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Health Monitoring of Induction Motor through Vibration Analysis

Mayuri Sonowal[1], Bedanta B. Gogoi[2], Mrinmoy Boruah[3], Jyoti Kumar Barman[4]

[1,2,3,4] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]emilosonowal@gmail.com, [2]bedanta.gogoi1000@email.com, [3]mrinmoyboruah67@email.com,*
[4]jyoti.barman@dbuniversity.ac.in

Abstract: ***Machinery monitoring is the process of monitoring a parameter of condition in machinery, such that a significant change is indicative of a failure in development. Temperature, vibration, noise, current, voltage, acoustic emission, etc. – all these measurements are used for machine condition monitoring. Measuring vibration signals of the Non-Destructive Testing (NDT) method is widely used to detect machine faults. There are many studies for the prediction of mechanical wear, fault and failure in this area for several decades. Signal processing techniques are used to obtain vital characteristic information from the vibration signals. This paper attempts to summarize the results of an evaluation of vibration analysis techniques as a method for diagnosis for three phase induction motors.***

Keywords: Vibration signals; Induction motor; Vibration analysis; Condition Based Maintenance (CBM); Frequency-Domain analysis; Time-Domain analysis.

 Article history: Received: 1 Feb 2019 and Accepted: 13 March 2019.

1. Introduction

Monitoring of machine is a process of monitoring a parameter of condition in machinery ,such that a significant change is indicative of a failure in development. Machine condition monitoring can be realized by monitoring the following characteristics, such as temperature, vibration, noise, current, voltage, acoustic emission, wear, etc. [1].

In a wide variety of industrial applications, an increasing demand exists to improve the reliability and availability of electrical systems. Amongst all types of electric motors, the induction motor is a frequent example due to its simplicity of construction, robustness and high efficiency. Moreover, induction motors may be simplified directly from a constant frequency sinusoidal power supply or by an ac variable frequency drive [2].

Electrical motors are designed to work under variable loads, most commonly under periodic loads. Thus, all machines are prone to forced vibrations and hence, dynamic stresses. In general rotating machinery is subjected to dynamic loads. Therefore, any change in the mechanical condition of the machine affects its dynamic conditions and thus the vibration behaviour.

There are many mechanical and electrical forces present in electrical machines that can produce vibrations. Further, these forces interact, making the identification of the root cause elusive. Vibration signatures are widely promoted as a useful tool for studying machine malfunctions. Early diagnosis of faults in electrical machines is an extensively investigated field for maintenance cost and downtime savings. The induction motor is subjected to primary types of fault and secondary faults. The source of faults may be internal or external or due to environment. Internal faults are classified with reference to their origin, i.e., electrical or mechanical. Similarly, external faults are classified with reference to their origin, i.e., electrical, mechanical or environmental. All rotating equipment produce vibration. Even new or healthy machine generates some level of vibrations. Over the entire service life of machines, component deformation and damage cause dynamic characteristics to change and eventually increase the level of the machine vibrations. The magnitude of vibration produced is primarily dependent on the magnitudes of the original forces on both mechanical responses of the structures of the original forces on both mechanical responses of the structures of the machine and its mountings. This response depends on the frequency and mode of vibration that is excited [11].

A relatively large force may cause little vibration if the response of the structure at the forcing frequency of the particular mode of vibration is small. Similarly, a relatively small force exciting a particular mode of vibration of some part of the structure at or near the resonant frequency may cause a considerable vibration. The vibration produced by an electrical machine may be reduced, either by reducing the magnitude of original forces or by modifying the machine structure and its supports so that the forces cause a smaller response.

2. Proposed Methodology

The proposed method is for fault detection and diagnosis in induction motor, which includes detection of faults occurring due to the electrical and mechanical origin. The faults occurring due to mechanical origin can be detected by the use of MEMS accelerometer. Justification is given for the change is machine vibration due to the excitation of voltage harmonics. This, in turn, will help in electrical fault detection in an induction motor.

2.1 The effect of voltage harmonics on motor vibration

The change in machine vibration due to excitation of voltage harmonic helps in electrical fault detection in induction motors.

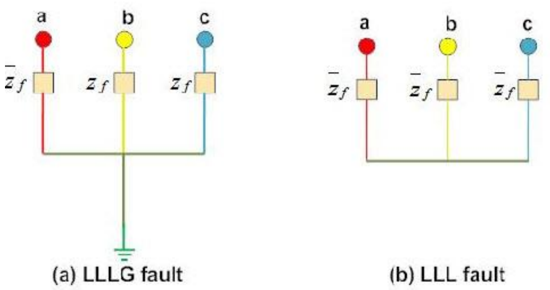

Figure 1: Various types of symmetrical faults in induction motor

The presence of fault causes changes in mechanical and electrical forces that act in a machine. The change in machine vibration is due to the excitation of some of the voltage harmonics. The degree of change depends upon the nature and intensity of fault. When the voltage supplied to the induction motor is distorted, then the voltage has harmonic voltage components.

