The filter sterilized vitamins were added after cooling. The contents were later introduced into a 250-ml Erlenmeyer flask. Mixing was provided by continuous shaking of the flask with culture. Lighting was supplied by four cool-white fluorescent tubes with an intensity of 5000 lux.

B. *Flocculation chemistry*

Particles suspended in water usually carry a positive or negative surface charge. To maintain electrical neutrality, such charged particles will attract ions with an opposite charge from the solution(counter ions). The system of the particle surface charge and associated counter ions in the surrounding solution is called the electrical double layer Fig. 1.

Fig. 1. Structure of the electrical double layer of



The cloud of counter ions surrounding charged particles in a suspension results in an electrical repulsion between the particles. The z potential is the potential difference between the bulk fluid and the layer of counter ions that remains associated with the charged particle when the particle is moving through the solution (the slipping plane).The z potential can relatively easily be estimated from the mobility of the charged particles in an electric field, therefore, it is a useful indicator of the degree of repulsion between charged particles in a suspension. When the z potential is high (>25mV, positive or negative), electrical repulsion between particles is strong and the suspension is said to be stable. When the z potential is close to zero, particles can approach each other to a point where they will be attracted by Vander Waals forces. When that happens, particles will aggregate and flocculation or coagulation will occur.

Just as in other stable suspensions of particles, micro algalcell suspensions are stabilized by the surface charge of the cells. This surface charge originates predominantly from the presence of carboxylic (-COOH) and amine ($-NH_2$) groups on the cell surface. The carboxylic groups dissociate and are negatively charged above pH4–5, where as the amine groups are uncharged at this pH. This results in a net negative surface charge above p H45.

Different approaches to induce flocculation in cludes Charge neutralization, Electro static patch mechanism, Bridging, Sweeping flocculation. Flocculation can be induced by several approaches. Metal salts such as alum and Zinc chloride are commonly used flocculants or coagulants. These metal salts dissociate in water and the metal ions can cause flocculation through charge neutralization. Metal ions readily hydrolyze in water to form metal hydroxides. Metal hydroxides can precipitate even at low metal concentrations. These metal hydroxide precipitates are often positively charged and can cause flocculation through charge neutralization, bridging, or sweeping flocculation.

A. Experiment setup

Flocculation experiment study was conducted when micro algal cells were in stationary growth phase. Stationary growth was obtained in 12 days when chlorella vulgaris species was grown in TAP medium. 50 ml volume of samples were taken in measuring cylinders and different concentrations of chemical flocculants were added at zero time keeping one measuring cylinder tube of microalgae without coagulant as control. Triplicates of each cylinder were taken and in those different pH conditions, say 6, 10, 12.5 were maintained.Four different flocculants were used (ZnCl2, $ZnSO_4$, alum and Moringa Olifera), at varying dosages which ranged in between 0.2 g L-1 to 1.0 g L-1.For MO pH 6 was identified as best condition[6]. The flocculation efficiency was measured for each parameter at different time intervals like 0, 30, 60, 90, 120, 150, 180, 210, 240, 360 min after start and continuous monitoring was done up to 24 hrs. This experiment was done in triplicates each time.

B. Flocculation Efficiency

After addition of flocculants, each tube was kept in orbital shaker and stirring speed was maintained at 250 rpm. The initial microalgal biomass concentration in the tubes was estimated from the optical density of 680 nm (OD 680) [6], in UV-Visible Spectrophotometer (Cintra 6, Australia). At every 30 minutes, the absorbance of the supernatant was measured at 3/4th the height of the clarified culture [10]. Culture broth containing no flocculants was used as control and culture medium with appropriate quantity of each salt were used for blank to respective Flocculants. Knowing the absorbance (O.D) values, concentration can be calculated with the help of standard curve plotted earlier with the help of dry cell weight or concentration obtained for known absorbance values.

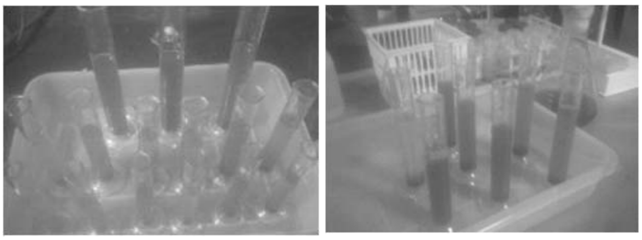
Flocculation efficiency was calculated by [11], [12].

Flocculation Efficiency (%) = 100 (1- A/ B), where, A= concentration of sample in mg/l and B=concentration of control in mg/l.

C. Results and Discussion

Effect of coagulants on micro algal cells were studied on four different salts namely, $ZnCl_2$, $ZnSO_4$, conventional alum ($KAl(SO_4)_2$) and natural coagulant moringa olifera at different concentrations for a period of 4 hours. Efficient flocculation of the microalgae cells were observed in $ZnCl_2$ and moringa olifera at 0.6 g/l and 1 g/ l respectively. The flocculation of microalgae salts are showed in figure 2.

