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Phone: 0471-2330696
Fax: 0471-2330853
E-mail: ksebea@gmail.com
Website: www.ksebea.in

Editorial...

Need for development of Transmission Network

The power transmission and distribution networks play an important role in deciding the state of development of a region. The adequacy of network, in terms of throughput, availability, redundancy, robustness etc. is an index of development of this mother infrastructure industry.

The state's share of internal generation is only 15 MU against the daily energy requirement of 72 MU. The rest of the energy requirement of the State is met through import from Central Generating Stations (CGS), purchases from outside pursuant to MTOA and STOA agreements. Thus our economy is a consumer state as far as the energy sector is concerned as is applicable for other consumables, perishable items of food, vegetables, fruits; manufactured goods etc.

In order to facilitate heavy imports of energy, our Inter State Transmission System (ISTS) needs to be strengthened. While strengthening the ISTS power transfer capacity, the intra state transmission network also needs to be strengthened. While striving to establish (n-1) security levels for transmission lines, transformers etc., we look ahead to create a better transmission network by adding interconnections between Stations which require acquisition of Right of Way (RoW) to a large extent. Almost every one, the world over are against construction of transmission line near their vicinity or in their landed property and the Not-In-My-Back-Yard (NIMBY) syndrome is very much there when it comes to construction of transmission line though ever citizen strongly advocates development of the area through development of power grid components.

In order to take care of the RoW issues, it is high time that we think of utilising narrow-based towers by employing line compaction techniques. Line compaction is achieved by reducing the tower dimensions such that it leads to a reduction in RoW requirement compared to the conventional towers. High Ampacity, high performance conductors can be used for increasing the current carrying capacity of conductors. Utilisation of mono-poles, high ampacity conductors, insulated cross-arms etc. leads to Transmission Line Compaction, thereby reducing the width of RoW.

In our utility, TRANSGRID 2.0, the second generation transmission grid is an answer to developing the power system grid to cater to the requirement of highly adaptive, flexible and resilient transmission grid. Special type tower designs are employed in TRANSGRID 2.0 which need only reduced RoW requirements. Most of the towers used are of Multi-Circuit Multi-Voltage (MCMV) category and this enhances the power throughput capability through the available RoW.

The power system planners should take into consideration the requirement of increased power transmission capacity and work for achieving it for maintaining a healthy, redundant and resilient transmission grid.

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Relationship between Electricity Consumption and Economic Growth in India

Dr. E. Mohammed Shereef

Deputy Chief Engineer, KSEBL

Abstract

Electricity has a critical role to play in the development process of a country especially a developing country like India. This study examines whether electricity consumption fuels economic growth or vice versa in the Indian context. An attempt has been made to investigate the relation between per capita electricity consumption and per capita Gross Domestic Product (GDP) using Granger causality test taking the annual data covering the period from 1971 to 2014. The study found that the increase in GDP directly affects electricity consumption.

Keywords: Per capita, Electricity consumption, Economic growth, GDP, Unit root, Stationarity, Granger causality.

Introduction

The relationship between use of energy and economic growth has been a subject of greater investigation as energy is one of the important driving forces of economic growth in all economies (Pokharel, 2006). Though India is the world's third largest producer and fourth largest consumer of electricity, the power sector is considered as one of the ignored sectors in the Indian economy. The relationship between energy consumption and economic growth has undergone extensive investigation.

For the last two decades, the debate has been focussed on whether energy consumption stimulates economic growth or vice versa. Consequently, the relationship between energy and economic growth has been a subject of intense research in finding its causal relationship. But no consensus has been reached from these studies (Soytas & Sari, 2003). The major findings of the research studies can be grouped into three. (i) no causality, (ii) unidirectional causality and (iii) bi-directional causality between energy consumption and economic growth.

Causal relationship between energy consumption and economic growth has been the focus of economists and policy analysts since 1970's (Kraft and Kraft, 1978; Yu and Choi, 1985; Erol and Yu, 1987; Cheng and Lai, 1995; Yang, 2000, Stern, 2000). The relationship between energy consumption and economic growth varies depending on the categorisation (developed/developing/ underdeveloped) of countries (Glasure and Lee, 1997). The relationship may vary at different times in the same country. This divergence is due to factors like structure and stages of economic development, the use of different econometric methods, variation of the analysis time horizon and the type/number of variable inclusion in the process. (Yu and Chai, 1985; Ferguson et al, 2000; Karanfil, 2009).

If there exists unidirectional Granger causality running from GDP to electricity consumption, it can be inferred that electricity conservation policies may be implemented without deteriorating economic growth. But, if unidirectional causality runs from electricity consumption to GDP, reducing electricity consumption may lead to a fall in income.

Review of Literature

There has been plenty of literature on the causal relationship between energy consumption and economic growth. Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985) and Yu and Jin (1992) observed no relationship between total energy consumption and income for the United States. But, Kraft and Kraft (1978), Stern (1993) and Cheng (1995) have identified a unidirectional causality running from economic growth to energy consumption in USA. Soytas and Sari (2003) examined the relation between energy consumption and GDP in France, West Germany, Italy, Japan and Turkey. Their findings support the growth led energy consumption.

Ghosh (2002) found causality from economic growth to energy consumption in Indian context. Paul and Bhattacharya (2004) examined the nexus between the two in Indian context covering the sample period from 1950 to 1996. The study found that in the long run economic growth leads to economic growth, but the standard Granger causality test shows that energy consumption leads to economic growth.

Behera(2015) examined the linkage between different forms of energy consumption and economic growth in the context of India. Mohanty and Chaturvedi (2015) examined the existence and direction of causality between electricity consumption and economic growth in India using the annual data covering the period 1950 to 1996 and established the existence of causality running from electricity consumption to economic growth without any feedback effect.

Data and Methodology

The annual data of per capita electric power consumption (kWh) and per capita GDP (constant 2010 US$) growth during the period 1971-2014 is used to investigate the relationship between economic growth and electricity power consumption. The data were taken from the World Development Indicators, 2016 of World Bank. The variables used in the econometric analysis and their symbols were presented in Table 1.

Table 1. Variables Used in the Econometric Analysis

Variable	Variable code
Per capita GDP (constant 2010 US$)	GDP
Per capita Electric Power Consumption (kWh)	EPC

The relationship between economic growth and electric power consumption was analysed using various statistical tests. To avoid bogus results, unit root test conducted using Augmented - Dickey Fuller (ADF) method to examine the stationary properties of the time series variables. Since the growth rates of all these variables are stationary at level, the study employed Granger causality test analysis for empirical analysis.

Findings

As shown in Figure 1, the co-movement between the per capita GDP growth and per capita electricity consumption growth exists from 1971 onwards

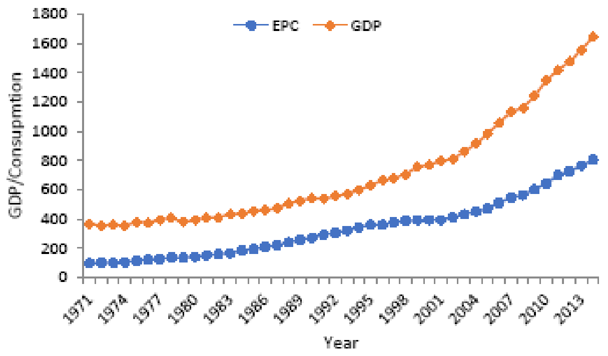

Figure 1. Growth of GDP and Electricity Consumption

Figure. 2 shows the relation between GDP growth and consumption growth. There is a close correlation (0.984) between the two.Figure.

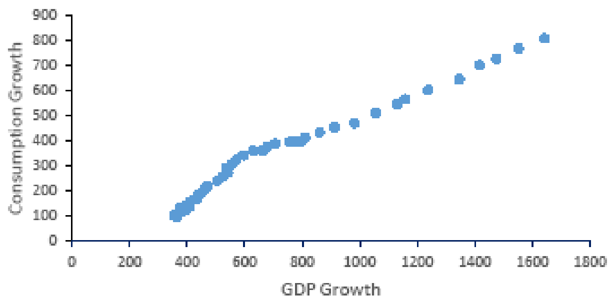

Figure 2. Electricity Consumption Growth Vs, GDP Growth

i) Stationarity Analysis To examine the relationship between per capita electricity consumption and per capita GDP, first it is to be established whether these time series data are stationary or not. This is done by performing a unit root test on time series data using ADF test. Null hypothesis (H0): The time series has unit root

Table 2. Unit root testing

Variable	ADF test (Level- Trend and constant)	
	Level (Critical value at 1%)	First- Difference (t-statistics)
GDP	5.0094116	4.192337
EPC	4.192337	3.986011

All values are significant at 1% level

Since the t-statistics of the estimate is less than the critical value, the null hypothesis can be accepted. Hence the two time series data (GDP and EPC) have unit roots and are non- stationary.

ii) **Causality Analysis**

The causality between GDP growth and electricity consumption is tested using Granger causality test. Granger causality test is used to examine whether the information contained in a variable is correctly predict the other variable and vice versa, The results of Granger causality test are presented in Table.3

Table. 3 Estimated Granger causality model

Null Hypothesis	F- statistic	p- value	Decision
EPC does not Granger Cause GDP	0.3981(1)	0.5317(1)	Do not Reject (since p>5%)
GDP does not Granger Cause EPC	6.05494(1)	0.0183(1)	Reject* (since p < 5%)

*Note: * indicates the rejection of null hypothesis at 5% significance level*
Figure in parentheses are number of lags

Null Hypothesis	F- statistic	p- value	Decision
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*Note: * indicates the rejection of null hypothesis at 5% significance level*
Figure in parentheses are number of lags

The null hypothesis is accepted in case of electricity consumption causes GDP whereas null hypothesis is rejected in case of GDP causes electricity consumption. It is apparent from the above table that there is a unidirectional Granger causality running from GDP to electricity consumption where as there is no evidence of Granger causality running in the other direction.

Conclusion

The present study examined the linkage between per capita GDP growth and per capita electricity consumption growth in the context of India. The relationship is examined by using the annual data covering the period from 1971 to 2014. The study investigated the relationship by employing the sophisticated econometric techniques like ADF test, Granger causality test etc.

The empirical result of Granger causality suggests that it is the economic growth leads to more demand of electricity consumption. The result also suggests that there could be unidirectional influence from an economic growth to electricity consumption. The findings of this study are in consensus with the Ghosh (2002) in the context of India. Because of economic growth led to electricity consumption growth is established, there is a scope for energy conservation policy.

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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 of land and Sun

An Investigation into the Hazards of Travelling Electromagnetic and Sound Waves on Human Health

B. Somanathan Nair[1], P. S. Chandramohanan Nair[2], S. R. Deepa[3], A. Kamala Priya[4], H. Sreejith[5]

[1] Department of Optoelectronics, University of Kerala, Thiruvananthapuram, India
[2] Department of Electrical and Electronic Engineering, College of Engineering, Thiruvananthapuram, India
[3] Sree Narayana Institute of Technology, Adoor, Pathanamthitta District, Kerala, India
[4] Department of Electronics Engineering, KMP College of Engineering, Perumbavoor, Kerala, India
[5] Department of Electronics Engineering, KMP College of Engineering, Perumbavoor, Kerala, India
email: profbsnair@gmail.com

***Abstract*:** Currently active discussion is going on regarding the hazards of microwave radiation from mobile towers and phones. Several experts have argued that microwave radiation is highly dangerous to man and animals. But so far, nobody has been able to give any concrete proof confirming this theory. In this paper, we intend to prove that microwave radiation from mobile towers and phones is not at all hazardous. To prove the conditions under which travelling waves in general, and microwaves in particular, become dangerous, we propose three basic laws. The theoretical proof is corroborated through computer simulations using COSMOL MULTIPHYSICS software, whose human-brain model is used for simulation. We also prove that radiation in concentrated form from any type of travelling wave is highly dangerous.

Key Words: Microwaves, Mobile Towers, Phones, Ultrasonic waves, Hazards, COMSOL.

I. Introduction

Currently there exists a widespread propaganda, belief, or myth that microwaves are dangerous to health. Some people argue that it is true; some others argue that it is false. But so far nobody has been able to give any solid proof on the fact that microwaves are really dangerous. In this paper, we make a detailed study on the conditions under which travelling waves, such as electromagnetic (EM) waves, sound waves, and water waves that hit human bodies can become hazardous. It may be noted that the concern about the waves arises from the fact that all these waves, except water waves, strike all the living and non-living things continuously without any break. Water waves, however, strike only those who are in touch with it.

II. Conditions making Waves Hazardous

We now introduce three basic laws specifying the conditions under which travelling waves can become hazardous. The newly proposed laws are:

Law 1: The wave-particle interaction law
Law 2: The high-power wave law
Law 3: The concentrated-power law

Statement of Law 1

A travelling wave will interact and strike only those particles whose physical dimensions are comparable to or larger than its own size (expressed in terms of its wavelength); it will not interact with objects much smaller in size than its wavelength.

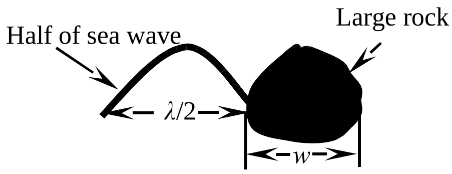

Fig. 1 A large wave striking a rock of similar size

Next, consider Fig. 2, which shows a small sand particle lying in the path of the same sea wave. It can be seen that the wave will not strike the particle at all, as its wavelength is much larger than the size of the particle. Instead of interacting with the particle, the wave will rather ride over it. In this process, the particle will not get destroyed by the wave. However, the wave may push and pull the particle so that it will move slightly forward or backward from its original location.

The arguments given above are sufficient to prove Law 1.

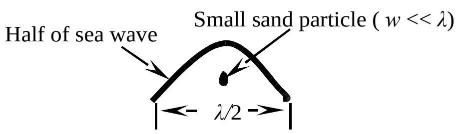

Fig. 2 A large wave riding over a very small particle

Statement of Law 2

High-power travelling waves of any kind are highly dangerous to human and animal health.

Proof: Law 2 can be proved using the example of sound waves generated by loudspeakers (LS) connected to public-address (PA) systems. It has been observed that modern musical troupes employ PA systems which generate a minimum of 10,000 watts of audio power. To compute, the amount of audio power spreading into the space surrounding the LS, we make use of the formula $P_R = P_T \pi \grave{A} r^2$, where P_R is the power received at *r* meters away from LS and P_T is the audio power generated by it.

To quantify the process, let us assume that P_T = 10,000 W. Then, using the formula given above, we find that P_R at 1 meter away from the LS is nearly 80 mW/cm^2. However, in the majority of these cases, LS used are highly directive so that most of the 10,000 watts of sound power hits the human body as such (see Law 3). This power is much above the power level that an average human body can bear!

A second aspect to be considered here is the danger of sound power hitting human ears. The minimum acoustic power that a normal human ear can identify is approximately 10 nW/cm^2 [1] Experiments have proved that sound power that can produce severe pain in human ears is about 120 dB above this basic level. Conversion from dB to W shows that 120 dB above 10 nW/cm^2 is equivalent to 10,000 W/cm^2. If this huge amount of acoustic power hits a human ear, then there will be no doubt about the final result!

The two examples cited above prove Law 2. Even though high-power sound waves are extremely dangerous, majority of the general public are unaware of this; in fact they are least bothered about them.

It may be noted in this context that if high-power travelling waves are dangerous, then it also suggests that low-power travelling waves in spread form (see Law 3 given below) are not at all dangerous to human and animal health.

Statement of Law 3

Any type of wave travelling in concentrated form is highly dangerous to the health of living bodies.