The induction motor may be subjected to various types of electrical faults, as stated before. The effect of these faults is distortion in the air-gap flux in the machine. The degree of distortion in the air-gap flux on the machine. It depends upon type and degree of faults and ultimately the induced vibration. The motor faults are due to mechanical and electrical stresses. Mechanical stresses are caused by overloads and abrupt load changes. On the other hand, electrical stresses are usually associated with the power supply. Induction motors can be energized from constant frequency sinusoidal power supplies or from adjustable speed ac drives motor overvoltage can occur because of the length of the cable connections between a motor and an ac drive. Such electrical stresses may produce stator winding short circuits and result in complete motor failure. We can use software like putty, Matlab, Arduino to plot the energy vs time graph and acceleration in the x,y,z-axis vs time graph of the motor running at various rpm.

Induction motor faults to the mechanical origin are directly related to motor vibration. The main source of mechanical faults is the rotor. Whenever there is a presence of any mechanical fault in the rotor, it causes a level of rotor vibration. It also depends on the stator response and the outer structure, foundation. The mechanical faults cannot be analyzed by changing the parameters like current, voltage, etc. we can do analysis by building portable hardware for measuring machine vibration.

2.2 Vibration Analysis Methods

Many sorts of faults or loss will enhance the machinery vibration levels. These levels of vibration are then transformed into electrical signals for data measuring by accelerometers. As a rule, the information related to the health of the monitored machine is included in this vibration signature. There are some vibration analysis techniques to analyse the bearing vibration [12]. Four categories of vibration techniques are investigated in this work: time domain, frequency domain, time-frequency domain and other techniques.

A. Time-domain Analysis

The time domain methods try to analyse the amplitude and phase information of the vibration time signal to detect the fault of the gear-rotor-bearing system. One of the simple and cheap faults determination method is time domain analysis of vibration signals. The traditional time-domain analysis is used the amplitude and transient information comprised in the signal of gear vibration time to determine gear faults. Time domain methods are suitable when periodical vibration is observed, and failures generate wideband frequencies based on periodic impulses [13]. Although utilization of the waveform allows variance in the vibration signature induced by faults to be detected, t is hard to determine the source of faults .

B. Frequency (Spectral) Domain Analysis

The frequency domain methods include Fast Fourier Transform (FFT), Hilbert Transform Method and Power Spectrum Analysis, etc. They are using the difference of power spectral density of the signal due to the fault of gear and/or bearing to identify the damage of elements. With this method, the vibration signal time domain is turned into its equivalent of frequency.

The measured signal spectral content is mostly even more practical than the time-domain to identify gear condition because the complicated time-domain signal can be separated into several frequency components [4]. Its height represents its amplitude, and its position represents the frequency. The frequency domain representation of the signal is called the signal. The frequency domain completely defines the vibration.

Frequency domain analysis not only detects the faults in rotating machinery but also indicates the cause of the defect. Theoretically, the time domain can be converted into the frequency domain using the Fourier Transforms and vice versa. It is easy to focus on these frequencies because of importance on them in fault diagnosis. The frequencies of vibrations generated by each component can be approximated for machines worked with known stationary speed. Thus, any variance in vibration level within a particular frequency band can be depended to a particular component. Relative vibration levels' analysis at varied frequency bands can procure some diagnostic information [6].

C. Time-Frequency Approaches

Audio signals are information-rich non-stationary signals that play an important role in our day-to-day communication, perception of the environment, and entertainment. Due to its non-stationary nature, time or frequency-only approaches are inadequate in analyzing these signals. Eventually, all methods have some restricts. Also, the Fourier Transform (FT) only valid for steady signals, have restricts on its results. A joint time-frequency (TF) approach would be a better choice to efficiently process these signals [7]. In this digital era, compression, intelligent indexing for content-based retrieval, classification, and protection of digital audio content are few of the areas that encapsulate a majority of the audio signal processing applications [8]. Fourier Transform can be utilized for analysis of unstable signals for detection that spectral components be within the signal. In case time information is necessary, using FT will not be proper for the analysis. A number of time-frequency analysis methods, like the Short-Time Fourier Transform (STFT), Wigner-Ville Distribution (WVD), and Wavelet Transform (WT), have been introduced. STFT method is used to determine of rolling element bearing failures.

2.3 Proposed circuit diagram

We propose the following circuit diagram set up, as shown in Figure 2 for motor vibration analysis.