Fig. 2.Settling of microalgae on effect of coagulants



ZnSO4 was comparatively less effective resulting in efficiency of 33.74, 36.24 and 49.85% at 0.6 g/l and 55.12, 56.92 and 57.80% at 0.8g/l at pH conditions 6, 10 and 12.5 respectively in 4 hours whereas $ZnCl_2$ (0.6 g/l^{-1}) at pH 6 was best having 91.55% efficient in 4 hours. Conventional Alum even though being a good coagulant for many species of microalgae provides only 18% efficiency with chlorella vulgaris. This may also be because of poor quality of the chemical used. On the other hand, moringa olifera provided 85.79% efficiency at a dosage of 1 g/l in 4 hours at pH 6.

O.D	0.2	0.4	0.6	0.8	1.0
Conc.	120	280	400	700	1040

Fig. 3. Standard curve for setting of algae

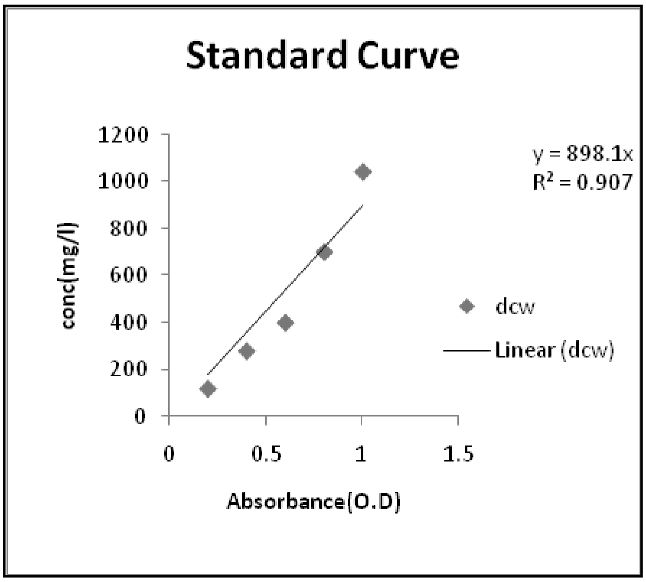


Table No.1: Percentage Efficiency for control and chemical coagulants at different concentration

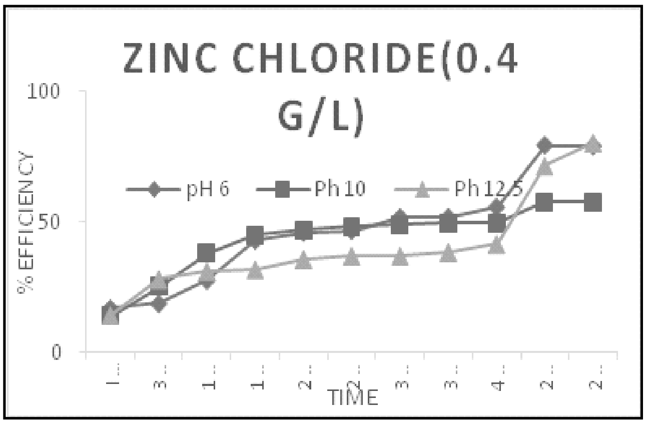
	control		
time	control	conc(mg/l)	%efficiency
initial	1.2978	1165.658	0
30 min	1.2849	1154.0715	0.99398983
1 hr	1.2762	1146.2573	1.66435506
1.5 hr	1.241	1114.6414	4.37663739
2 hr	1.2638	1135.1199	2.61981815
2.5 hr	1.2676	1138.533	2.32701495
3 hr	1.2695	1140.2395	2.18061335
3.5 hr	1.2619	1133.4133	2.76621976
4 hr	1.2675	1138.4432	2.3347203