Proof: Law 3 can be proved by using a couple of very common and simple examples.

As the first example, consider the case of solar power falling on earth. Everybody knows that if this solar power is focused on to a human body using a simple convex lens, it produces tremendous amount of heat that can lead to the burning of the focused part of the body.

As the second example, consider the situation in which the optical output from a low-power laser is permitted to fall directly onto a human eye. Let the power output of the laser be in microwatts. We find that when this low-power concentrated form of light falls on the human eye, the lens of the eye focuses it onto the retina. This focusing action produces further concentration of the laser power onto a very small spot on the retina. It can be seen that the power density at the focused point will be extremely high so that the retina gets destroyed if the focusing time is on the order of a few seconds. However, it may be noted that laser power of less than a few milliwatts directed on to the human skin (without focusing) may not create much danger.

We now make use of the laws given above to investigate into the truths and myths associated with travelling waves in general and microwaves in particular.

III. Dangers of Radiation from Sun

Sun is the most natural source that radiates huge quantities of EM waves towards the earth. It has been found that these radiations lie in the range of 1 mm to 0.1 μm. In this wide spectrum, radiations lying in the range of 1 mm to 0.7 μm are infrared (IR) waves, those lying in the range of 0.7 μm to 0.4 μm are visible light waves, and those lying in the range of 0.4 μm to 0.1 μm are ultraviolet (UV) waves [2].

Let us first consider the case of UV radiation from the sun. Assume that a human cell of size 1 μm [3] is subjected to a UV radiation of $\lambda = 0.3$ μm. Comparing their sizes, we notice that the size of the human cell is much larger than λ of the UV radiation. Then according to Law 1, this UV radiation will definitely attack and destroy the human cell, which means that UV radiations are highly dangerous to human health, *regardless* of its power content.

International regulatory bodies have laid down the condition that UV radiations of power equal to or greater than 1 mW/cm^2 are extremely dangerous [4][5][6]. This restriction does not mean that UV radiations of power less than 1 mW/cm^2 are not dangerous. Longtime exposure to such low-power UV radiations can definitely cause health hazards such as cancer and tumor.

We have thus seen that UV radiations of small λs attack human cells regardless of their intensity. Extending this theory, we find that attacks on human cells become more and more severe as λs of the EM radiation become shorter and shorter and enter into the X-ray, ϒ-ray, and cosmic-ray range of wavelengths. But in these cases also we have safe power limits defined by various international regulatory bodies above which only they become really hazardous [7].

In this context, it may be noted that in a recently published paper [8], it has been established that the term *electromagnetic* waves must be changed to *magnetic* waves alone. The waves travel as magnetic waves only; the electric part in the waves appears only when they strike an antenna and generate current in it.

Next, let us consider the IR waves in the solar spectrum. We know that IR waves are heat waves that heat the earth's atmosphere. If the atmospheric temperature exceeds 45ºC, then it will cause severe skin burns on the human and animal bodies which may ultimately lead to death. This is known as *sun stroke*. This is a major health hazard in countries which receive sun light directly (as per Law 2).

The visible light frequency part of solar radiation in between 0.7 μm (red) and 0.4 μm (blue) is highly essential for sustaining life on earth. Until recently, everybody believed that visible light is danger-free. However, as per Law 1, since these λs are comparable to the sizes of human cells, they are potentially dangerous to human health. That this observation is true have been proved in recent studies on the dangers of visible light on human skin and eyes [9][10]. However, these references have given only the experimental facts about the hazards of light on skin; they have not given any reason as to why visible light acts dangerously on human skin. But, we find, as stated above, that the actions obey Law 1, which confirms its validity.

IV. Hazards of Man-Made light Sources

Let us now consider the emission of magnetic waves from man-made light sources such as incandescent lamps, fluorescent and compact-fluorescent lamps, and LED lamps. It has been found that energy generated by incandescent lamps consists mainly of the infrared and visible-light waves and a very small amount of UV rays. However, fluorescent and compact-fluorescent lamps emit more amount of UV radiation than incandescent lamps. Similarly, LED lamps, also can cause damage to human health by excess of UV radiation [Law 1].

To get a quantitative idea about the power levels contained in these radiations, and the dangers lying in them, consider the light emitted by a 100-W incandescent lamp. This emission actually contains a large amount of infrared radiation also. Now, substituting for $P_T = 100$ W in the expression received power $P_R = P_T/4\pi r^2$, for the values of $r = 1$ m, 10 m, and 100 m, we find that P_R = 800 μW/cm^2, 8 μW/cm^2, and 80 nW/cm^2, respectively. These values of incandescent lamp radiations are low enough to create any health hazard. However, it may be noted that if the time of exposure of a body to these lamps is large, they can become hazardous.

V. Hazards of Ultrasonic Waves

Having discussed about the dangers of optical and sound waves, we now consider the dangers produced by ultrasonic (US) waves. It is generally believed that US scanning of human bodies is not at all dangerous. This assumption is not entirely correct; they do become dangerous under the conditions explained below.

Conventional US scanners make use of ultrasonic frequencies ranging from 1 MHz to 20 MHz for human-body scanning. Assuming that the velocity of sound is 340 m/s, corresponding λs of US waves lie in the range of 340 μm to 17 μm. These λs are much larger than the λs of visible-light spectrum and hence are not dangerous to human cells, provided that the power level involved in the scanning process is less than 720 mW/cm^2 [11]. This also implies that, if the power used for scanning exceeds this limit, it will be harmful to the body being scanned (Law 2).

Let us now assume that the US frequency to be used is 1000 MHz or more. The corresponding λ is 0.34 ¼ m, which become comparable to that of UV radiation. In this case, the US wave becomes dangerous to human cells [Law 1], even if the power used for scanning is much less than 720 mW/cm^2.

In applications such as cutting and welding, focused US waves are used. These waves are really dangerous and may indirectly harm a human body using them [Law 3].

VI. MW and SW Radio transmitters

It is well-known that waves emitted by medium-wave (MW) and short-wave (SW) radio transmitters can be highly dangerous if the radiating power exceeds a few kilowatts. This may be explained with the help of the antenna-radiation equation $H = A/r + B/r^2$, where H is the magnetic field produced by a transmitting antenna, r is the distance from the antenna to a given receiver, and A and B are constants [12].

The first of the two terms on the right-hand side of the equation represents a magnetic field that is inversely proportional to r. It is called as the *radiation field* and is responsible for spreading the transmission to distant places. Since power of the magnetic field in the radiated waves is very low due to wide spreading, this field does not produce any danger to human health. For example, the power density received at 1 km away from a 100-kW MW transmitter will be only 8 μW/cm^2, which is a very safe value [Law 2].

In this context, it is interesting to note that FCC regulations prescribe safe limits of MW emission as 100 mW/cm^2 for occupational (or controlled exposure) and $900/f^2$ (f in MHz) for general population [13]. In the second case, let the frequency of transmission $f = 1$ MHz. Then we get the safe limiting value as 900 mW/cm^2. Both these 'safe' values are much above 8 μW/cm^2, which confirm our argument that MW radiation is not dangerous. Reference [13] also gives the limiting safe values of radiations ranging from 0.1 MHz to 100 GHz.

The second term in the equation is inversely proportional to r^2 and is known as the *induction field*. It can be seen that as the distance from the transmitter increases, the value of this field reduces drastically. In fact, the distance up to which this field remains dangerous is approximately equal to λ/6 [12]. As an example, a MW station transmitting 1200-meter radio waves at 10-kW power is very dangerous up to a distance of 1200/6 = 200 meters. However, the induction field is much more dangerous than the radiating field. When a MW or SW high-power transmitter is in operation, nobody is permitted to go anywhere near the transmission tower. This is because the very strong induction magnetic field will attract and pull the objects near to it onto the antenna tower with very high velocity (in this case the antenna acts as a very powerful magnet). The result of this pulling action on a living body can be really imagined!

It may also be noticed in this respect that the induction field of a microwave transmitter operating at λ = 12 cm exists only up to a distance of 2 cm from the antenna tower. Further, its radiating power, as stated earlier, is usually in the range of a few watts only. Hence it is not at all dangerous to go near a microwave transmitter while it is radiating.

VII. Radiation from Transmission Lines

Another potentially dangerous candidate for the consideration of radiation effects is the very long high-power AC transmission lines. These power lines exist through out the length and breadth of many countries all over the world. Even though they appear as harmless to the common man, in reality, they can be hazardous to human health [14]. The reasons for this are:

1. They carry thousands of amperes of 50/60-Hz AC current at or above 110 kV. This huge current at very high potential produces very powerful induction magnetic field around the wires carrying it which can adversely affect the *mind* and *bodies* of people residing near these lines.

2. AC power lines are very long (extending over several hundreds of kilometers. Hence they can act as efficient EM radiators of 50-Hz EM waves. It may be noted that the power lines act as antennas because they have lengths comparable to $\lambda/8$, where λ of the 50-Hz AC wave = 3×108/ 50×8 = 750 km. These powerful radiating magnetic fields can also be hazardous.

VIII. Hazards of Microwave Radiation

Electromagnetic waves lying in the range of 1 GHz (λ = 30 cm) to 1 THz (λ = 0.3 mm) are generally called as microwaves. Of these, at present, mobile towers and phones all around the world operate only on the frequency ranges of 700 MHz to 900 MHz (*a"* 43 cm to 33 cm) and 1800 to 2100 MHz (*a"* 17 cm to 14 cm).

Now, comparing the size (1 µm to 100 µm) of human cells with *»* of microwaves (= 37.5 cm to 14.3 cm), we find that microwaves are much larger in size than human cells. Therefore, as per Law 1, it is very clear that microwaves can not harm human cells under any circumstances.

Next, consider the power radiated and received in mobile microwave transmissions. It is found that many of the transmitters installed in several countries around the world radiate typically 100 W of microwave power into the their surrounding space. Then, using the formula $P_R = P_T/4\pi r^2$ again, we find that at r = 1 m and 10 m, P_R = 800 µW/cm^2 and 8 µW/cm^2, respectively. Further, it is to be noted that mobile handsets of customers will be usually at least 100 m away from a radiating transmitter. At this point, P_R = 80 nW/cm^2 only, which is an extremely low power level that can cause any significant damage to human cells (Law 2).

The arguments given above also suggest that there is a possibility of these waves affecting the working of human DNA chains whose dimensions range from a few centimeters to a few meters. However, since the radiations from mobile towers are very weak, there is very little probability of them affecting the DNA chains adversely.

It has now been established that low-power mobile tower radiations are harmless (in Section X, we describe a computer simulation using COMSOL software that confirms this argument). However, there exists a negative propaganda against such transmissions preventing the installation of new mobile transmission towers at various locations within a country. The crowding of several antennas on a single tower is really a sight that can produce fear in the minds of even strong-hearted men. And it may be this fear that produces stress-generated diseases in people with weak mindset.

IX. Hazards Of Mobile Phones

Are mobile phones hazardous? This again is a question frequently raised by the general public. The answer to this question also is a vehement "no". This answer is based on the same arguments given in the case of radiation from mobile towers.

An additional reason to be considered in the case of mobile handsets is regarding the heat generated in them. Mobile phones are powered by lithium-ion batteries. The capacity of these batteries ranges from 1000 mAh (milli-ampere hour) to several thousands of mAh. 1 mAh is defined as the *capacity of a battery that supplies/ dissipates current at the rate of 1 mA for a period of 1 hour continuously*. Since in most cases, the battery voltage is about 3.7 V, the power dissipated for 1 mA of current over a period of 1 h is only 3.7 mW. This means that the power dissipated per second is only a few µW. This low power level can not heat the brain if handsets are used for short durations of time.

However, if a mobile phone is continuously used for several minutes, the heat developed in the handset can heat the brain cells because of the proximity of the phone to the human skull. As stated above, this heat is due to the power dissipated by the battery for energizing the electronic circuitry in the handset and not due to microwave radiation received or generated by the handset.

The problem described above can be eliminated completely by using earphones (or headsets) for conversation between calling and called parties. It may be noted that all modern mobile manufacturers supply headsets as an auxiliary gadget along with each mobile phone they sell. Headsets very conveniently keep mobile phones far away from human ears so that the heat developed in them will in no way affect the human brain. Any discomfort felt by persons using these gadgets is purely psychological.

X. A Computer Simulation to Prove that Microwaves Do Not Harm Human Brain

For studying the effects of microwave radiation from mobile towers and phones on a human brain, a series of computer simulations using COMSOL MULTIPHYSICS software were carried out. This software has a built-in human-brain model, called as the COMSOL Brain Model (CBM). It also has a built-in microwave generator that can simulate the generation of microwave frequencies ranging from 835 MHz to 10 GHz.

Simulations were performed to study specific absorption rate (SAR) of the brain tissues. SAR is defined *as the power* absorbed per unit *of human* . S*mass* AR is measured in the units of watts per kilogram (W/kg), averaged over the whole body or over a small volume of tissue weighing 1 gram (USA) or 10 gram (Europe). Simulations using COMSOL yielded data in the form of two different graphs.

The first graph, called as the SAR graph, shows the relation between SAR and the location of the point in the brain where microwaves are absorbed. On the graph, SAR is indicated by different colour patches. These colour patches, in turn, represent the heat generated in the brain by the incident microwave radiation. To get an idea of the SAR value in terms of equivalent temperature, consider the experiments conducted on rabbits' eyes. In these experiments, exposure of eyes to microwave radiation for a period of 3 hours continuously has been found to produce a temperature of 41°C for a SAR value of 100 to 140 W/kg [15].

The second of the two graphs mentioned above shows the relation between the total energy density generated within the brain by the incident radiation expressed in J/m^3 (*y*-axis), and the arc length representing the radius of the brain expressed in cm (*x*-axis).

Now, consider the first simulation using the frequency of 835 MHz (minimum frequency in the microwave range). Let this be applied as input to the 'ear portion' of the CBM. The input power of the microwave frequency is set at 20 mW, which is much more than that reaching a human body from a radiating mobile tower. The results of the simulation are shown in Figs. 3, 4. and 5, respectively. Figures 3 and 4 show two views of the human brain indicating the temperature generated in it by 835-MHz.

In Figs. 3 and 4, the blue-colour patch indicates the region of the human brain where it is least affected by the input radiation. Similarly, the brown-colour patch indicates the maximum affected region. The red line shown in Fig. 3 represents the 20-mW, 835-MHz power striking the human ear. It can be seen that the maximum temperature generated by the input power around the ear portion of the brain is too small (only 0.19 K at 835 MHz) to create any problem to the affected human body!

The graph shown in Fig. 5 is the energy density/arc length graph. In this graph, the peak represents the maximum energy absorbed by the human brain from the input power of 20 mW at 835 MHz. We find that the maximum power density absorbed in this case is only 1.6 mJ/m^3 (=1.6 pJ/cm^3). This is a negligibly small value and hence cab bot create any problem to human-brain tissues.

Next assume that we are applying 2.123 THz, which is the maximum frequency in the microwave range, as input to the 'ear portion' of the CBM. The results of the simulation outputs for this case are shown in Figs. 6 and 7, respectively. It can be seen that Fig. 6 is similar to Fig. 3. In this case also the maximum temperature generated is too small (9.86×10^{20} K at 2.123 THz) to create any problem to human brain!

Figure 7 is the energy-density plot and is similar to Fig. 5. The peak in this graph shows that the maximum power density is only 1.6×10"^{23} J/cm^3, which, as in the previous case, is negligibly small to create any sort of problems to human-brain tissues.

Simulations were done with several frequencies in between 835 MHz and 2.123 GHz. It has been found that in all these cases, the simulation results indicate that the heat generated in the human brain by these microwave frequencies is negligibly small and hence can not create any danger to human brain tissues.