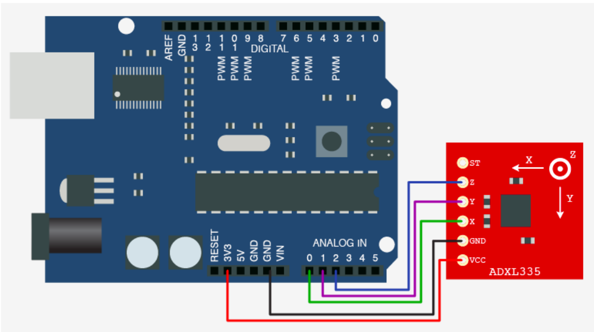

Figure 2: Circuit diagram of set up for vibration analysis

In Figure 2, the ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

2.3.1 Circuit Components

Table 1: List of Components

Sl. No.	Name	Specification/ Rating	Quantity
1	Arduino R3		1
2	ADXL 335		1
3	Induction Motor	3-phase, 1 HP	1
4	Computer System	300W	1

(i) Arduino R3: The Arduino UNO is a widely used open-source microcontroller board based on the ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board features 14 Digital pins and 6 Analog pins. It is programmable with the Arduino IDE (Integrated Development Environment) via a type-B USB cable. It can be powered by a USB cable or by an external 9 Volt battery, though it accepts voltages between 7 and 20 Volts. It is also similar to the Arduino Nano and Leonardo. "Uno" meant one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. The Arduino UNO is generally considered the most user-friendly and popular board, with boards being sold worldwide.

(ii) ADXL 335: The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The accelerometer measures acceleration with a minimum full-scale range of ±3 g and can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The bandwidth of the accelerometer can be selected using the CX at XOUT, CY at YOUT, and CZ at ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the x and y-axes, and a range of 0.5 Hz to 550 Hz for the z-axis.

(iii) Induction Motor: Nowadays, in industries, induction motors are generally used because of their construction, robustness and high efficiency
The Induction motor faults can be categorized into bearing faults, stator faults, rotor faults and other faults. The bearing faults account to a maximum of about 40% of the total induction motor faults. The machines bearings consist of balls and rolling bearings, which are the main cause of motor failure. The bearings consist of inner raceways, outer raceways and other rolling elements which produce unique frequencies in the measured machine vibration and other signal sensors. The stator faults account to about 38%. These are due to insulation failure between the adjacent turns in the coil. The induced resultant current may produce overheating of the motor and unbalance magnetic field will lead to heavy catastrophic damages. These faults must be identified at an early stage. The rotor faults report to 10% of the total induction motor faults and these are due to breaking of the rotor bars when they join the end rings. This is during the thermal and mechanical setup of operation. It gives rise to twice slip frequency side bands in the current spectrum of the supply frequency signal.

Figure 3: Induction Motor Construction

2.4 Data Analysis using Computer

After collecting the raw data from the DC motor, we have taken the help of Arduino to transfer the raw data into the computer system. Further, we have analyzed the obtained data using:

I) MATLAB for analysis
II) The algorithm used to convert the raw data into the time domain and frequency domain using FFT.

2.5 Operation of the Circuit

The accelerometer ADXL335 is connected to the Aurdino in the following manner:

VCC-V3V
GND-GND
A1-X
A2-Y
A3-Z

It is a very easy interface which allows interface with the USB like a serial device. The chip on the board is used to plug into our USB port. It has an inbuilt voltage regulation and is very easy to manage power inside the Arduino. There are 13 digital pins and 6 analog pins in the Arduino, and it allows the board to be connected externally with other devices for operations. The microcontroller can receive inputs from a variety of sensors and can sense the environment.

The sensor is placed on various parts of the 3-phase induction motor to collect data for the system analysis. The sensor on operation collects data from the induction motor in the form of raw data which are transferred to the computer system through Arduino. The vibration data in all the three axes, i.e. x,y and z-axis, are collected. The data are collected for every week.

3. System Implementation and Analysis

We have collected the raw data from a 1 HP, 3-phase induction motor rated 1400 rpm using ADXL335 vibration sensor, after collecting the raw data we have plotted it in time domain using Matlab. The data was collected once in a week to see the occurrence of any change in the vibration and frequency pattern.

Table 2 shows a sample of the collected raw data at 1400rpm:

Table 2: Raw data collected at 1400 rpm

Time(Sec)	x-axis	y-axis	z-axis
.0086	16	9	-2
.0172	20	7	2
.0258	11	10	1
.0344	13	13	-2
.0431	18	7	10
.0517	15	19	-8
.0603	20	3	6
.0775	11	9	-3
.0861	13	10	1
.0947	12	15	-2
.0947	22	5	6
.1033	11	12	-2
.1120	13	9	-2
.1206	14	9	2
.1292	17	12	-4
.1378	18	6	5
.1464	12	14	-4
.1550	16	5	5
.1636	11	15	-5
.1722	18	8	0

After the raw data was collected, it was plotted in the time domain using MATLAB, taking x-axis for the time in seconds and y-axis for acceleration (m/s^2). Some domain plots are shown below, for which data was collected over a period of time.