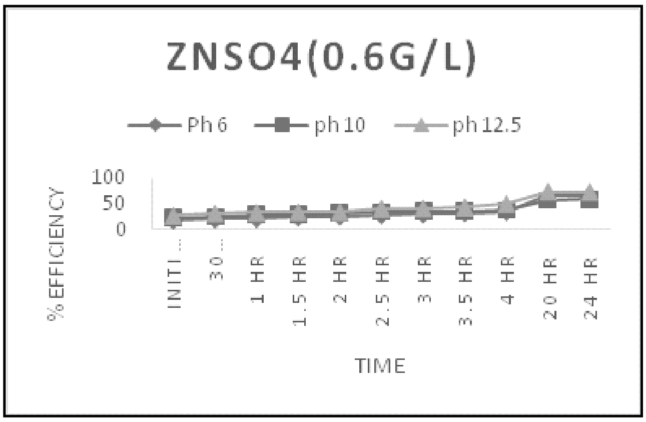
			ZnCl2(0.4g/l)					
Ph 6	conc(mg/l	%efficien	Ph 10	conc(mg/l	%efficien	Ph 12.5	conc(mg/l	%efficiency
1.0774	967.6991	16.98259	1.118	1004.165	13.85421	1.1123	999.0456	14.2934196
1.0436	937.3406	18.77967	0.9613	863.4204	25.18484	0.9242	830.098	28.0722235
0.9232	829.1998	27.66024	0.7948	713.8735	37.72136	0.8783	788.8715	31.1784987
0.7265	652.5278	41.4585	0.7032	631.6002	43.33602	0.8637	775.7581	30.4029009
0.686	616.1515	45.71926	0.6773	608.3373	46.40766	0.8139	731.0287	35.5989872
0.6783	609.2355	46.48943	0.6607	593.4275	47.87788	0.7974	716.2087	37.0937204
0.6111	548.8778	51.86294	0.6444	578.7872	49.23986	0.7947	713.7836	37.4005514
0.6104	548.2491	51.6285	0.6392	574.1167	49.34622	0.7767	697.6164	38.4499564
0.5527	496.4241	56.39448	0.6289	564.8654	50.38264	0.7243	650.5518	42.8560158

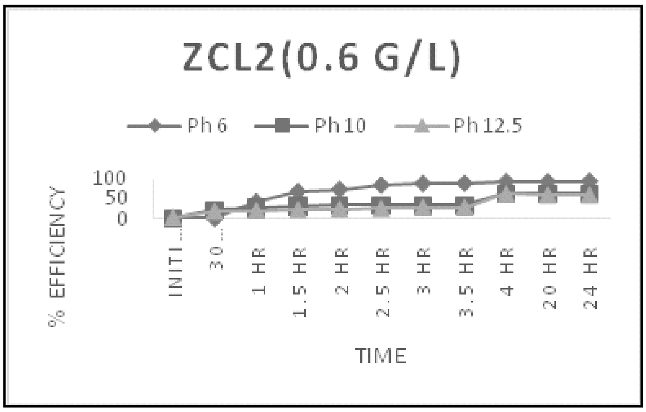
			ZnSO4(0.6g/l)					
Ph 6	conc(mg/l	%efficien	Ph 10	conc(mg/l	%efficien	Ph 12.5	conc(mg/l	%efficiency
1.0745	965.0944	17.20604	1.018	914.3472	21.55956	0.9486	852.0135	26.9070735
1.0398	933.9276	19.07541	0.9803	880.4859	23.70612	0.8792	789.6799	31.5744416
1.0157	912.2814	20.41216	0.9281	833.6009	27.27629	0.8611	773.4228	32.5262498
0.9776	878.0608	21.22482	0.9205	826.7747	25.82595	0.8386	753.2137	32.4254633
0.9529	855.8757	24.60041	0.8686	780.1591	31.27077	0.8371	751.8665	33.7632537
0.9203	826.5951	27.39823	0.8492	762.7345	33.00726	0.752	675.4314	40.6752919
0.8937	802.7035	29.60221	0.8277	743.4236	34.8011	0.7408	665.3717	41.6463174
0.8627	774.8599	31.63484	0.8188	735.4298	35.11372	0.7172	644.1747	43.1650685
0.8222	738.4836	35.13215	0.7913	710.7298	37.57002	0.6224	559.0272	50.8954635

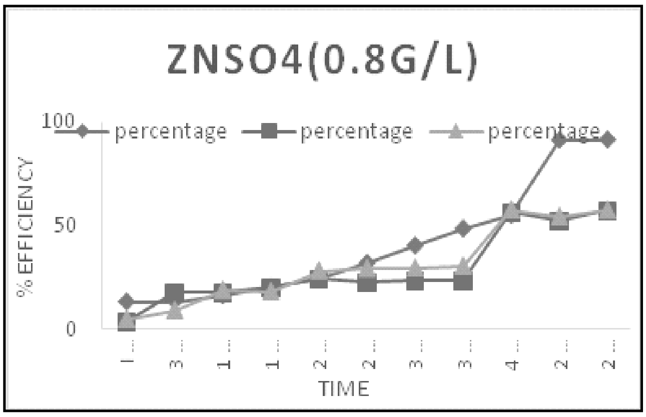
			ZnCl2 (0.6g/l)					
Ph 6	conc(mg/l	%efficien	Ph 10	conc(mg/l	%efficien	ph 12.5	conc(mg/l	%efficiency
1.2616	1133.144	2.789336	1.2616	1133.144	2.789336	1.2304	1105.121	5.1934042
1.2581	1130	2.085765	0.9864	885.9648	23.23138	1.0251	920.7243	20.2194723
0.7297	655.4019	42.82244	0.9126	819.6791	28.49083	0.9977	896.1142	21.8225983
0.4108	368.9723	66.89766	0.8572	769.9199	30.92667	0.9649	866.6539	22.2481889
0.3471	311.7583	72.53521	0.8404	754.8305	33.50214	0.9352	839.9779	26.0009495
0.2149	193.0189	83.0467	0.8391	753.6628	33.80404	0.9265	832.1638	26.9091196
0.1633	146.6728	87.13667	0.8319	747.1959	34.47026	0.8865	796.2366	30.169358
0.1569	140.9244	87.56637	0.8208	737.2261	34.95523	0.8764	787.165	30.5491719
0.1049	94.21908	91.72387	0.4698	421.965	62.93491	0.4502	404.3606	64.4812623