The simulation plots shown in Figs. 3 to 7 are very small and hence the axes may not be clearly recognizable. However, in the soft copy of this paper, these figures can be expanded using the Microsoft-word technique of pulling outwards their corners.

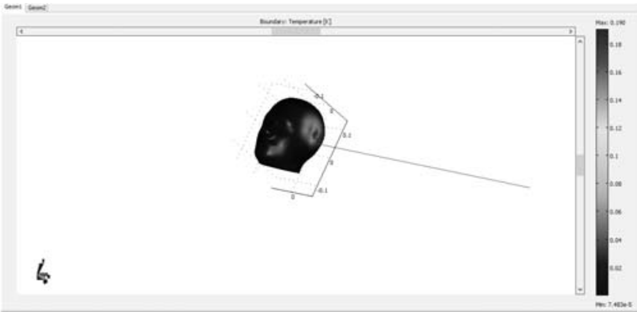

Fig. 3 Temperature for 835 MHz (brain view 1)

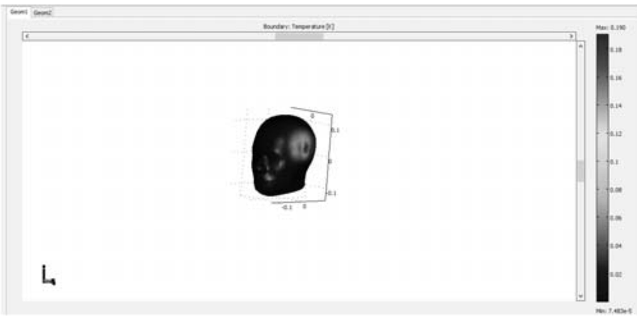

Fig. 4 Temperature for 835 MHz (view 2)

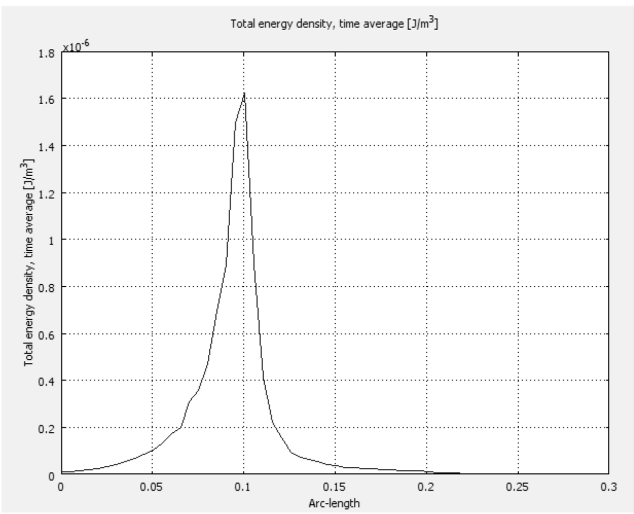

Fig. 5 Energy density/arc length (835 MHz)

Fig. 6 Temperature (2.123 THz)

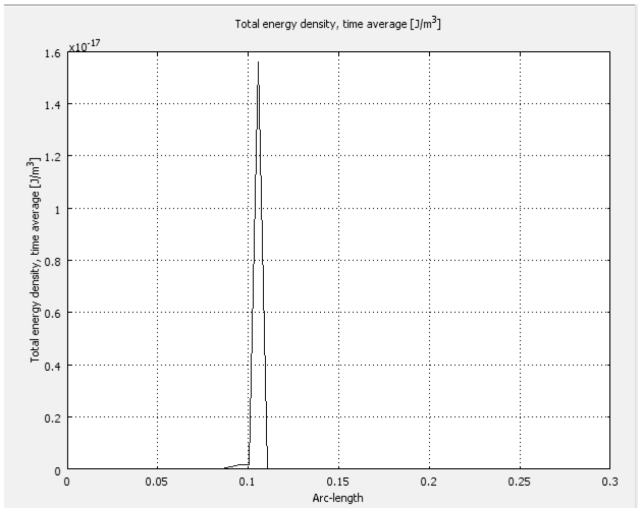

Fig. 7 Energy density/arc length (2.123 THz)

XI. CONCLUSION

Employing actual physical examples, and using three logical fundamental laws, it has been proved that microwaves at low-power levels and in spread form are not at all dangerous to human beings and animals. This has been corroborated through computer simulation employing real practical values. The propaganda that microwave radiation from mobile towers and phones is dangerous is false and not based on logical arguments. It is also concluded that power in travelling waves (such as microwaves, optical waves and sonic and ultrasonic waves) in concentrated form and at high power levels is definitely dangerous.

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ENGINEERS' DAY

September 15

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

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

Er. Mokshagundam Vishveshwariah, (popularly known as **Sir MV**)was a notable Indian engineer, scholar, statesman and the Diwan of Mysore during 1912 to 1918. He was a recipient of the Indian Republic's highest honour, the Bharat Ratna, in 1955. He was knighted as a Commander of the British Indian Empire by King George V for his myriad contributions to the public good. Every year, 15 September is celebrated as Engineers' Day in India in his memory. He is held in high regard as an eminent engineer of India. He was the Chief Designer of the flood protection system for the city of Hyderabad, now capital city of Andhra Pradesh, as well as the Chief Engineer responsible for the construction of the Krishna Raja Sagara dam in Mysore. He was born in Muddenahalli in Karnataka state.

Bharat Rathna
Sir MOKSHAGUNDAM VISVESVARAYA
1860-1962

Environmental Compliances in Thermal Power Plants – Issues and Challenges

CEA

Introduction:

Climate change and global warming has made lots of challenges to human life in Earth. The basic reason for the above issue is due to uncontrolled emission of Green House Gases (GHG), especially by developed and developing countries. In India also we are experiencing the global warming and climate change issues and the same has affected Indian economy also.

Installed capacity of Power plants in India is 326848.53 MW as on 31.03.2017 and out of which nearly 66.8% is thermal power stations. The thermal power stations are emitting huge quantum of GHG to atmosphere and aiding the global warming. Hence, Ministry of Environment, Forest & Climate Change(MoEF and CC) have issued new Environmental standards for thermal power stations, vide Gazette Notification dtd 07 Dec.2015. All existing stations are required to comply with the new standards within two years, i.e. by Dec.2017. It is very clear that coal and lignite based TPPs shall be largely affected by the new environmental norms. Many no. of old stations would be required to changeover to Cooling tower system, for which new investment and space is required. Many TPPs installed near coastal area, using sea water may be required permanent shutdown as they are unable achieve new norms.

Revised environmental norms are tabulated below for reference:

Emission Parameter	TPPs installed before 31.12.2003	TPPs installed after 31.12.2003 and up to 31.12.2016	TPPs to be commissioned after 01.01.2017
Particulate Matter	100 mg/Nm³	50 mg/Nm³	100 mg/Nm³
SO_2	600 mg/Nm³ for units < 500MW capacity 200 mg/Nm³ for units 500MW and above capacity	600 mg/Nm³ for units < 500MW capacity 200 mg/Nm³ for units 500MW and above capacity	100 mg/Nm³
NOx	600 mg/Nm³	300 mg/Nm³	100 mg/Nm³

Norms for water consumption are listed below:

1	All plants with OTC shall install Cooling Tower (CT) and achieve SWC of 3.5 m^3/MWh within two years of notification.
2	All existing Cooling Tower based plants shall reduce SWC up to maximum of 3.5 m^3/MWh within two years of notification.
3	New plants to be installed after 01.01.2017 shall have to meet SWC of 2.5 m^3/MWh and achieve zero water discharge.

SWC = Specific water consumption

Now almost all major power utilities are in the process of detailed study on technical and commercial matters based on the new norms in the power sector. It is very clear that high investments would be required for achieving new norms for which compensations or proper returns has to be ensured by implementing agencies or through CERC regulations.

a) Major Technical Issues for the Existing Thermal Power Plants:

Suspended Particulate Matter(SPM)

Retro-fitting of additional fields in ESP or replacement of existing ESP with new one is required for achieving the norm of 100mg/Nm^3 for the units installed before 31.12.2003. Similarly for units installed after 01.01.2004 is also required modification to achieve the revised norm of 50mg/Nm^3

The main challenge for achieving the above norms is space constraints in the existing plants and additional investments.

Sulphur Dioxide (SOx):

It is not possible to achieve the new norms in the existing stations without installation of DeSOx systems and Flue Gas Desulphurization(FGD). In many old stations, spare land will not be available for installation of new FGD systems. Thus most of the stations may not be in a position to install FGD and attain new norms.

For units more than 500MW, where space provisions for FGD system have already been made, arrangement for supply and transportation of good quality limestone per annum will be involved. Quality and least transportation cost are to be ensured for the limestone. The gypsum produced per year for 500MW unit will be appx. 85,000MT. Disposal or utilization of the same is area of concern of the TPPs.

Finally APC(Aux. Power consumption) will increase for FGD operation by 1.0~1.5% which will affect plant efficiency.

Oxides of Nitrogen (NOx)

The new norms require modification in the combustion process using low NOx burners or installation of de-nitrification systems like Slective non-catalystic reduction (SNCR) / Selective catalystic reduction (SCR) system or combination of the above. It is very clear that NOx emission in the range of 300 & 100mg/Nm3 cannot be achieved without installation of Selective catalystic reduction system.

Indian coals are having high ash content and hence the available SNCR/SCR system available in the international market may not suitable for TPPs operating in Indian coal. This shows that TPPs operating on Indian coals shall undergone detailed study on suitability of the systems available in the international market.

SCR systems would require extensive changes in duct work, relocation of air pre-heater, change of ID fan, etc for which no provision is available in the existing plants. In addition to above, SCR systems require Ammonia as a de-nitrification agent. Procurement, transportation, storage, environmental approval for storage & use of ammonia, etc to be arranged by the plant.

Catalyst for the SCR system is very expensive which will have direct impact over O&M charges and increased APC.

Mercury:

There is no proven technology available to control mercury. Emission of mercury can be controlled through other pollution control equipments like ESP, FGD and SCR.

Water Systems:

The new norm for SWC of 3.5m³/MWh can be achieved through various water conservation measures. The various issues to be faced by existing TPPs are detailed below:

Conversion of existing OTCW system to Cooling Tower(CT) system the following challenges are to be considered. Large space for (i) Raw water reservoir& installation of cooling tower, new CW pump house, laying of CW ducts, CW treatment systems and side stream filters. Hence, the land requirement will be very high for implementing CT system in old station, which may be practically very difficult or impossible.

Water drawal of OTCW system is high compared to CT system. But , re-discharge level of water is less in OTCW, compared due to CT.

The Turbine efficienecy depends upon condenser vacuum which in turn depends on cooling water temperature. Cooling water temperature is lower in the case of OTCW. Conversion to CT system will reduce efficiency of the turbine by around 2%, which will further increase in coal consumption.

TPPs are using either sweet water or sea water. The new norm can be achieved in the case sweet water using TPPs. But it is not possible to achieve the new norms with CT & sea water. Since TDS in sea water is very high and hence it is estimated that 8.0m³/MWh or more is required. As such, all coastal TPPs shall require shutdown ultimately.

b) Major Technical Issues specific for Plants under Construction:

Plants under construction would have already finalized their specifications, configurations and prices with EPC / Subcontractors. The same had finalized after issuance of clearances from MoEF &CC. Any modification / changes in ESPs /FGD/SCR/CT during construction stage require design & layout changes, which invite huge unwanted cost on the project and delays schedule of completion.

Additionally, plants likely to be commissioned in the beginning of 2017 will be in a difficult position to implement the new norms, as the time requirement is very short. This will further delay the CoD of the plant and the same will affect warranty period and similar contractual conditions.

It is seen that Wet lime based FGD require additional water of the tune of 0.3m³/MWh. The water consumption limit may not be sufficient if FGD is installed to control SOx emission.

Time Limits: Timeline specified for the implementation of new norms is 31 Dec.2017.Design, finalization of modification works, shut down schedule, etc are important mile stones for implementing the new norms. Moreover, modification works in existing plant is more complicated and time consuming. Additional shutdown and temporary rearrangements of equipments are required to carry out the modification works.

This shows that implementation of new norms will be difficult to implement within short span of time.

c)Impact on Power Supply Position:

For existing power plants lots of retrofit works are required and long shutdown for meeting new norms

Plants under construction are required modification in design and change in scope of works. This also results in delayed completion of the project for meeting new norms.

Due to above reasons, the Power position in our country will be hampered by the implementation of new environmental laws for next two to three years. We, KSEBL is procuring power from outside and which is 80~90% of the total daily consumption. In addition to above, KSEBL is getting about 1350MW as central share for meeting daily power requirement. This share from Central Generating stations will be curtailed considerably during the retrofit works period and ultimately people in Kerala will be affected due to shortage of power.

d)Financial Aspects:

It is estimated that 1.0~1.5Cr/MW is required for implementing modification to achieve new norms of MoEF & CC. Also the above expenditure will be capitalized by the Utilities and directly reflect on FC and VC. Hence, each generator will be forced to revise existing PPA with DISCOM. Ultimately, the burden will be shared by the consumers in India.

Most of the equipments to be imported and hence huge outflow on foreign exchange will take place.

Plants with very low PLF will be forced for either permanent shutdown or increase Unit rate considerably to meet the expenditure on investment. Similarly for old stations having period of operation more than 15~20years will be difficult to recover investment for achieving new norms in their balance life period.

Availability of adequate vendors and suppliers as well as suitable consultants will be a challenge to all TPPs for meeting new norms. Lack of indigenous equipments and its spares will be a threat for the retrofit works to be done by old plants.

After the inaugural function, three technical sessions were conducted. In the Session-I, Executives of NTPC, TATA Power, STEAG Energy Services-Germany and WB State Elec. Regulatory Commission were presented paper. The main area of concentration was on retrofit options in the existing stations to achieve new norms and shared their experience.

In the Session –II, Executives of M/s Doosan Lentjes-Germany; M/s Japan Coal Energy Centre- Japan; Enexio-Hungary, M/s Shanghai Elec. India Pvt Ltd; etc were presented paper. The area of presentation was to installation of equipments to reduce NOx ; SO2 and water conservation measures.

In the Session-III, main concentration was on issues of Financing & Regulations. Exe. Director-PFC & Chief Engineer(CERC) had made presentations.

The seminar concluded at 18.30Hrs by the address of Mr. A Kumar, J.S., Thermal, MoP and J.S, Pollution, MoEF.

c) Conclusion

As far as KSEBL is considered both, KDPP & BDPP plants were commissioned before Dec.2003 an dhence the new norms are not applicable. Moreover each unit is less than 25MW. However, KSEBL is the beneficiary of many TPPs outside Kerala. Generation balance of KSEBL is being met by power from TPPs outside Kerala and hence generation balance is not possible to maintain without additional cost on power. Finally, Kerala may pay more cash to purchase power at higher rate for next three to four years. The additional investment for new norms will also to bear by the consumers in Kerala for the quantum of power purchase.

Sri. S.C. Shrivastava, CE(Engg), Central Electricity Regulatory Commission is also agreed to the problems actually facing by the TPPs for implementing new norms and agreed to present the same in CERC.

Extension of Blind Source Separation Model for Near Field Ground Borne Vibrations

Krishna Kumar M.
Kerala State Electricity Board Ltd.
krishnakumarkseb@gmail.com

Geethu R. S.
Dept. of Electronics & Communication Engg.
Amrita Vishwa Vidyapeetham-University,
Amritapuri Campus
geethurs@amritapuri.amrita.edu

Pramod K. V.
Dept. of Computer Applications
Cochin University of Science &
Technology, Cochin-22
pramod_k_v@cusat.ac.in

Introduction

Most of the Blind Source Separation (BSS) methods deal with the problem of air borne acoustic signals. These general frame works are not be optimal for the BSS of Ground Borne Vibrations (GBV). This paper presents an extension of general BSS model for the near field problem in ground borne vibration.