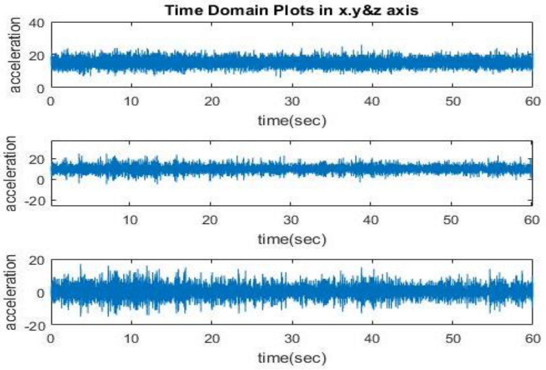

Figure 4: Time domain plot-1

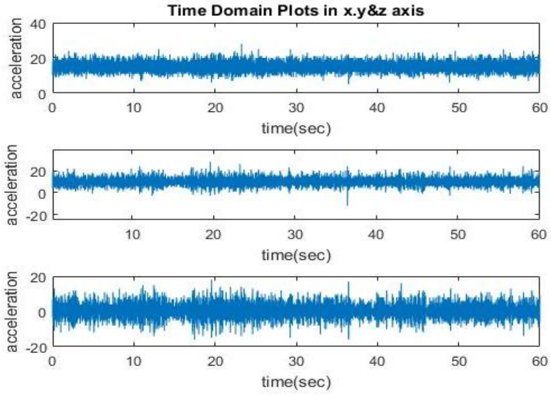

Figure 5: Time domain plot-2

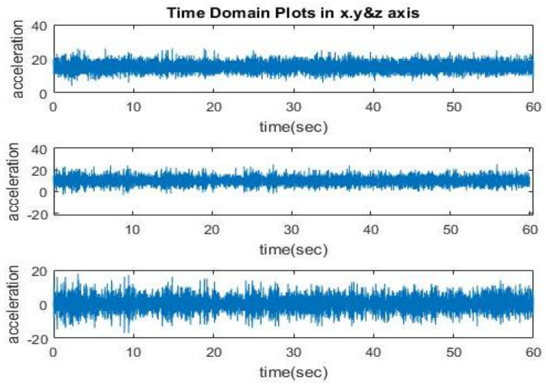

Figure 6: Time domain plot-3

After the time domain analysis, the data are analyzed at the frequency domain, where we can see a clear picture of the frequencies caused by various components of an induction motor. For frequency analysis, the time domain plot is converted into the frequency domain, where the frequency components of the obtained signal can be clearly observed.

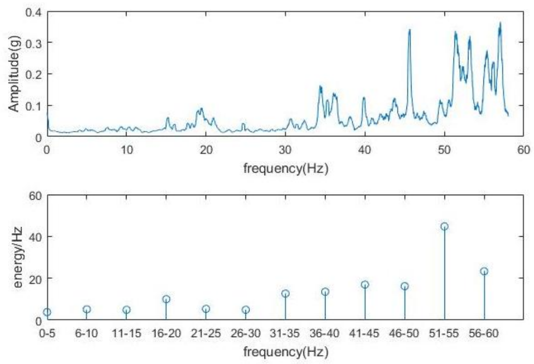

Figure 7: Frequency domain plot-1

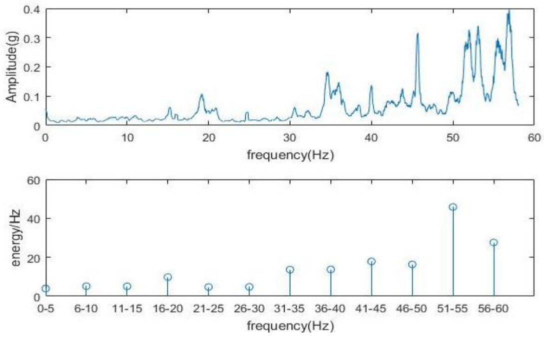

Figure 8: Frequency domain plot-2

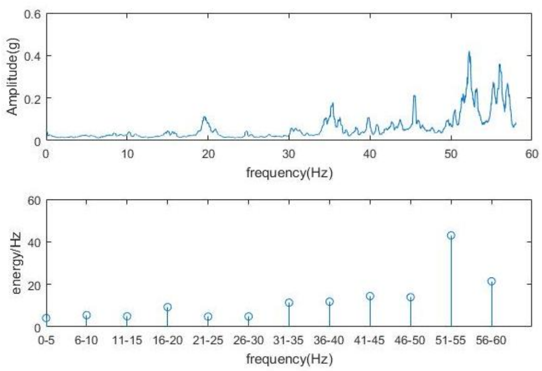

Figure 9: Frequency domain plot-3

Table 3: Energy bin table

Bin No.	Frequency Range (Hz)	Equivalent Energy (Feb 2019)	Equivalent Energy (Mar 2019)	Equivalent Energy (April 2019)
1	0-5	4.1481	3.9780	3.8023
2	6-10	5.5189	5.1900	5.1447
3	11-15	4.9823	5.1149	4.9307
4	16-20	9.2897	9.8550	10.0050
5	21-25	4.8519	4.7465	5.3533
6	26-30	4.9084	4.8306	4.9230
7	31-35	11.3939	13.6531	12.6809
8	36-40	11.8257	13.7741	13.5254
9	41-45	14.4755	17.8680	16.9525
10	46-50	13.9413	16.3507	16.1870
11	51-55	42.9931	45.7928	44.7573
12	56-60	21.4293	27.602	23.3242

The above Table 3 shows the bin energies of the data collected in the month of February, March and April. Here we can clearly see that the bin energies are almost similar in each month's data. Hence we can conclude that the machine is in a stable condition.