			ZnSO4(0.8g/l)					
Ph 6	conc(mg/l	%efficien	Ph 10	conc(mg/l	%efficien	Ph 12.5	conc(mg/l)	%efficien
1.1252	1010.632	13.29943	1.2472	1120.21	3.898906	1.2328	1107.276304	5.008476
1.1094	996.4409	13.65865	1.0571	949.4661	17.72901	1.0381	932.400658	19.20772
1.0661	957.5497	16.46294	1.0519	944.7955	17.57562	1.0367	931.143206	18.76665
1.0112	908.2396	18.51732	1.0089	906.1738	18.70266	1.036	930.51448	16.51894
0.9532	856.1452	24.57667	0.9618	863.8695	23.89619	0.9063	814.020534	28.2877
0.8632	775.309	31.90281	0.9775	877.971	22.88577	0.8933	802.344194	29.52824
0.7541	677.3175	40.59866	0.9689	870.2466	23.67861	0.8878	797.404204	30.06696
0.6489	582.829	48.57754	0.9621	864.139	23.75783	0.8758	786.626044	30.59672
0.5569	500.1964	56.06312	0.5346	480.167	57.82249	0.5237	470.376866	58.68245



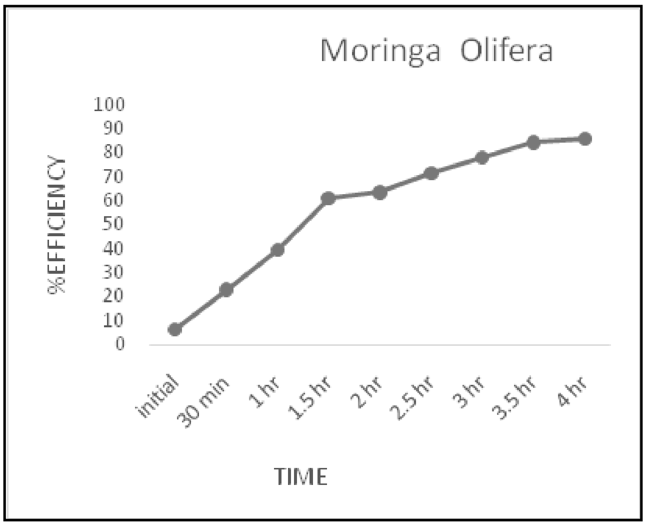






									moringa olifera									
Time	control	conc	%effiiciency	O.D(0.2g/l)	conc	%effiiciency	O.D(0.4g/l)	conc	%effiiciency	O.D(0.6g/l)	conc	%effiiciency	O.D(0.8g/l)	conc	%effiiciency	O.D(1g/l)	conc	%effiiciency
initial	1.4485	1301.01373	0	1.4418	1294.995924	0.46254746	1.4401	1293.469018	0.57991025	1.4367	1290.415206	0.81463583	1.4278	1282.421404	1.42906455	1.3552	1217.213536	6.441146013
30 min	1.4321	1286.28358	1.13220573	1.4366	1290.325388	-0.3142239	1.4332	1287.271576	-0.07681028	1.3731	1233.290958	4.11982403	1.4172	1272.900696	1.04043014	1.104	991.59072	22.91041128
1 hr	1.4288	1283.31958	1.36002761	1.4086	1265.176348	1.4137738	1.4329	1287.002122	-0.28695409	1.3551	1217.123718	5.15817469	1.4165	1272.27197	0.86086226	0.8631	775.219158	39.59266517
1.5 hr	1.4207	1276.04433	1.91922679	1.4073	1264.008714	0.94319702	1.4298	1284.217764	-0.64052932	1.1526	1035.242268	18.8709791	1.4052	1262.122536	1.09101147	0.5551	498.579718	60.92771169
2 hr	1.4165	1272.27197	2.20918191	1.4061	1262.930898	0.73420402	1.4288	1283.319584	-0.86833745	1.128	1013.14704	20.367102	1.4026	1259.787268	0.98129192	0.518	465.25724	63.43099188
2.5 hr	1.4073	1264.00871	2.84432171	1.4017	1258.978906	0.3979251	1.4272	1281.882496	-1.41405528	1.0416	935.544288	25.9859305	1.3513	1213.710634	3.97925105	0.4033	362.235994	71.34228665
3 hr	1.4061	1262.9309	2.92716603	1.3889	1247.482202	1.22324159	1.4207	1276.044326	-1.03833298	1.036	930.51448	26.3210298	1.3416	1204.998288	4.58715596	0.31	278.4358	77.9532039
3.5 hr	1.4052	1262.12254	2.98929928	1.3665	1227.36297	2.75405636	1.4014	1258.709452	0.27042414	0.9216	827.762688	34.4150299	1.3354	1199.429572	4.96726445	0.2221	199.485778	84.19442072
4 hr	1.405	1261.9429	3.00310666	1.3647	1225.746246	2.8683274	1.371	1231.40478	2.41992883	0.831	746.38758	40.8540925	1.2811	1150.658398	8.81850534	0.1997	179.366546	85.78647687