Blind Source Separation Model

Blind Source separation techniques are based on statistical concepts and aim at revealing the independent components hidden within a set of measured signal mixtures [1, 2, 3]. The term 'blind' means that the source signals are extracted from the rough data without much information about initial components. The methods are said to be versatile in the sense that the data can originate from various domains, and that no apriori knowledge is required about the physical phenomenon of interest [2]. The effect of BSS can be improved from overall knowledge of the mixing system [4, 5].

Consider a simple system with four sensors and four sources. The blind source separation can be stated into (1) to (4); given the source signals s_1, s_2, s_3 and s_4 the captured signals x_1, x_2, x_3 and x_4 at sensor P1 to P4 as:

$$x_1 = a_{11} s_1 + a_{12} s_2 + a_{13} s_3 + a_{14} s_4 \quad \textbf{(1)}$$

$$x_2 = a_{21} s_1 + a_{22} s_2 + a_{23} s_3 + a_{24} s_4 \quad \textbf{(2)}$$

$$x_3 = a_{31} s_1 + a_{32} s_2 + a_{33} s_3 + a_{34} s_4 \quad \textbf{(3)}$$

$$x_4 = a_{41} s_1 + a_{42} s_2 + a_{43} s_3 + a_{44} s_4 \quad \textbf{(4)}$$

a_{11} to a_{44} are constant coefficients that gives the mixing weights. They are assumed to be unknown, since the properties of the physical mixing system are not known. The source signals are also unknown. The original source signals are required to be found from the mixtures x_1 to x_4 .

This is the blind source separation problem. The Eq. 1 to Eq. 4 can be written as:

$$X = A \cdot S \quad \textbf{(5)}$$

The coefficients a_{ij} 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_i as:

$$Y = B.X \quad \textbf{(6)}$$

where y is as close to s as possible. B is the inverse of A [3, 4]

BSS for Near Field GBV

Ground vibration propagates through the soil or rock as waves. The amplitude of the waves generally decreases with distance from the source. The compressional waves or primary or P-waves, shear waves or secondary or S-waves, and Rayleigh waves or R-waves are the significant ground vibration waves, which propagate through different means and exhibit different behaviors [6]. We restrict our discussion to near field problem. The near field is the area very close to the source where the vibration pressure level may vary significantly with a small change in position. The area extends to a distance less than the wavelength of the lowest frequency emitted from the source, or at less than twice the greatest dimension of the source, whichever distance is the greater. Since the source sensor distance is small we consider only compression waves. In the case of ground borne vibration; the effect of signal damping is considerable and cannot be ignored as in the case of acoustic models[6,7,8]. The vibration propagation through the ground is a complex problem in elastodynamics. The complex problem in elastodynamics can be reduced to a simple acoustics problem by a method known as 'Ungar and Bender approach'. This method predicts the attenuation of vibration through soil with a simplified formula by neglecting all wave types except compressional waves. A general formula for vibration propagation with damping can be written as

$$S(r) = S(r_0)\, e^{-\omega\eta . r/2c}$$

where $S(r)$ is the vibration signal at source-receiver distance of r, $S(r_o)$ is the vibration signal at source-receiver distance of r_o, ù is the frequency in rad·s^{-1}, ç is the soil loss factor (which can be frequency-dependent) and c is the compressional or dilatational wave speed. The method does not allow any modification to account for unusual or complex situations. It is essentially a flat-ground model, which assumes only simplistic changes in soil type in the direction of propagation. This method is not ideally suited for use in situations where the soil is saturated, because the method neglects Biot waves. [7,9]

In the case of near field problem ù, ç, c are assumed to be constants. The equation can be re-written as

$$S(r) = S(r_o)\, e^{k.r}$$

where $k = -\omega\eta / 2c$

From the equation given above it is clear that the mixed signal is only depending on the source-sensor distance.

The BSS problem of ground borne vibration in this case can be given by

$$x_1 = e^{k.r11} s_1 + e^{k.r12} s_2 + e^{k.r12} s_3 + e^{k.r14} s_4 \quad \textbf{(7)}$$

$$x_2 = e^{k.r21} s_1 + e^{k.r22} s_2 + e^{k.r23} s_3 + e^{k.r24} s_4 \quad \textbf{(8)}$$

$$x_3 = e^{k.r31} s_1 + e^{k.r32} s_2 + e^{k.r33} s_3 + e^{k.r34} s_4 \quad \textbf{(9)}$$

$$x_4 = e^{k.r41} s_1 + e^{k.r42} s_2 + e^{k.r43} s_3 + e^{k.r44} s_4 \quad \textbf{(7)}$$

The original source signals are required to be found from the mixtures x_1 to x_4. The equation can be rewritten in the matrix form as

$$\boldsymbol{X} = \boldsymbol{K} \cdot \boldsymbol{S} \quad \textbf{(11)}$$

The element $e^{k.rij}$ of matrix K are assumed different enough to make the matrix that they form invertible. We can see that this is just the basic BSS model, $X = A.S$ with modified mixing matrix. We can estimate the independent component using any basic BSS algorithm. It should be noted that we get only damped estimates of the independent component.

We assume that the mixture is instantaneous. This is valid as the source-sensor distances are small. Neglecting the source noise and considering only sensor noise, the BSS model can be expressed as, $X=KS+n$ where n is the noise vector, and assuming zero-mean and uncorrelated Gaussian noise $n \sim N(0, diag(\Sigma))$ [4] The sensor noise can be filtered by any standard methods.

BSS of GBV using Weight Adjusted Second Order Blind Identification

Blind separation of sources with different spectra can be attained using second-order statistics. Weight Adjusted SOBI (WASOBI) is a typical second order BSS algorithm. This second-order blind identification (SOBI) algorithm uses approximate joint diagonalization. [10] A modified model of Second Order Blind Identification (SOBI) algorithm, Weight Adjusted SOBI rely on time-structures in the source correlation and 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 [11]. The proper weighting is inversely proportional to the covariance in the correlation estimates into AJD process. The weighting is asymptotically optimal for the case of Gaussian sources. WASOBI are based on approximate joint diagonalization of M time lagged estimated correlation matrices.

$$\hat{R}_x[\tau] = \frac{1}{N-\tau} \sum_{n=1}^{N-\tau} x[n] x^T[n+\tau]$$

$$\tau = 0,1, \ldots M-1$$

$$\tau = 0,1, \ldots M-1 \quad \textbf{(12)}$$

Where $x[n]$ denotes the n-th column of x[11]

$x[n]$

Field Data Collection

The experiment was conducted using four shakers as the signal sources. They produce low level stable vibrations. These sources can be modeled as point sources. The sensors were sensitive vibration sensors with 5 V/g at resonance. The signals are amplified using a low noise amplifier and converted to digital signals using an 18 bit ADC. The vibration signals from the sources four shakers V1, V2, V3 and V4 are recorded from the ground at various perpendicular distances from the line joining the sensors. Both the sensors and sources are buried in ground at a depth of 5 cm and the airborne noise is considered negligible. The signal processing and simulation is performed using MATLAB 7.3 We used 15 sets with 40000 samples for the experiments in each source-sensor distance [12,13] A general arrangement and data collection procedure for data acquisition is shown in the figure 1.

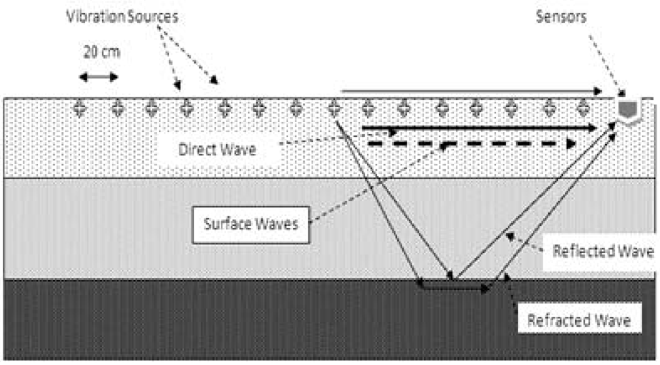

Fig 1: General Arrangement of field data Collection

Performance of Measures of Algorithm

Performance index

The performance indices for separation resemble Amri's index and work properly when the sources are normalized to unit variance.

The Performance Index (PI), is defined by (13) [14]

$$PI = \frac{1}{n(n-1)} \sum_{i=1}^{n} \left\{ \left(\sum_{k=1}^{n} \frac{|w_{tk}|}{max_j|w_{ij}|} - 1 \right) + \left(\sum_{k=1}^{n} \frac{|w_{ki}|}{max_j|w_{ji}|} - 1 \right) \right\} \quad (13)$$

Where w_{ij} is the (i,j)th element of the global system matrix W. The term $max_j |w_{ij}|$ is the maximum value along the ith row of W and $max_j |w_{ji}|$ is the maximum value of the ith column of W. When perfect separation is achieved PI is zero. In practice this is too optimistic.

Signal to Interference Ratio

The ratio of the useful signal power to the interference power that determines the performance of the separating system. This performance index could be used for full-rank or non-full rank analysis. The SIR is defined as for each pair of signals (y_i, s_j) [15,16]

The coefficients a_{ij} 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_i as

$$SIR\_S_{ij} = -10 \log 10 \left(\frac{\|y_i - s_j\|_2^2}{\|s_j\|_2^2} \right) \quad \textbf{(14)}$$

The one component estimation, we have

$$y_i = w_i^T X = (w_i^T A)S = g_i S = g_{ij} s_j$$

where $\mathbf{y}_i$ and $\mathbf{s}_j$ are the estimated component and the *j*-th source, respectively; w_i^T is a row vector of demixing matrix **W**, g_i is a normalized row vector [0 0 g_{ij} 0 0]. Because $\mathbf{y}_i$ is the estimation of $\mathbf{s}_j$, the ideal normalized vector is the unit vector = [0 0 …1 …0]. Therefore, one analysis is successful if and only if its vector similar to one unit vector

Actually, vector $\mathbf{g}_i$ is one row of matrix **G**. So, the quality of each estimated component just depends on one row of matrix **G**. The more different each row of G is to each corresponding unit vector of R^{NxN}, the less quality of output we have.

The expression which evaluates the succeed of one component separation is defined as

$$SIR\_g = -10 \log 10 \left(\|g_i - u_j\|_2^2 \right)$$

For the problem of multi – component estimation, the general procedure will be done as follows:With each row vector w_i^T of matrix W, we find the corresponding value of SIR and the order of the most matchable component of the sources.

Discussions

Table 1 shows the PI of separability for various source sensor distances. The plot of the Mean SIR of separated components with WASOBI algorithm applied to the extended model for various source-sensor distances is shown in the figure 2 . The mean SIR shows variations that is not uniform with source sensor distance. The trend shows a linear decrease in the Signal to Interference ration. The Performance Index of separability for various source sensor distance is plotted in the figure 3.The trend shows a linear decrease in performance of separabilty with distance. It should be note that the lesser the value of PI better the separation.

Conclusion

The extended model of BSS for GBV was introduced and proved in this paper. A novel method for field data collection based in seismic refraction test was used for data collection The BSS for GBV signal based on the extended model was performed using WASOBI method and the results were analyzed.

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	Source Sensor Distance in cm										
	20	40	60	80	100	120	140	160	180	200	220
WASOBI	0.05929	0.12871	0.1895	0.171	0.19433	0.21664	0.22685	0.23767	0.27476	0.20085	0.24338
	0.10703	0.17405	0.21094	0.16954	0.17311	0.2293	0.26728	0.21357	0.28066	0.2262	0.23415
	0.07652	0.12596	0.2463	0.16816	0.18604	0.17717	0.26528	0.24645	0.31308	0.24221	0.33117
	0.0578	0.15736	0.2643	0.19342	0.19245	0.15206	0.28589	0.20668	0.32675	0.29374	0.25372
	0.06202	0.15991	0.22658	0.16679	0.2264	0.18347	0.27653	0.22612	0.26243	0.29101	0.22894
	0.06452	0.19641	0.22852	0.15901	0.21587	0.1798	0.29984	0.22486	0.06452	0.25326	0.26635
	0.06473	0.18829	0.25149	0.19032	0.20541	0.17247	0.2924	0.22214	0.2721	0.28479	0.23612
	0.07265	0.14935	0.24012	0.18161	0.1988	0.16696	0.24492	0.20975	0.27674	0.32775	0.24772
	0.28877	0.14287	0.21861	0.188	0.18629	0.17088	0.23226	0.22205	0.27204	0.31755	0.22161
	0.19112	0.17059	0.2342	0.15124	0.20538	0.18991	0.30755	0.21231	0.25111	0.31638	0.3307
	0.0625	0.17949	0.24584	0.18946	0.21095	0.18721	0.32359	0.21655	0.27206	0.32254	0.22238
	0.05706	0.17386	0.243	0.17648	0.17756	0.17551	0.33552	0.19619	0.25796	0.3459	0.25888
	0.07155	0.19858	0.23632	0.17018	0.17515	0.19897	0.31353	0.21082	0.26049	0.35405	0.2468
	0.12955	0.19337	0.23534	0.17929	0.19507	0.16004	0.21333	0.23324	0.31159	0.28878	0.20513
	0.0989	0.18788	0.25158	0.16995	0.19963	0.17516	0.33663	0.21839	0.29547	0.29254	0.25253
	0.0976	0.16844	0.23484	0.17496	0.19616	0.18237	0.28143	0.21979	0.26612	0.2905	0.25197

Table 1: The performance index of separability for various source sensor distances

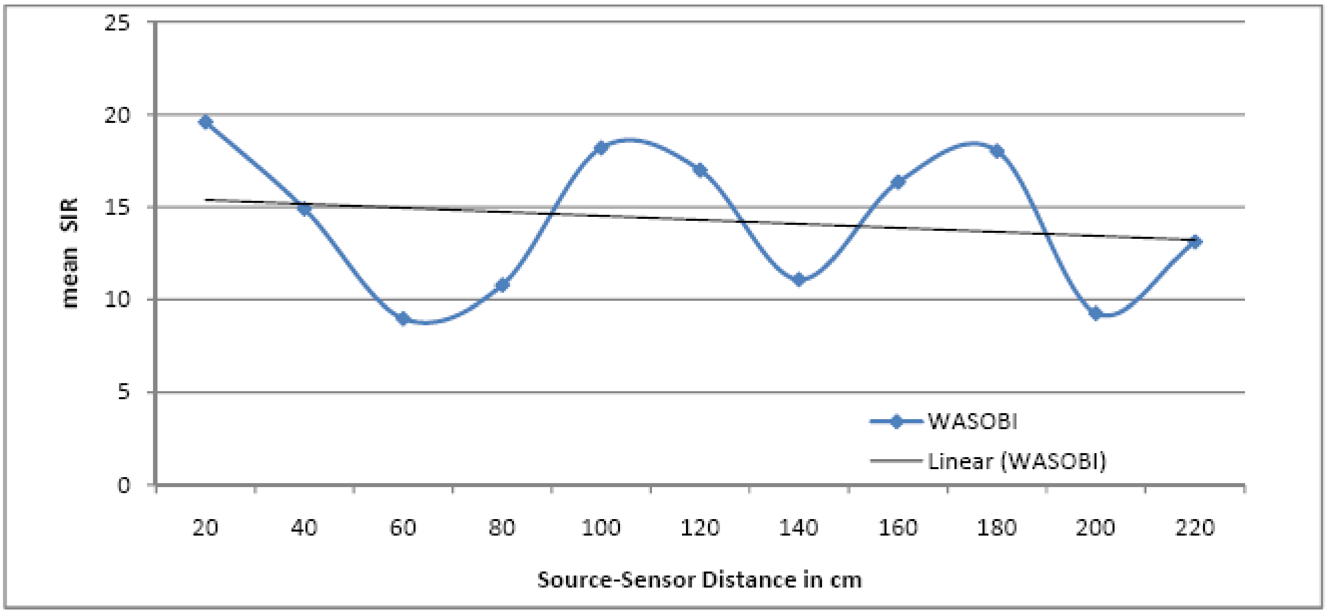


Fig 2: Mean SIR of separated components with WASOBI algorithm for various source-sensor distances