Also, in the frequency domain plots, there is a spike at 20-25 Hz frequency range, which is caused due to the rotor, as for the rotor the concerned frequency is 23.33 Hz at 1400 rpm (this frequency can be calculated by converting the speed of the rotor from rpm to rps), moreover there is no noticeable changes in the amplitude or any significant frequency shifts, which indicates that the rotor is in a good condition. And, for the stator part, the energy is concentrated in the frequency range 50-55 Hz, which is due to the supply frequency i.e. 50 Hz; this indicates that the stator is in a good condition. But, some energies can be found in the frequency ranges 31-35 Hz, 36-40 Hz and 56-60 Hz, which might be due to loose bolts, low bearing lubrication, etc.

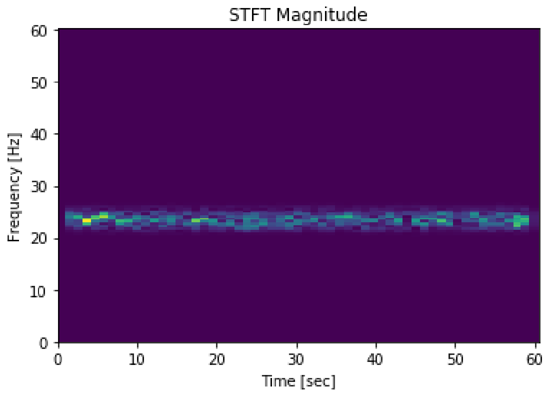

Figure 10: STFT of rotor frequency

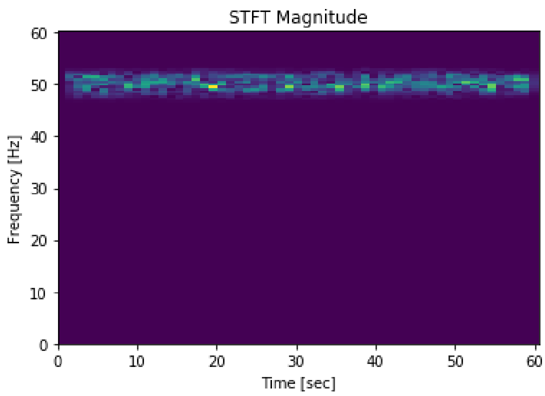

Figure 11: STFT of stator frequency

The above Figures 10 and Fig. 11 were obtained by STFT in the time-frequency domain. To perform STFT, a bandpass filter was designed to pass 23.3 Hz and 50 Hz frequencies. Where we have observed that there were no significant changes in the magnitude both the frequencies (i.e.

23.33 Hz for the rotor and 50 Hz for the stator); from this, we can conclude that both the stator and rotor are maintaining a good stability in both transient and steady-state periods.

4. Conclusion and Future Directions

This paper listed some of the most traditional features used for machinery diagnostics and prognostics and presented some of the signal processing parameters that impact their sensitivity. First, the art data processing methods, which are generally used in the gear failure determination and identification area that includes frequency domain, time-domain, joint time-frequency analysis, time simultaneous averaging and order domain were discussed. After a short theoretical background, the pros and cons of each technique were discussed, a review of applications of the methods that include the studies made by researchers, who carried out these methods to their applications, was investigated. The results of this study have given more understanding of the dependent roles of vibration analysis in predicting and diagnosing machine faults.

After successfully plotting the data in time-domain, we did analyze at frequency-domain, where we saw a clear picture of the frequencies caused by various components of an induction motor. For the frequency analysis, the time domain plot is converted into the frequency domain, where the frequency components of the obtained signal can be clearly observed. Then time-frequency analysis is done, we can observe the change in frequency over the period of time.

In the future, a web server can be set up, the required hardware interfacing could be done, and algorithms are to be developed. This project has a high potential for up gradation in the future. The features that can act as add on for this project are listed below:

1. A web server can be developed and send feedback to the concerned personnel.
2. The health estimation of the induction machine can be further strengthened by monitoring current along with the vibration.

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Authors' Profiles

Mayuri Sonowal, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester) at Assam Don Bosco University, India.

Bedanta Bikash Gogoi, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester) at Assam Don Bosco University, India.

Mrinmoy Boruah, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester) at Assam Don Bosco University, India

Jyoti Kumar Barman, is working as Assistant Professor at Assam Don Bosco University, India. He is currently doing his Ph.D in Assam Engineering College, Assam.