									alum									
Time	control	conc	%effiiciency	O.D(0.2g/l)	conc	%effiiciency	O.D(0.4g/l)	conc	%effiiciency	O.D(0.6g/l)	conc	%effiiciency	O.D(0.8g/l)	conc	%effiiciency	O.D(1g/l)	conc	%effiiciency
initial	1.4485	1301.01373	0	1.4261	1280.894498	1.54642734	1.4204	1275.774872	1.93993787	1.4398	1293.199564	0.60062133	1.4335	1287.54103	1.03555402	1.4168	1272.541424	2.188470832
30 min	1.4321	1286.28358	1.13220573	1.4215	1276.76287	0.74017178	1.417	1272.72106	1.05439564	1.4338	1287.810484	-0.11870679	1.4115	1267.78007	1.43844704	1.415	1270.9247	1.194050695
1 hr	1.4288	1283.31958	1.36002761	1.4091	1265.625438	1.3787794	1.4169	1272.631242	0.83286674	1.428	1282.60104	0.05599104	1.4105	1266.88289	1.28079507	1.4089	1265.445802	1.392777156
1.5 hr	1.4207	1276.04433	1.91922679	1.4065	1263.29017	0.99950729	1.4073	1264.008714	0.94319702	1.4268	1281.523224	-0.42936581	1.3943	1252.332374	1.8582389	1.4052	1262.122536	1.091011473
2 hr	1.4165	1272.27197	2.20918191	1.4012	1258.529816	1.08012707	1.4039	1260.954902	0.88951641	1.4109	1267.242162	0.39534063	1.3936	1251.709648	1.61666078	1.4051	1262.032718	0.804800565
2.5 hr	1.4073	1264.00871	2.84432171	1.382	1241.28476	1.79776878	1.3946	1252.601828	0.90243729	1.4105	1266.88289	-0.22738577	1.3935	1251.61383	0.98060015	1.4023	1259.517814	0.355290272
3 hr	1.4061	1262.9309	2.92716603	1.3772	1236.973496	2.05533035	1.3932	1251.344376	0.91743119	1.3992	1256.733456	0.49071901	1.3929	1251.074922	0.9387668	1.4002	1257.631636	0.419600313
3.5 hr	1.4052	1262.12254	2.98929928	1.3714	1231.764052	2.40535155	1.3773	1237.063314	1.98548249	1.392	1250.26656	0.93936806	1.3905	1248.91929	1.04611443	1.3969	1254.667642	0.590663251
4 hr	1.405	1261.9429	3.00310666	1.3624	1223.680432	3.03202847	1.3246	1189.729228	5.72241993	1.3891	1247.661838	1.1316726	1.3821	1241.374578	1.62989324	1.1389	1022.937202	18.93950178



3. CONCLUSION

The overall study revealed that Zinc chloride were the most efficient flocculants causing no damage to the micro algal cells. Zinc sulphate also showed good efficiency at higher concentration but in larger time duration. But as concentration increases, cells were found to be affected. Moringa olifera also exhibited good efficiency close to Zinc chloride while conventional alum is showing comparatively less efficiency. Less efficiency with alum is a contradiction to few other research papers which reveals alum showing high efficiency with most species of microalgae. Illumination was a major criterion for flocculation, increasing the efficiency whereas flocculation declined under darkness. From this study, to harvest microalgae chlorella vulgaris for biodiesel production, ZnCl2 at pH 6 was found to the most effective chemical flocculants which could flocculate at a shorter time, 360 min., at a minimum concentration of 0.6g/1. Also, almost same efficiency with minimum contamination can be obtained with moringa olifera at 1 g/l within the same time.

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National Energy Conservation Day - 14th of December

National energy conservation day is celebrated every year by the people all over India on 14th of December. The Energy Conservation Act in India was enacted by the Goverment of India in the year 2001. The Bureau of Energy Efficiency is a statutory body constituted under theact and helps in the development of policies and strategies in order to reduce the energy use. The Energy Conservation Act in India aims to employ the professional, qualified and energy managers as well as auditors who are experts in managing the energy, projects, policy analysis, finance or implementing the energy efficiency projects.