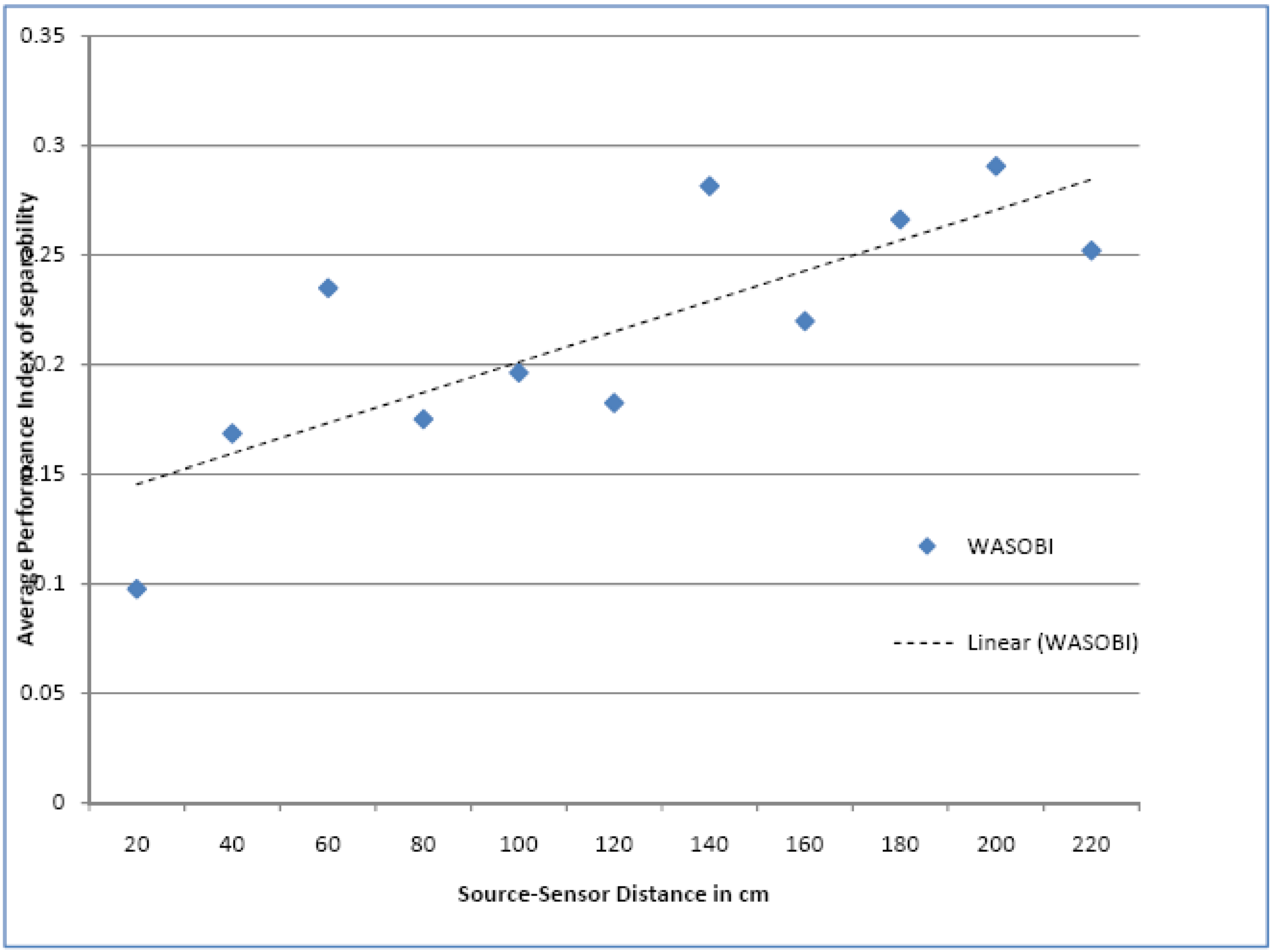


Fig 3:The performance Index of separability for

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.

DISTRIBUTION AUTOMATION SYSTEM

VINEETH V. V.
Assistant Engineer
Regional IT Unit Kozhikode

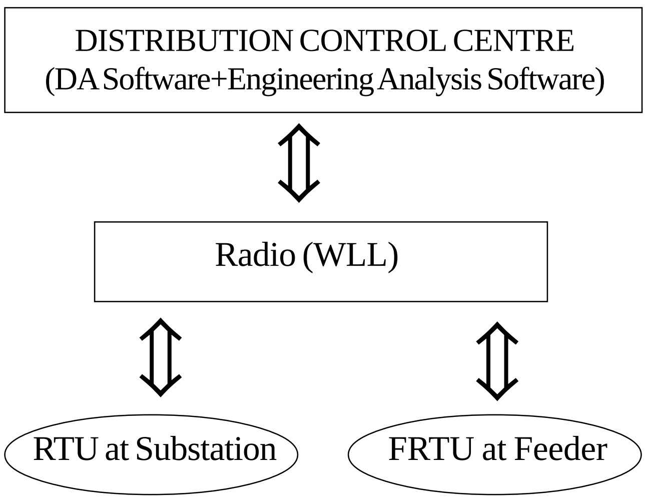
The Distribution Automation in the distribution field allows utilities to implement flexible control of distribution systems, which can be used to enhance efficiency, reliability, and quality of electric service. Presently, worldwide research and development efforts are focused in the areas of communication technologies revolution and application of **IEC 61850 protocol** in the distribution automation to make distribution automation more intelligent, efficient and cost effective. The Efficient operation and maintenance of distribution system are hampered by non-availability of system topological information, current health information of the distribution components such as distribution transformers and feeders, historical data etc. Other reasons include the lack of efficient tools for operational planning and advanced methodology for quick fault detection, isolation, and supply restoration, etc. All these lead to the increased system losses, poor quality and reliability of power supply in addition to the increased peak demand and poor return of revenue.

The application of automation in distribution power system level can be define as automatically monitoring, protecting and controlling switching operations through intelligent electronic devices to restore power service during fault by sequential events and maintain better operating conditions back to normal operations. The distribution automation system is not just a remote control and operation of substation and feeder equipment but it results into a **highly reliable, self-healing** power system that responds rapidly to real-time events with appropriate actions and this automation does not just replace manual procedures; it permits the power system to operate in best optimal way, based on accurate information provided in a timely manner to the decision-making applications and devices.

The Distribution Automation System encompasses data acquisition, telemetry and decision making system. It involves collecting information, transferring it to a Control Centre, displaying the information and carrying out analysis for control decisions and improvement in system operation. The control action is then initiated either through remotely operable devices or manually. A typical Distribution Automation System is composed of field instruments,remote terminal units, communication systems and distribution automation software.

The field instruments connected to the equipment being monitored and controlled are interfaced to a **Local Unit** that allows data manipulation and help in implementing control action in the field. Another key function of this unit is to gather data from the equipments and transfer it to the Control Centre. Normally local unit at Substation is called **Remote Terminal Unit (RTU)** and Feeder is called **Feeder Remote Terminal Unit (FRTU)**.

The Communication System is required to communicate data from Control Centre to various remote terminal units and vice versa. Essentially, the communication system refers to the communication equipment and interface needed to transfer data between Control Centre and different remote terminal units. Thus, the point to multi-point communication is an inherent need of DA system. The communication media can either be wired or wireless.



Analog: CTs,PTs
Status: all switches
Control: CB & Isolator

Analog: CTs,PTs
Status: all switches
Control: CB & LBS

There are two key software elements in the Control Centre.

1. Master Distribution Automation Software.
2. Engineering Analysis Software.

The master Distribution Automation Software acquires the system data (both static and dynamic) and converts it into an information system. The Engineering Analysis Software provides the control decision utilizing the system information, available at the Control Centre. The decision making feature of the distribution automation distinguishes it from the normal SCADA (Supervisory Control and Data Acquisition) system. The engineering analysis software for network re-configuration, load shedding, volt-var control through capacitor switching, and fault detection,isolation and supply restoration can be developed and integrated with the master Distribution Automation Software.

RTU at Substation

Microprocessor based Substation RTU fabricated using standard input/output cards used to control 11kV & 33kV substation breakers. The above mentioned acquired data (voltage and current) through a multi function transducer and it will give more than 15 output values like power factor, frequency,export,import etc. A command from the control centre will reach to the RTU by using **IEC 60870-5-104 or DNP3 protocol** to operate the switches and the status change will report to control centre.

FRTU at Feeder

Microprocessor based and pole-top Feeder RTU is provided with enclosure of IP-55 protection fabricated using standard input/output cards used to control Air break type Load Break Switch at 11kV feeders or Load Break Switch in the 11kV RMU (Ring Main Unit). The acquired data (voltage and current) through a multi function transducer and it will give more than 15 output values like power factor, frequency,export,import etc. A command from the control centre will reach to the FRTU by using **IEC 60870-5-104 or DNP3 protocol** to operate the LBS and the status change will report to control centre.

The next stage of DA is Distibution Management System (DMS) is an integral part of Smart Grid. The DMS for any utility is a mission-critical tool. It is the tool that operators use for command control of valued assets, optimize the life or output of those assets and to maintain the highest degree of reliability for their customers. A DMS solution creates the context to tightly integrate tools and systems addressing different aspects of the distribution operator’s work tasks, including Outage Management Syatem (OMS), Mobile work force management (MWFM), Distribution network analysis (DNA), Distribution supervisory control and data acquisition (D-SCADA).

National Energy Conservation Day - 14th of December

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

MICROGRID WITH DISTRIBUTION AUTOMATION SYSTEMS FOR RELIABILITY ENHANCEMENT

Nowshad A.[1], **S. Arul Daniel** [2] and **Krishna Kumar M.**[3]

[1] *Dept. of Electrical and Electronics Engineering, TKM College of Engineering, Kollam-5,* *nowshadalatheef@gmail.com*

[2] *Dept. of Electrical and Electronics Engineering, National Institute of Technology, Thiruchirappalli* *daniel@nitt.edu*

[3] *Assistant Engineer, KSEB Ltd.* *krishnanow@gmail.com*

Abstract

Reliability indices viz. System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average interruption Duration Index (CAIDI), Average Service Availability Index (ASAI), Average Service Unavailability Index (ASUI), etc. are measures of system wide reliability provided by an electricity distribution utility. These indices also indirectly indicate the utility's Operations and Maintenance (O&M) efficiency, system's ability to transfer load to the neighbouring units in case of cable or equipment failures, response time to locate and isolate a fault and restoration time. In this project a detailed description is given for improving the reliability of the distribution utility. The improvement in reliability by suitable interventions is ascertained by the improvement in reliability indices. An attempt is made for identifying suitable components for improving reliability indices, placement of different components, operation of different components and computation of reliability indices after the introduction of microgrid etc. have been carried out in this work. Case studies are presented to bring out the usefulness of the proposed approach.

Keywords: Reliability Indices, Microgrid, DA Components.

I. INTRODUCTION

The distribution system is a part of the power system that links the generation source to the consumer. The reliability of the distribution system plays a vital role in ensuring continuity of supply to the consumers. Therefore, evaluation of reliability is important for utilities as they try to provide supply with optimal reliability within economic constraints. A fault in one or more components of the distribution network can affect reliability. A failure in one network component can interrupt power to a large number of consumers. The duration of this outage will depend on possibility of restoring supply from an alternate source. If the faulty part can be isolated and supply restored, the outage duration will be shorter than the duration if no alternate supply route is available. Thus, reliability of distribution networks is dependent on frequency of faults and their duration [1].

This paper presents the reliability studies on one sub-station and one distribution automation project centre in the state of Kerala, India. A number of system indices such as SAIFI, SAIDI, CAIDI, ASAI, and ASUI are computed for a real radial distribution system. The project also investigates the improvement in reliability indices by employing microgrids with automation in the distribution network.

Reliability indices viz. System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average interruption Duration Index (CAIDI), Average Service Availability Index (ASAI), Average Service Unavailability Index (ASUI) etc. are measures of system wide reliability provided by an electricity distribution utility[1]. These indices also indirectly indicate the utility's Operations and Maintenance (O&M) efficiency, system's ability to transfer load to the neighbouring units in case of cable or equipment failures, response time to locate and isolate a fault and restoration time.

1.2 OBJECTIVE OF THE PAPER

The objective of this paper is to propose a method for improving the reliability of an electrical sub-station by employing microgrid with distribution automation system (DAS). This is to achieve increased simplicity in 11 KV network operation & control, faster fault location, isolation, and service restoration. It also calls for supply reliability improvement, reduction of losses in the system and improved voltage profile due to feeder rearrangement.Improvement in quality of service, equipment availability, manpower saving in operation and maintenance can be achieved. In order to use technology advancement in network management and to have better tools for short term and long term distribution planning.

1.3 ORGANISATION OF THE PAPER

In section 2, the practical system data of the Mavelikkara sub-station of Kerala State Electricity Board (KSEB) used for the study, is presented. Section 3 gives the reliability indices calculation of the sub-station. A detailed discussion of the result and proposal for reliability improvement is given in section 4. Section 5 concludes the paper.

2. SYSTEM DETAILS

The 110 kV distribution sub-station at Mavelikkara consists of two numbers of 40 MVA, 110 kV/66 kV transformers, three numbers of 10 MVA, 66 kV/ 11kV transformers. Two numbers of 110 kV incoming feeders, seven numbers of 66 kV feeders running to 66 kV sub-stations, three numbers of 11 kV incomers, eight numbers of 11 kV outgoing feeders and one 11 kV auxiliary feeder for station supply. This area has approximately 40,000 consumers served through overhead and underground distribution feeders. The customer mix is mostly residential and small commercial, the feeders are radial and mostly overhead. Given the characteristics of the customers and their sensitivity to interruptions, the main goal pursued in this paper was achieving SAIDI (reducing customer interruption duration).

3. CALCULATION OF RELIABILITY INDICES

As a first step, one year interruption data is collected from 110 kV sub-station Mavelikkara. Reliability indices SAIFI and SAIDI are calculated from the interruption data under the present operating condition. Table 3.1 shows one year interruption data for the period August 2011 to July 2012. Table 3.1 tabulates one year interruption data for the period between August 2011 and July 2012. Table 3.2 shows the reliability indices SAIFI and SAIDI of 11 kV incoming and outgoing feeders for scheduled and un-scheduled interruptions between August 2011and July 2012. The unscheduled interruptions are the interruptions of the power supply due to the 11 kV feeder fault as a result of earth fault and over current fault. The scheduled interruption includes the momentary switch offs given to the feeder managers to isolate a portion of the line by opening an AB switch or to put a portion of feeder back to service by closing the AB switch after clearing a fault condition or maintenance. This also includes the 'permit to work' issued to the feeder managers on request to carry out a maintenance work, which can be a pre-planned or contingency maintenance.