Identification of optimal path through Network Reconfiguration in Distribution System

P L Nongkynrih[1], Rishandonborlang Mawrie[2], Lyon Ch Marak[3], Pushpanjalee Konwar[4], Mriganka Gogoi[5]

[1,2,3,4] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]meo.awezomenatz@gmail.com, [2]sakaenoch8@gmail.com, [3]lyonmarak14@gmail.com,*
[4]pushpanjalee.konwar@dbuniversity.ac.in

[5]Department of Electronics and Communication Engineering, School of Technology, Assam Don Bosco University,
Airport Road, Azara, Guwahati -781017, Assam, INDIA.
[5]mriganka.gogoi@dbuniveristy.ac.in

Abstract: ***Network Reconfiguration is basically the changing the topological structure of the tie and sectionalizing switches. Distribution Networks are operated either in meshed or in radial configuration. Optimal reconfiguration of a primary meshed distribution network results in better performances and minimizing the overall conductor length during installation. The search for the optimal radial reconfigured network from a large number of feasible configuration is done by the selection of the best set of switches on the feeders that are to be opened or closed so that each existing feeder can be operated close to its optimal load-ability limit and the resulting optimal network is supposed to operate at lowest power loss and overall highest voltage stability index. This theoretical concept is however difficult to implement in practice due to heavy computational burden and unacceptably long search durations, therefore Heuristic search approaches are more common. In the project, we use Edmond's Maximal Spanning Tree Algorithm to achieve an optimal solution.***

Keywords: Edmond's Maximal Spanning Tree algorithm; Kruskal's algorithm; Radial Distribution Network; Voltage Stability.

 Article history: Received: 5 March 2019 and Accepted: 11 April 2019.

1. Introduction

The Optimal Power Flow (OPF) problems were first defined in the early 1960's as a supplement of the standard viable dispatch problem. The OPF problems require determination of the optimal settings of control variables subject to the operating constraints such that the operating costs are minimized. As a result of the continuous research efforts over the last three and a half decades, the OPF algorithms have significantly matured alongside developments in the other areas of technology. Modern OPF algorithms cover both real and reactive power dispatch and can solve very large and complex formulations in a relatively short time, the OPF algorithms are constantly reviewed, and newer methods are evolved in a continuous effort to address these new concerns and better the existing methods. The activities of optimal reactive power planning of a power system assume significance in view of their overbearing financial and operational implications. Proper reactive power planning has a wide-ranging effect on the operation and control of power system. Voltage security and voltage stability of a power system are profoundly affected by reactive power planning. System voltage profile, transmission loss, etc. are among many that can be improved by effective network reconfiguration.

In this paper, Edmonds Maximal Spanning Tree Algorithm has been proposed to generate optimal radial network from a Meshed network, which may be considered a step forward as it consumes less time and delivers a more effective solution to the problem.

2. Background Theory

2.1 Voltage Stability Assessment by L-Indicator

In the present study, the single–feeder equivalence method of distribution network consisting of multiple Feeders has been used for voltage stability assessment. The single feeder system is illustrated in Figure 1.

Figure 1: Single feeder

Where, P = Injected Real Power,
Q = Injected Reactive Power, r = Resistance of Feeder; V_s= Sending End Voltage, V_R = Receiving end voltage, X = Reactance of Feeder,δ_1 and δ_2 are phase angles.

From Figure1, the current flowing through the branch, $I = \frac{V_S\angle\delta_1 - V_R\angle\delta_2}{R+jX}$ .....(1)

$P - jQ = V_R^* I$, substituting value of I from eqn.(1):

$\therefore$ P - jQ = $\frac{V_S V_R\angle(\delta_1-\delta_2) - V_R^2}{R+jX}$

(P - jQ)(R + jX) = $V_S V_R\angle(\delta_1 - \delta_2) - V_R^2$

V_R^2 + (RP+XQ) + j(XP-RQ) = $V_S V_R \angle\delta_1 - \delta_2$ ...(2)

The real term of the above equation is

$V_S V_R \cos(\delta_1 - \delta_2) = V_R^2 + (RP + XQ)$ ....(3)

The imaginary term is

$V_S V_R \sin(\delta_1 - \delta_2) = XP - RQ$ ....(4)

Squaring and adding eqn.(3) and eqn.(4), we get

$V_R^4 + V_R^2(2RP + 2XQ - V_S^2) + (P^2 + Q^2)R^2X^2 = 0$

The above equation is a quadratic equation of V_R^2

The system is stable if $V_R^2 \geq 0$. It is attainable when $b^2 - 4ac \geq 0$

i.e., [2(RP+XQ)-V_S^2)]^2-4$(P^2 + Q^2)(R^2 + X^2) \geq 0$

Simplifying the above equation, we get

4(PX-RQ)^2 + 4V_S^2(RP+XQ)$\leq$ V_S^4 ....(5)

Dividing both sides of eqn.(5) by V_S^4, we get

$4[\frac{PX-RQ}{V_S^2}]^2 + 4[\frac{RP+XQ}{V_S^2}] \leq 1$

$\therefore L_{INDEX} \leq 1$

Where, $L_{INDEX} = 4[\frac{PX-RQ}{V_S^2}]^2 + 4[\frac{RP+XQ}{V_S^2}]$ ......(6)

The stability index (L_{INDEX}) ranges between 0 to 1, with the value close to '0' indicates stable systems and a value closer to '1' indicates the possibility of voltage collapse.

2.2 Reconfiguration Strategy

A 4-node distribution power network is shown in Figure2 may be considered to illustrate the proposed reconfiguration strategy.