Neural Network Applications in KSEBL

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***Abstract* – Neural network is an advanced mathematical technique which is used for solving problems in pattern recognition, optimization etc.Neural network technology is now an inherent part in developing smartgrid.This paper presents some applications in which Neural network can be used in our utility. A brief introduction of neural network is presented. Case studies in Generation and transmission are discussed with the results. Analysis was done in Matlab software.**

Index term: **Neural network, generation, transmission**

I. INTRODUCTION

Advanced mathematical techniques are prevalent for improving efficiency in various sectors of power system to make the Grid more elegant and classy. One such area is Neural network which is a major branch of Artificial Intelligence (AI). Due to the developments in the field of VLSI and computation, the programs based on this type of AI when used in control rooms and distribution offices can make Grid more stable and profitable to the Utility sector. In this article some case studies related to Generation and Transmission of power in KSEB is presented to divulge the vast knowledge available on this subject.

In section I of this article we have attempted to introduce the concept of neural network and in the later sections we have presented some studies in the area of generation, transmission and distribution .The programs were implemented in Matlab, and SimPower system. Finally we have concluded pointing out the possibilities of using neural network in our system. The results of these researches are published in IEEE and other journals and are cited in the reference.

I. NEURAL NETWORK

Neural network is a program which imitates the biological nervous system of our Brain. The nervous system is made up of millions of interconnected neurons. The input to the neuron is an electrical signal, and the output is another electrical signal. The output signal is passed to another neuron or a set of neurons and fires them as well and continues like a chain reaction till desirable output is obtained. The speed by which the signal propagates is the reason behind the processing power of our brain.

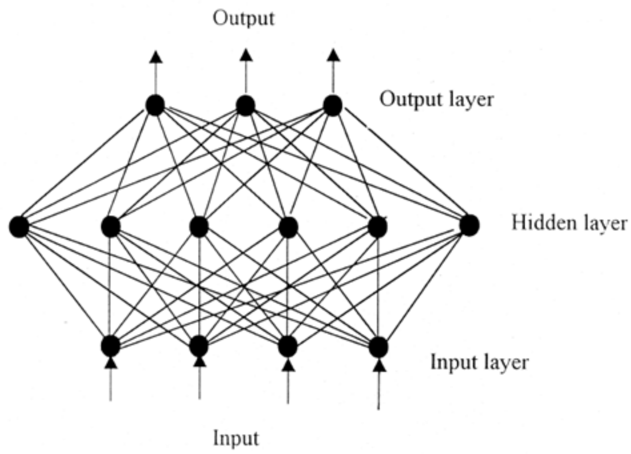

Fig 1.A neural network architecture

In Fig 1, neural network architecture is shown. The black nodes are neurons which are arranged in layers. In this nodes are stored mathematical functions known as activation functions. This activation function 'F 'produces an output Y=F(X) where X is the input signal. There are different types of activation functions which are used depending on the application, the details of which are available in the reference .Now you can find that neurons are arranged in layers. The number of neurons in a layer and number of layers etc. also depend on the application and calculated based on experiments but as the architecture size increases the computational complexity increases and processing time also increases.

Subsequently, in the architecture we can find that neurons are interconnected by black lines through which the signal is transmitted, just like veins in the nervous system. As in our transmission lines, the capacity of this veins also determines the strength of the signal, which is transmitted through it. This capacity or transmission gain, is called 'weight' of that line. In other words when signal X when presented to an interconnecting path with a weigh 'W' becomes WX when it reaches the end point.

II. ALGORITHMS AND CONVERGENCE

After we create the above network, we must train it to obtain the desirable result suited for our application. Training is nothing but changing the weights till we get the desired output. The updating of the weight is based on the algorithm loaded in the neural network. After we create the above network, we must train it to obtain the desirable result suited for our application. Training is nothing but changing the weights till we get the desired output. The updating of the weight is based on the algorithm loaded in the neural program. There are different algorithms for training the neural network. The algorithm continues training till weights are optimized. This is by comparing the neural network output with the expected output .The algorithm searches for weights which minimizes the Mean square error (MSE) between these two outputs. Obtaining the optimum weight is called convergence. The algorithms differ according to the convergence time. There are other different mathematical characteristics, along with convergence time, which helps in deciding the Engineer to choose the algorithm suited for solving his problem.