Name of feeder	Number of scheduled Interruption	Duration of scheduled Interruption(s)	Number of unschedule dInterruption	Duration of un-scheduled Interruption(s)	Number of interruption/ duration(min)
11 kV Incomer no:1	21	2161	2	64	23/37.082
11 kV Incomer no:2	20	2646	2	8	22/44.233
11 kV Incomer no:3	28	9449	8	136	36/159.746
11 kV Olakety	572	7573	208	2393	780/166.099
11 kV Chenganoor	537	7069	242	3601	779/177.832
11 kV Pathiyoor	479	9115	273	4297	752/223.53
11 kV Kayamkulam	544	6500	207	2051	751/142.513
11 kV Mannar	574	9280	305	4456	879/228.932
11 kV Thatarambalam	474	8762	240	3079	714/197.349
11 kV Mavelikara	516	7616	869	2977	785/176.549
11 kV Chennithala	541	6816	301	2424	842/154

Table 3.1 The one year interruption data for the period between August-2011 and July-2012 of 110 kV Substation, Mavelikara

Name of feeder consumers	Total no: of duration(min)	Number of interruption/	SAIFI	SAIDI
Incomer no:1	9250	23/37.082	0.00238	0.0040089
Incomer no:2	14000	22/44.233	0.00157	0.0031595
Incomer no:3	13700	36/159.746	0.00263	0.0116602
11 kV Olakety	3950	780/166.099	0.19746	0.0420504
11 kV Chenganoor	4750	779/177.832	0.16400	0.0374383
11 kV Pathiyoor	5000	752/223.532	0.1504	0.0447064
11 kV Kayamkulam	4000	751/142.513	0.18775	0.0356283
11 kV Mannar	4500	879/228.932	0.19533	0.0508738
11 kV Thatarambalam	5500	714/197.349	0.12982	0.0358816
11 kV Mavelikara	4500	785/176.549	0.17444	0.0392331
11 kV Chennithala	4750	842/154	0.17726	0.0324211

Table 3.2 SAIFI and SAIDI of 11 kV incoming and outgoing feeders for scheduled and un-scheduled Interruptions (Aug 2011-Jul 2012)

2. RESULTS AND DISCUSSION

A complete automation system for fault detection, identification, isolation, and clearing and electricity restoration has been developed. The proposed system has detecting relays which detect the faults, RMU, automatic switches, circuit breaker, RTU and fully developed SCADA and software system for controlling, operating and monitoring the distribution system. Whenever the supply is failed the alternate supply can be availed by microgrid through the RMU, which have two supply inputs available, one is the normal supply and other is the distributed energy resources (DERs).

The average time for fault detection, isolation and restoration without Distribution Automation system is assumed to be 30 minute and from the above data the total number of consumers per feeder is 5000. From the above data SAIDI = 30/5000 = 0.006. The average time for fault detection, isolation and restoration with DA is 3 minute and the corresponding SAIDI = 03/5000 = 0.0006. So from this we obtained the improvement in SAIDI = ((0.006 – 0.0006) / 0.006) *100 = 90%. With Full Loop scheme, mid-circuit re-closers & RMU, SAIFI can be improved by 50%.

For the last decade Kerala is a water surplus energy surplus State and in the present scenario the state is in a water deficient energy deficient situation. So the generation of electrical energy from distributed energy resources is necessary for meeting the increased demand.

4.1 PROPOSED DISTRIBUTION AUTOMATION SYSTEM

Loop distribution system is the most widely used distribution configuration of any modern system [2]. Figure 4.1 shows the proposed full loop scheme feeding from both ends with mid-circuit re-closers and Ring Main Unit (RMU).

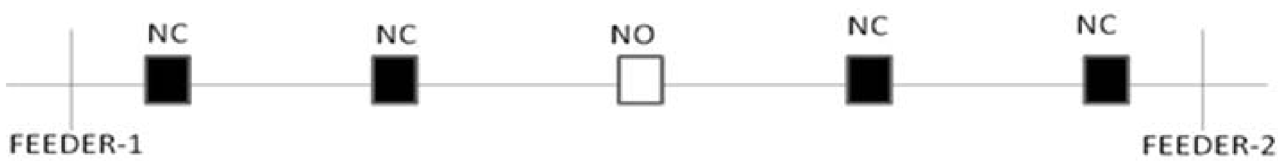


Fig: 4.1 Full loop schemes with reclosers

Name of feeder	Number of	SAIFI interruption/ duration(min)	SAIDI W/O LS	SAIDI With L/S(1 Hr)	SAIDI With MG	NO: OF CUSTOMERSJ
Incomer no:1	23/37.082	0.00238	0.00400886	0.00400886	0.00400886	9250
Incomer no:2	22/44.233	0.00157	0.0031595	0.0031595	0.0031595	14000
Incomer no:3	36/159.746	0.00263	0.0116602	0.0116602	0.0116602	13700
11 kV Olakety	780/166.099	0.19746	0.0420504	5.586354	0.31926	3950
11 kV Chenganoor	779/177.832	0.16400	0.0374383	4.6479646	0.26796	4750
11 kV Pathiyoor	752/223.532	0.1504	0.044706	4.4247064	0.263706	5000
11 kV Kayamkulam	751/142.513	0.18775	0.0356283	5.5106283	0.309378	4000
11 kV Mannar	879/228.932	0.19533	0.0508738	4.9175404	0.294207	4500
11 kV Tatarambalam	714/197.349	0.12982	0.0358816	4.0176998	0.234972	5500
11 kV Mavelikara	785/176.549	0.17444	0.0392331	3.923311	0.282566	4500
11 kV Chennithala	842/154	0.17726	0.0324211	4.6429474	0.262947	4750

Table 4.1 SAIFI and SAIDI of 11 kV incoming and outgoing feeders for scheduled and un-scheduled Interruptions (Aug 2011-Jul 2012)

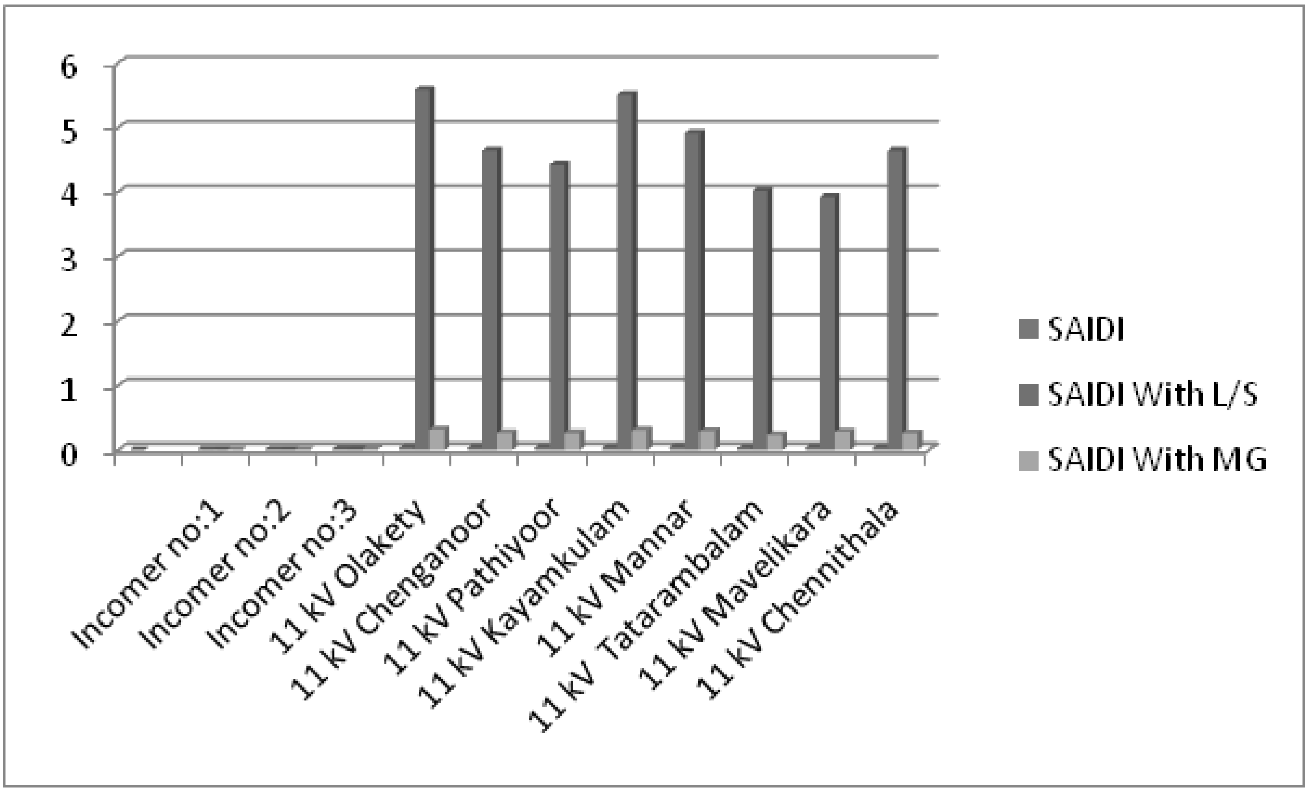


Fig. 4.2 The histogram showing the improvement in SAIDI, SAIDI with L/S & SAIDI with MG

Name of feeder	CAIDI W/O L/S	CAIDI with L/S	CAIDI with MG	ASAI W/OL/S	ASAI with L/S	ASAI with MG	ASUI W/OL/S	ASUI with L/S	ASUI withMG
Incomer no:1	1.6858	1.6858	1.6858	0.9999	0.999929	0.9999	0.0000706	0.0000706	0.0000706
Incomer no:2	2.0111	2.0111	2.0111	0.9999	0.999916	0.9999	0.0000842	0.0000842	0.0000842
Incomer no:3	4.4369	4.4369	4.4369	0.9818	0.999696	0.9997	0.000304	0.000304	0.000304
11 kV Olakety	0.213	14.613	0.8352	0.981	0.958017	0.9976	0.0189611	0.0419827	0.0023994
11 kV Chenganoor	0.2283	14.631	0.8435	0.9997	0.957995	0.9976	0.0003383	0.042005	0.0024217
11 kV Pathiyoor	0.2973	14.928	0.8897	0.9996	0.957908	0.9975	0.0004253	0.042092	0.0025087
11 kV Kayamkulam	0.1898	14.884	0.8356	0.9997	0.958062	0.9976	0.0002711	0.0419378	0.0023545
11 kV Mannar	0.2605	13.753	0.8228	0.9996	0.957898	0.9975	0.0004356	0.0421022	0.0025189
11 kV Tatarambalam	0.2764	15.303	0.895	0.9996	0.957958	0.9975	0.0003755	0.0420421	0.0024589
11 kV Mavelikara	0.2249	11.653	0.8393	0.9997	0.957997	0.9976	0.0003359	0.0420026	0.0024193
11 kV Chennithala	0.1829	14.029	0.7945	0.9997	0.95804	0.9976	0.000293	0.0419597	0.0023764

Table 4.2 CAID, ASAI and ASUI of 11 kV incoming and outgoing feeders for scheduled, un-scheduled and load

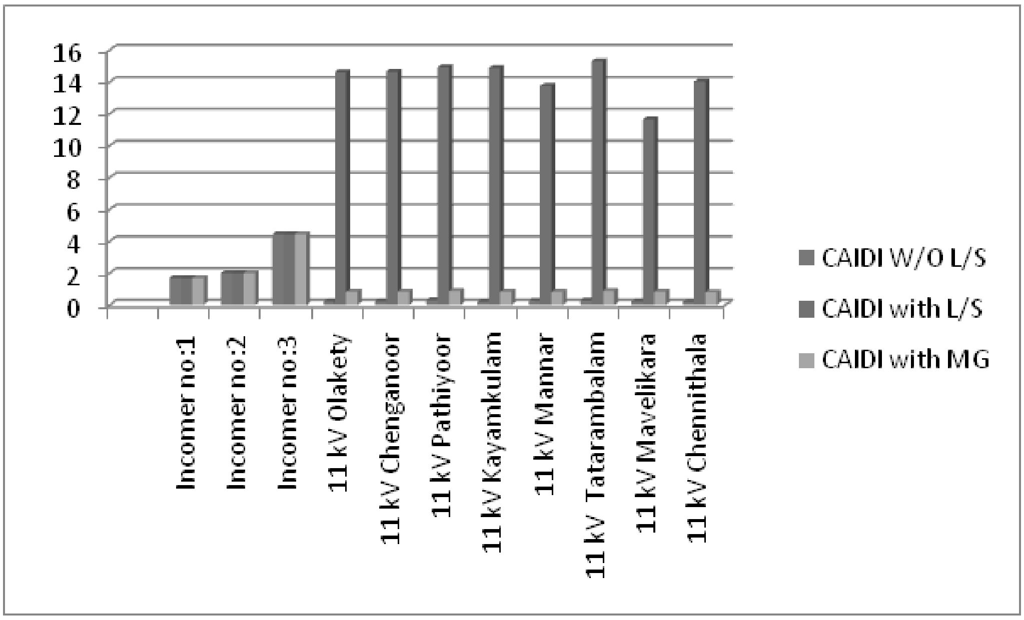


Fig. 4.3 The histogram showing the improvement in CAIDI, CAIDI with L/S & CAIDI with MG