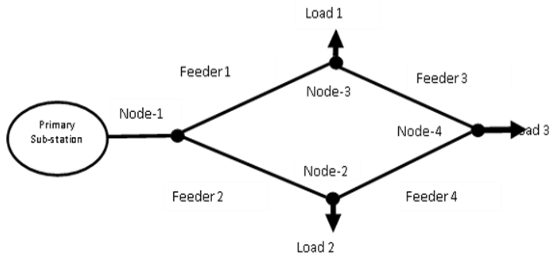

Figure 2: A 4-node mesh Distribution System

Considering the reactances (p.u.) of Feeder-1, Feeder-2, Feeder-3, Feeder-4 to be X_1, X_2, X_3, X_4 respectively and voltages (p.u.) at node 1, node 2, node 3 and node 4 to be $V_1\angle\theta_1$, $V_2\angle\theta_2$, $V_3\angle\theta_3$, $V_4\angle\theta_4$ respectively, the load carrying capability of feeders 1 to 4 can be formulated as:

$$LC_1 = \left| \left(\frac{V_1 V_3}{X_1} \right) \sin(\theta_1 - \theta_3) \right| \quad ....(7)$$

$$LC_2 = \left| \left(\frac{V_1 V_2}{X_2} \right) \sin(\theta_1 - \theta_2) \right| \quad ....(8)$$

$$LC_3 = \left| \left(\frac{V_3 V_4}{X_3} \right) \sin(\theta_3 - \theta_4) \right| \quad ....(9)$$

$$LC_4 = \left| \left(\frac{V_2 V_4}{X_3} \right) \sin(\theta_2 - \theta_4) \right| \quad ....(10)$$

Also, let us consider that the load carrying capabilities of feeder-1 to feeder-4 are in decreasing order. Since, the load carrying capability of the feeder-4 is the minimum, while forming a radial network, as shown in Figure 3, the most desirable option would be opening the sectionalizing switch of feeder-4. The power will be fed to node 4 via feeder-3, in that case. Under this condition, the feeder-3 shall not become overloaded, provided, the load carrying capability of the feeder-3 is greater than approximately the sum of power flow through feeder-3 and feeder-4 before the opening of the switch. The new radial configuration ensures that all the feeders have higher load carrying capability than earlier.

In the present study, Edmond's Maximal Spanning Tree algorithm has been successfully utilized to achieve this goal for larger networks with the help of the Cost Matrix of the edges of the graph corresponding to the network. The generalized Cost Matrix(Weight matrix) for an 'n' node distribution network is of size n × n and a_{ij} presents a cost- matrix element which refers to the load carrying capability(p.u.) of the feeder connected between nodes i and j node. The Edmond's Maximal Spanning Tree search a radial network having feeders with a higher load carrying capacity, and rejects those with lower load carrying capacity.

Thus, in the proposed technique sectionalizing switches on the feeders would be opened in such manner that the feeders with load carrying capabilities in descending order are selectively chosen and the lower load carrying capability feeders are kept out of service by opening sectionalizing switches.

The present problem can, therefore, be formulated as a multi-objective optimization problem to achieve the goals of low overall power loss and maximum overall voltage stability under given operating condition, subject to the constraints that none of the nodes is left isolated or supply of power to each and every load is ensured, and power flow through none of the feeders exceeds the maximum power transfer capability limit. The primary tool that has been used to realize this practice is first to radialize an originally meshed distribution network configuration and then to employ an efficient search algorithm like "Edmond's Maximal Spanning Tree" algorithm to search for an optimal radial configuration, looking for those trees (Set of feeders) which delivers the desired optimization goal subject to constraint satisfaction.

There are 30 feeders in the test systems and hence the total number of possible network configuration would be 2^{30}. The best voltage stability condition will result in from a unique switching configuration out of these huge combinations. However, it would be tedious task to study each one of this huge number of possible combinations individually, as each of configured network Distribution Load Flow Analysis solution would take an unacceptably long time. Thus for on Feeder operation, repetitive Distribution Load Flow Analysis solution is not at all a practical solution to the problem.

2.3 Kruskal Algorithm

The Kruskal algorithm is explained stepwise:

1) Examining the Issues to be to form a simple weighted graph is not governed.
2) A table is produced that lists the sides and weights, from a simple weighted graph is not governed has been described in step 1, and then list on the side of the table are sorted in terms of weighing the smallest to the largest.
3) All the points covering the graph portrayed without including all sides to form an empty graph.
4) The sides that weigh the smallest on the table that was depicted in step 2 is made so that it attaches the two points on the blank graph above.
5) Separate the Side and the weight that was used in Step 4 from the table.
6) Repeat step 4 on the condition that the graph does not appear as a mesh.
7) If the graph is shaped circuit then go back to step5
8) Repeat steps 4 until the number of edges in the graph is one less than the number of vertices.
9) Since the number of trees is one less than the number of vertexes then the Kruskal's algorithm processing is stopped.