III.RESERVOIR WATER LEVEL FORECASTING

Muthirupuzha River Basin

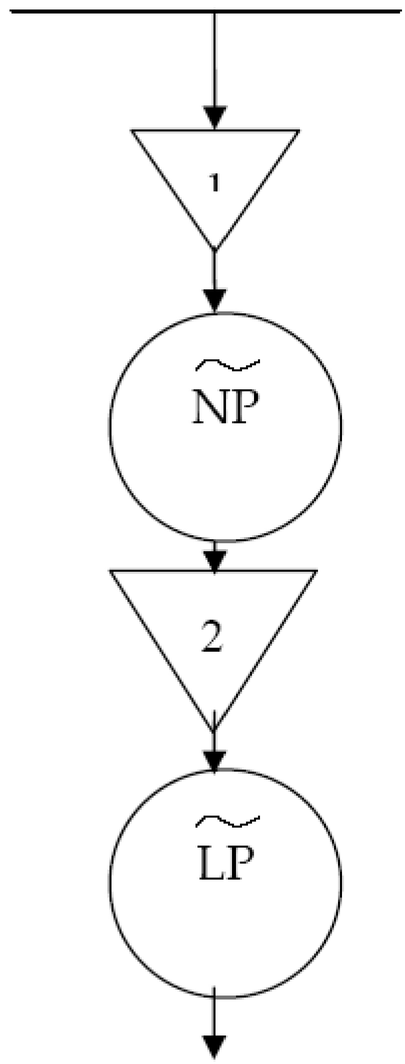

Fig 2: Cascaded Hydro system, NP-Neriamangalam, LP-LowerPeriyar, 1-kallarkuttyReservoir, 2-Pambla Reservoir

This study was conducted in lower periyar station.which is located in Iuka district of Kerala. The reservoir is the last of a string of reservoirs located in the Periyar River, which originates in the eastern region of Kerala. The reservoir has the maximum capacity of 253 Mcm and a minimum of 247 Mcm is the needed capacity of electricity generation. The catchment area is comparatively low. The power house has 3*60 MW capacities.

Generation is 24 hours normally during the monsoon and limited to evening peak during December-may months. In the study the statistics from 2003-2011 was utilized. The cascaded structure of power houses is shown in Fig 2.

The above figure shows a part of a string of reservoirs and powerhouses originating from same river basin. The reservoir level is recorded every hour. This statistics is sent to the load dispatch centre and machine scheduling decision is made based on this statistics. The studies on this statistics when analysed with ANN shows that they followed certain pattern due to following factors.

1. During monsoon season the rain in catchment area increases the reservoir level.

2. Since the reservoir is the lowest of a cascaded reservoir link, as in Fig 2, the running of machines in the upper end, increases the reservoir level.

3. Running of machines in the power house (LP) reduces the reservoir level especially in monsoon.

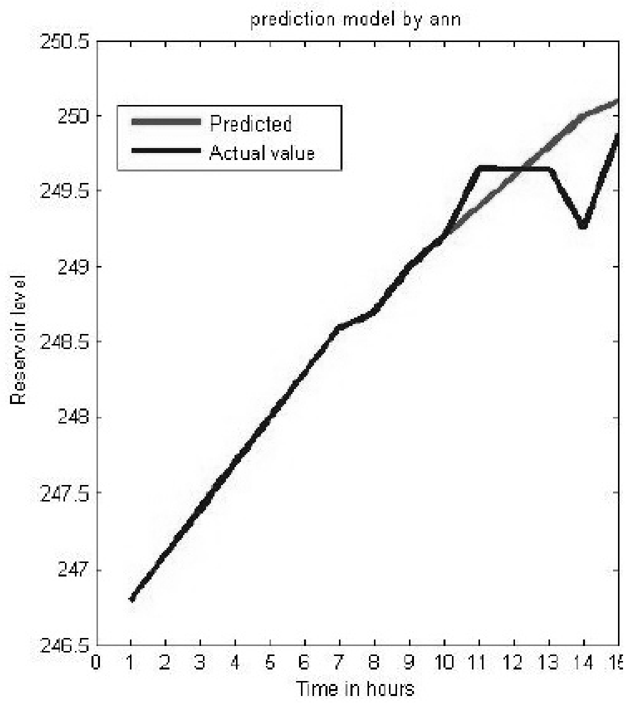

Fig 4: Prediction results with ANN (actual and forecasted)

Data up to 8 hours was used to train the net iteratively using a 30 neuron hidden layer. The prediction error increases at the end of the time series. This is because of the drop in reservoir level due to the service of machines in the evening peak load. This problem can be solved by predictions incorporating large volume of data, and changes in NN architecture. The studies pointed out that short term predictions can be possible with reasonably good results.

IV.VOLTAGE STABILITY INDEX COMPUTATION

This index indicates how far the load buses are from their voltage stability limits and hence identifies the critical buses. The technique uses measurements of voltage phasors and no-load voltage at the bus to calculate the voltage stability *L*-index. The index gives the distance of the bus to the voltage stability limit. The mathematical formulation of the Voltage Stability *L* index technique is derived from voltage equations of a two bus network. Consider a line connecting two buses 1 and 2 where P1 and Q1 are the power injected into the line as shown.