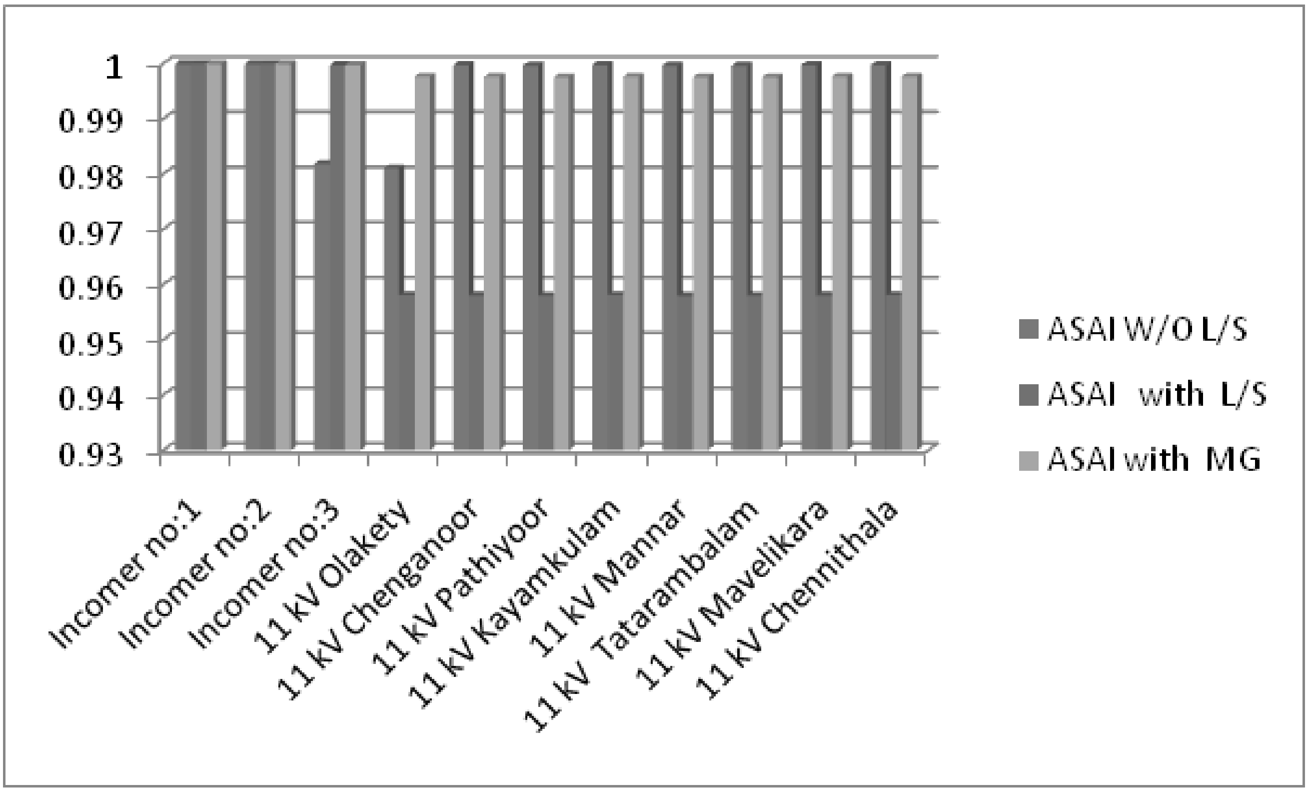


Fig. 4.4 The histogram showing the improvement in ASAI,

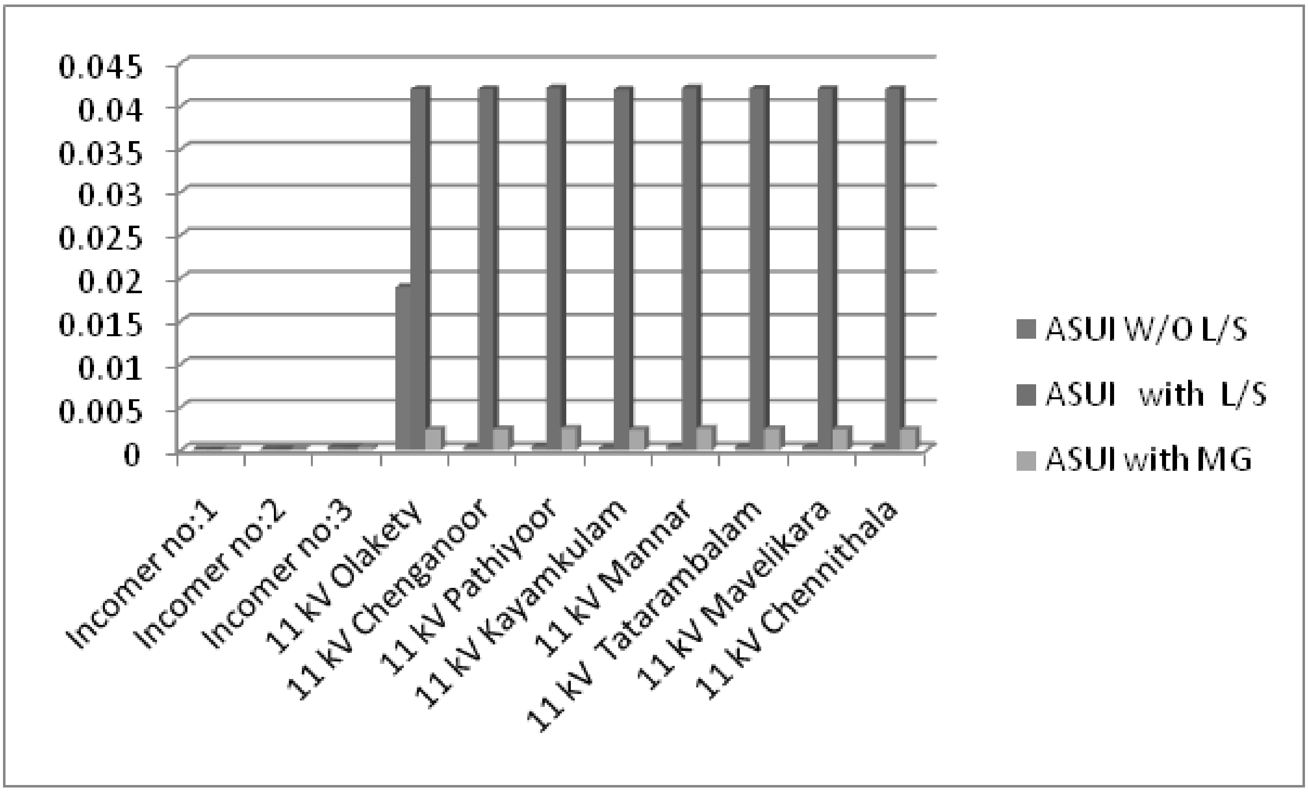


Fig. 4.5 The histogram showing the improvement in ASUI, ASUI with L/S & ASUI with MG

In this study the reliability is calculated for an automated sub-station and the reliability indices obtained have wide variation from the actual value. This is because after a feeder is declared faulty , the utility engineers has to isolate the faulty feeder by opening Air-Break switch and charge the healthy portion from the sub-station. Depending on the fault location and nature of fault, restoration time may vary from sever minutes to hours .The interruption data taken from the sub-station does not give the actual duration of fault and the actual number of consumers affected by the fault.

If the interruption data of the feeders at various locations is made available, then the reliability of the distribution system can be improved considerably by employing the proposed distribution automation system.

2. CONCLUSION

This paper has presented the methodology and procedures used for improving the reliability of a distribution system by introducing microgrid technology in an automated environment. The Microgrid technology that integrates distributed generation systems, energy storage device and load together is an effective way to solve the problems of large-scale distributed power generation system to network. The reliability indices SAIFI, SAIDI, CAIDI, ASAI and ASUI are calculated using one year interruption data of a real utility under the normal operating condition. The improvement in reliability indices SAIFI, SAIDI, CAIDI, ASAI and ASUI are calculated by introducing microgrid technology with distribution automation.

3. ACKNOWLEDGEMENT

The authors would like to thank Member (T&GO) and other officers of Kerala State Electricity Board for giving permission and their help to carry out the study in the 110 kV Substation, Mavelikara and at Distribution Automation Project For Thiruvananthapuram City, Joint Project by Dept. of Information Technology, Kerala State Electricity Board & CDAC Thiruvananthapuram.

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15. 11kV Feeder Interruption data and other related information from 110 kV Sub-Station Mavelikara , Kerala, India

Distribution Automation Project For Thiruvananthapuram City, Joint Project by Dept. Of Information Technology, Kerala State Electricity Board & CDAC Thiruvananthapuram.

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.

Earth Hour

Earth Hour is a worldwide movement for the planet organized by the World Wide Fund for Nature (WWF). The event is held worldwide annually encouraging individuals, communities, households and businesses to turn off their non-essential lights for one hour, from 8:30 to 9:30 p.m. on the last Saturday in March, as a symbol for their commitment to the planet. It was famously started as a lights-off event in Sydney, Australia in 2007. Since then it has grown to engage more than 7000 cities and towns worldwide. Today, Earth Hour engages a massive mainstream community on a broad range of environmental issues. The one-hour event continues to remain the key driver of the now larger movement.

A Case Study on Different Lighting Systems

Sreeram K (PG Scholar)

Dept. of Electrical and Electronics Engineering,
Rajagiri School of Engineering and Technology,
Rajagiri Valley P.O, Kochi-682039, Kerala , India
Email:sreeramk65@gmail.com,Contact No:8138822376

Mr. Unnikrishnan L

Dept. of Electrical and Electronics Engineering,
Rajagiri School of Engineering and Technology,
Rajagiri Valley P.O, Kochi-682039, Kerala , India
Email:unnikrishnan4u@gmail.com,Contact No:8891801885

Abstract—**Techno-economic performance comparison of Compact Fluorescent Lamps (CFL) with Light Emitting Diodes (LED), fluorescent tubes, incandescent bulbs was carried out in view of worsening power and energy crisis. However, tubes, LED, CFL and External Electrode fluorescent lamps (EEFL) lamps worsen electric power quality of low voltage networks due to high current harmonic distortions (THD) and poor power factors (PF). Fluorescent lamps emit UV and pollute environment by mercury and phosphors when broken or at end of their life cycle. Energy consumption, bio-effects, and environmental concerns prefer LED lamps over phosphor based lamps. Costs of low THD and high PF CFL, EEFL and LED lamps may be five to ten times higher that high THD and low PF lamps. Choice of a lamp depends upon its current THD, PF, life span, energy consumption, efficiency, efficacy, color rendering index (CRI) and associated physical effects. This work proposes manufacturing and user level innovations to get rid of low PF problems. Keeping in view downside of phosphor based lamps our research concludes widespread adoption of LED lamps. Government and commercial buildings may consider full spectrum hybrid thermal photovoltaic and solar fiber optic illumination systems.**

IndexTerms— ***CFL, LED** , **THD**, **Efficacy***

I. Introduction

Lighting is an essential part of everyday life. Lighting or illumination is the deliberate use of luminosity to achieve a practical effect. Lighting includes natural illumination as well as artificial sources like lamps. Proper lighting can have positive psychological effects on occupants and increases one's ability to perform tasks. It is indeed a fact that lighting accounts around 40 % of the world's total energy consumption.Lamp cost depends on its rated power, current THD, PF, life, efficiency, efficacy, CRI and environmental effects. Two lamps of same rated power (10 W), 82 CRI, 2700 CCT, 520 lumens output may cost $9–10 for 8000 h life, high current THD and low PF or $40–50 for 12,000 h life, low current THD and high power factor.No doubt, CFL and LED lamps save energy but the energy conservation factors projected by the manufacturers are often overstated. CFL starting inrush current is 20–100 times higher than the steady state current. Bulbs are cheaper but their efficacies and efficiencies are much poorer than CFL, fluorescent tubes and LED lamps. Tube, CFL, LED and EEFL power requirements are 4.35–5 times lower than bulbs for the same luminous flux. A 100W bulb produces same luminous flux as 18W fluorescent tube, 23W CFL, 15W LED or 21W EEFL lamp.Bulb life (1000 h) is much shorter than tube (5000 h), CFL (10,000 h), LED (50,000 h) and EEFL (100,000 h).

II. DIFFERENT LIGHTING SOURCES

Lighting system is categorized as Direct Lighting, Indirect Lighting and Direct/Indirect Lighting. Various types of lamps used in domestic and industrial lighting are incandescent lamps (GLS), fluorescent lamps (FL), T 12 lamps, T 5 lamps, compact fluorescent lamps (CFL), light emitting diodes (LED), mercury vapour lamps, sodium vapour lamps, halogen lamps and others. Among these the major portion of domestic lighting is through GLS, CFLs,Tube lights, while the other three contribute a major portion in industrial lighting. A new lighting technology has been evolved as light emitting diodes (LEDs) that can be over 10 times more efficient than conventional-old incandescent lamps. The efficient use of artificial lighting can provide energy as well as cost savings. There can be several measures that can be taken for energy savings. By controlling the lighting in such a way that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency . Light sources which provide significantly more light or lumens per unit of energy consumption can be used. Another method is to replace older fixtures or lamps with the new and more improved lamps which can definitely improve efficiency.

A. *Incandescent lamps or GLS*

It is the oldest and very common lamp used in homes, indoors and outdoors especially in rural areas. Of the common lamps, it is the most inefficient. It emits light by heating a filament of wire which glows white hot when a current is flown through it. It produces and emits much heat as compared to the amount of light. In actual, only 8-10 percent of the energy is utilised in producing light. This bulb is often used, especially in a fixture that actually controls the light output rather than scattering it everywhere.

B. *Fluorescent lamps*

These lamps are almost four to five times more efficient than

incandescent lights. They are nowadays most widely used for indoor applications. Energy saving is achieved because they are lower wattage lamps and provide more lumens. It means

wattage rating of these lamps reduce giving the same lumens output as of incandescent lamps. The objective is to provide maximum light output with minimum energy consumption.

Fluorescent lamps are of different types such as Compact Fluorescent Lamps (CFLs), tubelights or tube lamps which are further classified into T 5, T 8 and T 12. Among these T 12

lamps are the oldest and most energy inefficient. They have the largest tube diameter also and are heavy. T 8 or T 9 lamps are comparatively new and even have less tube diameter. They

are more efficient than the older ones. The most efficient and most compact among these are T 5 lamps. These are light and have less tube diameter.

C. LED Lamps

An LED lamp is a LED unit that is fitted into a lamp for lighting purpose.LED lamps have greater lifespan and much more efficiency than other lamps. LEDs have more efficacy than incandescent bulbs. Incandescent or fluorescent lamps often need an external reflector to collect light and direct it in a usable manner. LEDs are ideal for use where frequent on-off cycling is required. LEDs are very expensive which is the biggest disadvantage, but the payback period of installation is very less. The additional expense is due to low lumen output and the drive circuitry and power supplies needed. LED based lamp technology is relatively new as compared with conventional lamps

III. LIGHTING TERMS AND DEFINITIONS

A. power factor

Lagging PF loads are a nuisance but leading power factor are welcome due to overall lagging PF system. Utilities often try to maintain system PF from 0.85 to 0.95. Low PF loads require utility increasing apparent power to be able to supply small real power loads. Same rated supply can feed 90–95 kW load at unity PF compared to 50 kW load at 0.5 PF. Term PF reflects efficiency of an electrical power distribution system. Loads that cause poor power factor include induction motors, arc furnaces, machining, stamping, welding, variable speed drives, computers, servers, TV, fluorescent tubes, compact fluorescent lamps.Utility charges industries for poor factor but exempts houses and offices.

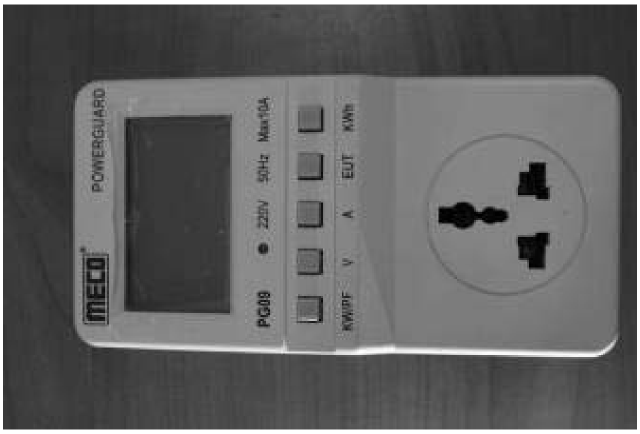

Fig.1.Powerguard meter for PF measurement

B.Total Harmonic Distortion(THD)

IEEE Std.519 (1992) recommends keeping voltage THD _ 5% and current THD _ 32% in utility power distribution network <69 kV. ANSI C82.77 (2002) recommends all commercial indoor hard wired ballasts >28W maintain 0.90 PF with maximum 32% current THD. It requires residential hard wired luminaries below 120W meet a minimum PF of 0.50 with a maximum of 200% current THD. However, it recommends luminaries ballasts <50W to maintain 0.50 PF at maximum 32% current THD. CFL takes extremely distorted current peaks injecting current harmonics towards electric grid. Capacitors can improve displacement PF but not the distortion power factor. IEC/TR3 61000-3-6 has included allowable levels for low, medium, high and ultrahigh voltage systems. It allows up to 6% voltage THD for 5th harmonic, 5% for 3rd and 2% for 2nd harmonics in low and medium voltage circuits.Maximum permissible harmonic current per watt is 3.4 mA (for 3rd harmonic) corresponding to current THD of 78.2%. Voltage THD arises from the interaction between distorted load currents and utility system impedances.

Fig.2.Flukemeter for Power quality indices measurement

C .LIGHTING TERMS

(i) Lumen: Lumen is the SI unit of luminous flux. It is the total amount of light emitted by a light source in any direction.

(ii) Watts:-Watts is the SI unit of total electrical power consumed by the lamp or light source.

(iii) Luminous flux:-The luminous flux is the factor used to describe the brightness of an area.It is measured in lumens.