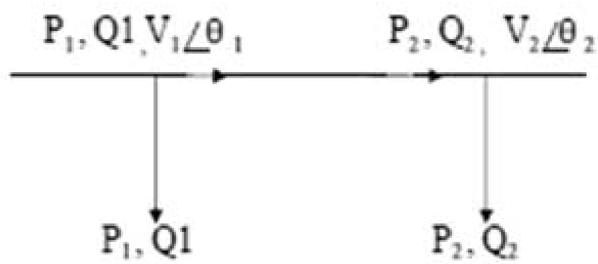

Fig5: A two bus network

Referring to load flow distribution load flow technique, the voltage stability index equation can be written as,

vi4+1+VI+12[2(Pi+Iri+Qi+1Xi) - VI2] +PI

+12+Qi+1ri2+Xi2 = 0

Where P, Q is the real and reactive powers, V corresponds to the bus voltage, r and x corresponds to the resistance and reactance of the buses. The variable i denotes the bus number. The voltage stability *L*-index is given by the equation:

$$L = 4(V_O V_L - V_L^2)/\ V_O^2$$

Where, *Vo* is the no load voltage at the node and *VL* is load voltage. When the value of *L* at every load bus in the system is near to 0, the system is voltage stable. As the value of *L* approaches 1.0 at any bus, the system approaches its stability limit and becomes unstable. In order to maintain a stability of voltage condition in the system network, the value of L any load bus must be kept less than 1.0. If the value of L evaluated at load bus approaches 1.0 the voltage is referred as collapse conditions. This index will be used in the voltage stability analysis caused by the heavy loadings. However, as the operating continuously changes, it is difficult to calculate the index L for each load bus directly by the mathematical analysis for a real power system. The main factor causing instability is the inability of the power system to meet the demand for reactive power. Knowledge of the voltage stability margin is of vital importance. The system operator must be provided with an accurate and fast method to predict the voltage stability margin so as to initiate the necessary control actions. If the operator has better knowledge of the stress on the major bus, the power correction methods can be easily implemented.

In the case study, the voltage stability index computation was calculated by neural network in Perumbavoor 110 KV substation. The single line diagram is shown below. In the casestudy, Voltage stability of the 110kv major bus was calculated with ANN and found that the predicted index follows the index derived from the standard equation.

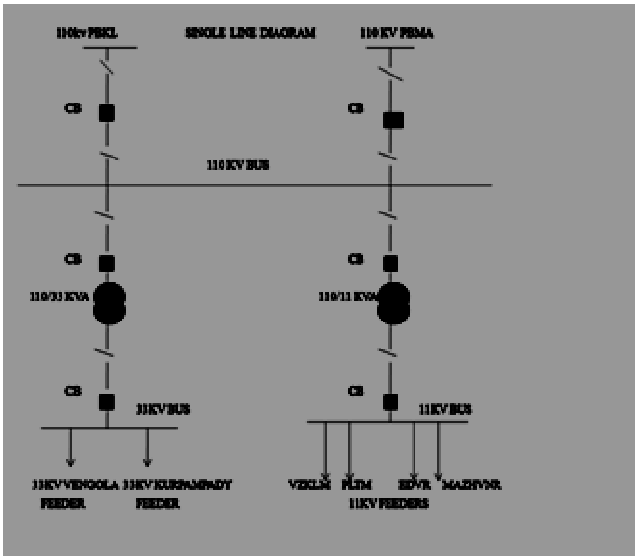

Fig 6: Single Line diagram of Perumbavoor 110 KV substation

The readings from the substation are taken in an hourly basis. The readings include the major quantities involved like load current, bus voltage, real and reactive powers and power factor. The tripping details are marked on the operator's diary. From these details, we collected the relevant load patterns of 2011-2012 year. The dataset was classified into three. Normal case (without contingency), the contingency on EHT feeders (110kv, 33kv) and contingency on HT feeders (11kv).From this field data we created the input vector database for training the neural network. Results are shown in table below.

Active power	Reactive power	L-index	Predicted Index
-8	1	0.36	0.2482
-4	0	0.38876	0.2482
-6	-2	0.38876	0.2469
-4	-1	0.38876	0.2665

V. CONCLUSION

The article discussed the application of neural network in different sectors of power system. It can be employed in a copious number of applications like temperature prediction of turbines, transformers, and fault location of transmission lines, adaptive relays etc.The can be utilized to solve different concerns in distribution sector as well as to make the system more actively operational and profitable.

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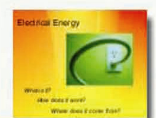
Grid resilience refers to the ability of power system to recover quickly following a disaster or more generally, to the ability of anticipating extra-ordinary, high-impact, low-probability events; rapidly recovering from those disruptive events and absorbing lessons for adapting its operation; and make structural modifications to prevent or mitigate the impact of similar events in the future.
Adaptation thus refers to long-term planning and operational measures taken to reduce the vulnerability to external sudden shocks.
It is a multi-dimensional dynamic concept with several intrinsic complexities.
However, it needs to be quantified for evaluating the effectiveness of the strategies aimed at achieving resilience and to make amendments thereupon. it is quantified based on the degree of robustness to initial shock to the power grid, the functionality achieved during the event or post-event recovery duration.



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