(iv) Luminous efficacy:- Luminous efficacy is the total luminous flux or lux emitted by the light source per unit lamp wattage. It is expressed in lumens per watt (lm/W).

(v) Burning hours:- Burning hours of a lamp is the total time in hours that a bulb can work if left ON. It can also be called as life of a lamp.

(vi) CRI:- The colour rendering index (CRI), is a quantitative measure of the ability of a lamp to divulge the colour of various objects in comparison with an ideal source or natural lighting. Numerically, the highest possible CRI can be 100. It is for the black body objects especially incandescent lamps. Sodium vapour lamps have negative CRI whereas of CFLs range from about 50 to 90. LEDs have CRI more than 80.

Fig.3.Flukemeter showing Total Harmonic Distortion

IV.EXPERIMENTAL METHODOLOGY

For comparison of various domestic lamps at least one quantity should be fixed and that is lumens output. It means the light output required should be same for a particular application. Thus keeping lumens almost constant around 2500, comparison of other parameters is done in Table 1

TABLE I. Comparison of some technical parameters of domestic lamps

Lamp	Lumens	Watts(W)	Burning	Hours Bulb/ Lamp Cost in Rupees
Incandescent	2600	150	1200	20
CFL	2600	50	8000	700
Fluorescent				
Tube	2500	25	15000	140
LED	2600	25	50000	2000

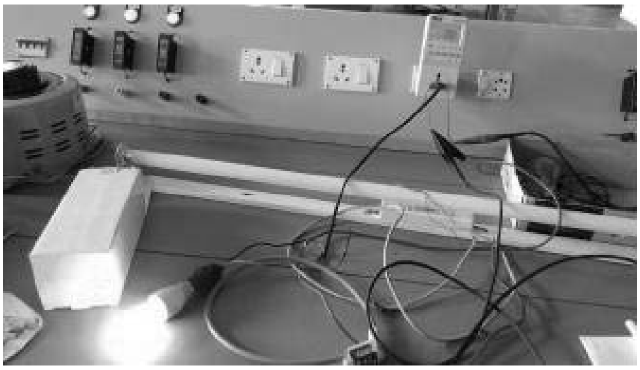

Fig.4.Experimental Setup

So taking burning hours of one light source as reference (which is maximum), number ofbulbs required for all other light sources and their cost are calculated. Number of bulbs and cost for light sources taking burning hours of one light source as reference can be calculated as:

(Number of bulbs/ cost) = Number of bulbs required for burning hours * Cost of one bulb

For fixed burning hours energy required can be calculated as:

Energy required in KWh= (Burning hours * Rating in watts)/1000

Taking the local tariff, cost of energy can be calculated as:

Energy cost= Energy required * Tariff

Finally the life cycle cost is calculated by adding the bulbs cost and energy cost as:

Life cycle cost=Energy cost + Bulb cost

It is clear that LEDs have maximum burning hours. The objective is that the light source should have maximum burning hours. So taking 50000 burning hours as reference, all the calculations are evaluated in Table 2.

TABLE 2: LIFE CYCLE COST ESTIMATION OF DIFFERENT LIGHT SOURCES

Lamp	For 50000 hours no of bulbs required	cost of bulbs (Rs)	For 50000 hours energy required (Kwh) (50000*W)/ 1000	Energy cost (Rs)	Life cycle cost (Rs)
Incan-descent	42	840	7500	38625	39465
CFL	6	4200	2500	8000	7000
Fluore-scent Tube	4	560	1260	6438	8438
LED	1	2000	800	4056	6998

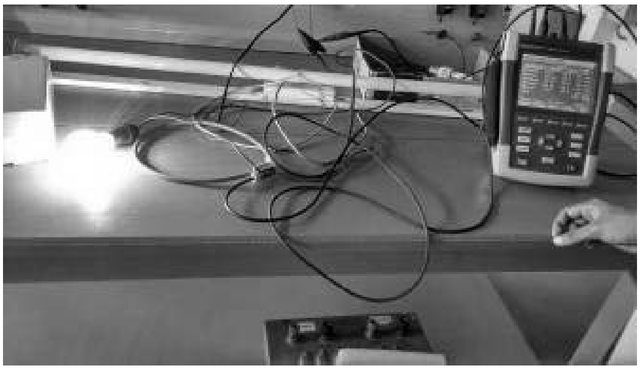

Fig.5.Experimental Setup

As a next experimental test, a flickermeter and a powerguard meter is used to measure the operating voltage,current drawn,power consumption, energy consumed, power factor and the Total Harmonic Distortion(THD) and the results are tabulated in Table 3 as a comparison of power quality indices of different lighting sources.

TABLE 3: COMPARISON OF POWER QUALITY INDICES OF DIFFERENT LIGHTING SOURCES

Lighting source	Power factor	Harmonic content (as a % of fundamental)
Incandescent Bulb	0.99	4.7
CFL	0.92	4.4
Fluorescent Tube	0.55	1.8
Light emitting Diode (LED)	0.98	

Fig.6.Experimental Setup

II .RESULTS AND DISCUSSIONS

For approximately same luminous flux or lumens output, it is confirmed that luminous efficacies of LEDs or T5 lamps is maximum. For same lumens, power consumption of these two light sources is very less. For efficient light sources, this should be the objective. Finally the study shows that the life cycle cost is much more for the incandescent lamps while it is far lesser for the other lamps. The life cycle cost is very less for T5 lamps and LEDs. For an efficient light source, it should have high luminous efficacy, minimum power consumption and minimum life cycle cost. Comparative study of various parameters of light sources for same luminous flux and accordingly their performance evaluation is tabulated . Star rating indicates the performance of lamps according to their ability of minimum power consumption, maximum luminous efficacy and minimum life cycle cost. More the star rating, more good is the quality or performance according to these factors.The incandescent lamp operates with the highest power factor and has highest harmonic content in the input current while the LED has lowest power factor.

TABLE 4 : PERFORMANCE OF DIFFERENT LAMPS

Lamp	Star Rating	Performance
Incandescent	*	Poor
CFL	**	Satisfactory
Fluorescent Tube	****	Very Good
LED	*****	Excellent

III. CONCLUSION

The comparative study of various parameters of light sources explains that incandescent lamps are the most inefficient with maximum power consumption and maximum life cycle cost. CFLs are good alternative for incandescent lamps with somewhat lesser power consumption and very less life cycle cost. Similarly tube lamps like T12 and T8 have very

less life cycle cost. LED lamps have very low life cycle cost as compared to other lamps but somewhat higher than T5 lamps. This is because their lamp cost is far higher than other lamps. If this cost would be less, they would have least life cycle cost. Only advantage with LEDs is that they have maximum burning hours. The incandescent lamp operates with the highest power factor and has highest harmonic content in the input current while the LED has lowest power factor. It means once the LED lamps are installed, they do not need to be replaced again and again for years. The life cycle assessment shows that replacing older lamps of high power consumption and high cost with new and innovative lamps of comparatively low power consumption and less cost could be beneficial for a particular application from the aspect of both energy and cost saving.

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Earth Hour

Earth Hour's logo

Earth Hour

Earth Hour is a worldwide movement for the planet organized by the World Wide Fund for Nature (WWF). The event is held worldwide annually encouraging individuals, communities, households and businesses to turn off their non-essential lights for one hour, from 8:30 to 9:30 p.m. on the last Saturday in March, as a symbol for their commitment to the planet. It was famously started as a lights-off event in Sydney, Australia in 2007. Since then it has grown to engage more than 7000 cities and towns worldwide. Today, Earth Hour engages a massive mainstream community on a broad range of environmental issues. The one-hour event continues to remain the key driver of the now larger movement.

KSEBEA Code of Ethics

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

The 10 biggest hydroelectric power plants in the world

Hydropower is one of the oldest and most widely-used renewable sources of energy. China, the world's largest producer of hydroelectricity, operates two of the 10 biggest hydroelectric power plants in the world, including the world's largest Three Gorges project. Power-technology.com profiles the world's ten biggest hydroelectric power production facilities based on installed capacity.

Three Gorges, China

The 22,500MW Three Gorges hydroelectric power plant in Yichang, Hubei province, China, is the largest hydropower station in the world. It is a conventional impoundment hydropower facility exploiting the water resource of the Yangtze River. The project is owned and operated by China Three Gorges Corporation through its subsidiary China Yangtze Power.

Construction of the CNY203bn ($29bn) power project was started in 1993 and completed in 2012. A 181m tall and 2,335m long gravity dam was built as part of the Three Gorges project. The power plant consists of 32 turbine / generator units rated 700MW each, and two 50MW power generators. Six foreign groups were involved in the supply of equipment for the project, including Alstom, which supplied 14 Francis turbine units.

The generating units of the Three Gorges power station were commissioned between 2003 and 2012. Annual power output of the plant is estimated at 85TWh. The generated power is supplied to nine provinces and two cities, including Shanghai.

Itaipu, Brazil & Paraguay

The Itaipu hydroelectric power plant with an installed capacity of 14,000MW ranks as the world's second largest hydropower plant. The project is located on the Parana River, at the border between Brazil and Paraguay. The facility is operated by Itaipu Binacional.

Construction of the $19.6bn plant began in 1975 and was completed in 1982. A consortium of US-based IECO and Italy-based ELC Electroconsult carried out the construction. Power production at Itaipu started in May 1984.

The Itaipu hydro-electric facility supplies about 17.3% of Brazil's energy consumption and 72.5% of the energy consumed in Paraguay. It consists of 20 generating units with a capacity of 700MW each. It produced 98.2TWh in 2012, which made it the biggest generating hydropower plant in the world.

Guri, Venezuela

The Guri power project, also known as the Simón Bolívar hydroelectric power station, ranks as the world's third biggest hydroelectric power station, with an installed capacity of 10,200MW. The Venezuelan power facility is located on the Caroni River in the Bolívar State of southeastern Venezuela. CVG Electrification del Caroni owns and operates the plant.

Construction of the power project started in 1963. It was carried out in two phases, with the first phase completed in 1978 and the second phase in 1986. The power plant consists of 20 generating units of different capacities ranging between 130MW and 770MW.

Alstom was awarded two contracts in 2007 and 2009 to refurbish four 400MW units and five 630MW respectively. Andritz received a contract to supply five 770MW Francis turbines for the powerhouse II of Guri in 2007. The Guri power station supplies around 12,900GW/h of energy for Venezuela.

Tucuruí, Brazil

The Tucuruí Hydropower Complex situated on the lower Tocantins River in Tucuruí, Pará, Brazil, ranks as fourth largest hydroelectric power plant in the world. The 8,370MW power plant was built in two phases and has been producing since 1984.

Construction of the $5.5bn Tucuruí hydropower project started in 1975. The first phase was completed in 1984. It involved construction of a concrete gravity dam 78m in height and 12,500m in length, 12 generating units with a capacity of 330MW each and two 25MW auxiliary units.

Construction of the second phase to add a new powerhouse was started in 1998 and completed in late 2010. It involved installation of 11 generating units with 370MW capacity each. A consortium of Alstom, GE Hydro, Inepar-Fem and Odebrecht supplied the equipments for this phase. The power station delivers electricity to the Belém town and the surrounding area.

Grand Coulee, United States of America

The 6,809MW Grand Coulee hydropower project located on the Columbia River in Washington, US, is currently the world's fifth biggest hydroelectric power station. The project, built in three phases, is owned and operated by the US Bureau of Reclamation. The power facility commenced operation in 1941. The annual generating capacity of the plant is more than 24TWh.

The Grand Coulee hydro-power station consists of three power plants and a concrete gravity dam 168m high and 1,592m in length. Construction was started in 1933. The left and right power houses, consisting of total 18 Francis turbines rated 125MW and three 10MW additional units, were operational by 1950.

The third power plant consists of three 805MW units and three 600MW units. Construction of the third power plant began in 1967 and the six units of the plant were commissioned between 1975 and 1980. The overhaul of three 805MW units at the third station began in 2013 and is expected to be completed in September 2017. The overhaul of the rest three 600MW units is set to start in 2018.

Sayano-Shushenskaya, Russia

The Sayano-Shushenskaya hydropower plant located on the Yenisei River in Sayanogorsk, Khakassia, Russia, ranks as sixth biggest hydroelectric power station in the world. The power facility, operated by RusHydro, has an installed capacity of 6,400MW.

Construction of the power station started in 1963 and was completed in 1978. An arch-gravity dam 242m in height and 1,066m in length was constructed as part of the project. The power plant consists of 10 Francis generating units with a capacity of 640MW each. It generates 23.5TWh of energy annually, of which 70% is delivered to four aluminum smelters in Siberia.

The plant was shut down in 2009 following an accident which caused damage to nine to 10 turbines. It was reopened in 2010. Ten new units with 96.6% efficiency are planned to be installed at the plant. The upgrades are estimated to cost $1.4bn.

Longtan, China

The Longtan hydropower project located on the Hongshui River in Tian'e County, Guangxi, China, is the seventh largest hydroelectric facility in the world and sixth biggest in Asia. The installed capacity of the plant is 6,300MW.

The hydroelectric power station consists of nine Francis 700MW generating units. The Longtan dam is a roller-compacted concrete gravity dam 216.5m in height and 832m in width. The power station is owned and operated by Longtan Hydropower Development. The power project was designed by Hydrochina Zhongnan Engineering and built by Sinohydro.

Construction of the Longtan hydropower project started in May 2007. The first generating unit was commissioned in May 2007. The project became fully operational in 2009. The turbine generators for the plant were supplied by Voith, Dongfang, Harbin and Tianjin. The annual generating capacity is estimated at 18.7TWh.

Krasnoyarsk, Russia

The Krasnoyarsk Hydroelectric Power Plant located on the Yenisei River in Divnogorsk, Russia, is currently the eighth largest hydroelectric power station in the world. The 6,000MW power facility is operated by JSC Krasnoyarsk HPS.

Construction of the power project started in 1956 and was completed in 1972. Krasnoyarsk Dam is a 124m high and 1,065m long concrete gravity dam. The power plant comprises of 12 Francis generating units with a capacity of 500MW each.

Turbines and generators for the plant were supplied by Leningradsky Metallichesky Zavod (LMZ) and Electrosila. Gidroenergoproek was the engineering, procurement and construction (EPC) contractor. The power station's annual generating capacity is 18.4TWh.

Robert-Bourassa, Canada

The 5,616MW Robert-Bourassa generating station located on the La Grande River in northern Quebec, Canada, ranks as the world's ninth largest hydroelectric power plant. The power station is owned and operated by Hydro-Québec.

Construction of the C$3.8bn power project started in 1974. It involved construction of an embankment dam 162m in height and 2835m in length. The generating station comprises of two power plants installed with total 16 Francis turbines rated at 351MW each. The generating units were commissioned between 1979 and 1981.

A major rehabilitation project is underway at the Robert-Bourassa generating station since 2012 to improve its operational reliability energy performance. It is expected to be completed in 2020. Alstom was awarded a contract in January 2012 to upgrade the power station's efficiency as part of the rehabilitation project.

Churchill Falls, Canada

The 5,428MW Churchill Falls Generating Station located on the Churchill River in Newfoundland and Labrador, Canada, ranks as tenth largest hydroelectric power plant in the world. The power project is owned by Churchill Falls Labrador Corporation and operated by Newfoundland and Labrador Hydro, a subsidiary of Nalcor Energy.

Construction of the $C946m hydropower station started in 1967. The project did not involve construction of any large dam. The water reservoir is, rather, contained in 88 rock-filled dikes. The underground power house consists of 11 Francis turbines rated at 493.5MW each.

The generating units of the hydroelectric power station were commissioned between 1971 and 1974. The annual generating capacity of the power plant is 35,000GWh. It is one of the largest power facilities in North America.