2.4 Edmond's Algorithm

Edmond'salgorithm is applicable for a directed graph. The algorithm begins by traversing the directed graph (Digraph) and examines vertices and edges. The examined vertices are placed in a so-called Vertex Bucket (BV). Provisionally selected edges are placed in an Edge Bucket (BE). Throughout the execution of the algorithm BE always contains an acyclic collection of directed edges with at most one edge being incident on any vertex not in BV.

This algorithm works in two phases, as described below:

1. *BV = BE =* Φ
2. *i = 0*
3. *if* $BV \neq V_i$ *(*V_i → *set of total vertices of the graph* G_i*)*
   Go to 4.
   Else
   Go to 8.
4. *For some vertex* $v \notin BV$ *and* $v \in V_i$*,*
   Do
   a. $BV = BV \cup \{v\}$
   b. *Find an edge* $e = \{x,v\}$ *such that* $w(e) = max\{w(y,v) \mid (y,v) \in E_i\}$*(*$E_i$ → *set of all edges of the graph* G_i*)*
   c. *If* $w(e) \leq 0$*, then go to 3 (don't select negative weight edges)*
   Done
5. *If* $BE \cup \{e\}$ *contains a circuit*
   a. $i = i + 1$
   b. *Construct* G_i *by shrinking* C_i *to new vertex* u_i*.*
   c. *Modify BE, BV and corresponding edge weights*
6. $BE = BE \cup \{e\}$

7. *Go to 3*
8. *While i ≠ 0,*
   Do
   a. *Reconstruct* G_{i-1} *and rename some edges in BE*
   b. *If* u_i *was a root of an outbound tree in BE, then*
      $BE = BE \cup \{e \mid e \in C_i \text{ and } e \neq e_i^0\}$
      Else
      $BE = BE \cup \{e \mid e \in C_i \text{ and } e \neq \tilde{e}_i\}$
   c. $i = i - 1$
   Done
9. *Maximum Branching Weight* = $\sum_{e \in BE} w(e)$

3. Description of the test system

A test system of a 30-node mesh network system is shown in Figure 3. In the network, each individual feeder consists of single series sectionalize switch and are assigned as S1 to S40. The data is incurred from IEEE-30 bus system, and the total real and reactive power demands on the system are 283.40MW and 126.20MVAR.The cost values of the network edges are utilized to find the maximal directed spanning tree which is the optimal radial network. In the next phase, the developed graph is optimized using the Edmond's Maximal Spanning Tree algorithm described in section. The Optimal graph is depicted in Figure 4.

To show the effectiveness of the proposed algorithm, alternative system radial configurations obtained manually and Kruskal's Spanning Tree algorithm have been compared with the result obtained by Edmond's algorithm.

A few samples of Voltage stability indicator and active power loss data corresponding to different switch combinations of radial networks have been presented in Table 1.

Using the proposed method, the optimal radial configuration has been found in an efficient manner. The comparative results obtained using different means such as manual, Edmond's algorithm and Kruskal's algorithm for 30 nodes. The 1st configuration corresponds to arbitrarily (and manually) chosen network configuration. The 2nd configuration is obtained using Edmond's algorithm, while the 3rd example is of the configuration obtained using Kruskal's Maximal Spanning Tree algorithm.

The graph of the network is developed after the simulation is performed using Edmond's algorithm shown in Figure 4. The sectionalised switches are disconnected as according to the nodes which are not connected in the below obtained graph as shown in Figure 5. The voltage stability index is calculated for the newly obtained sectionalised switch configuration, and the results are clearly indicative of the fact that the present algorithm is by far superior obtained by manual and the kruskal algorithm, as it succeeded in finding even better (Optimal) switching combination.

4. Results

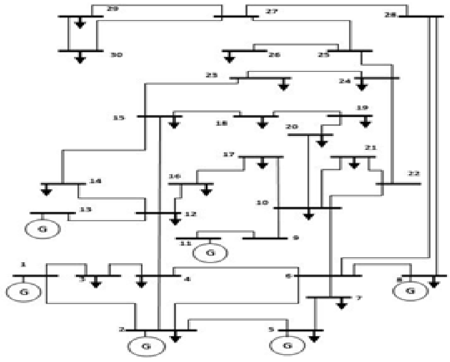

Figure 3: 30-bus system under study

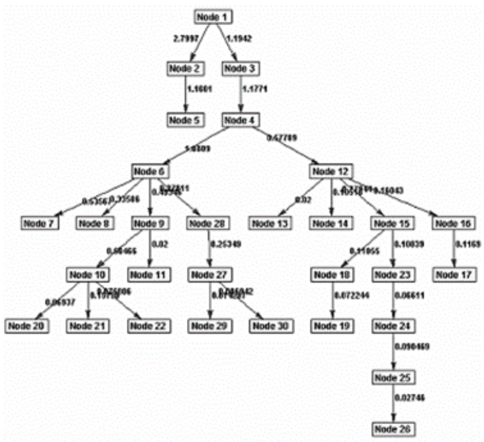

Figure 4: Optimal radial path of the 30 bus system

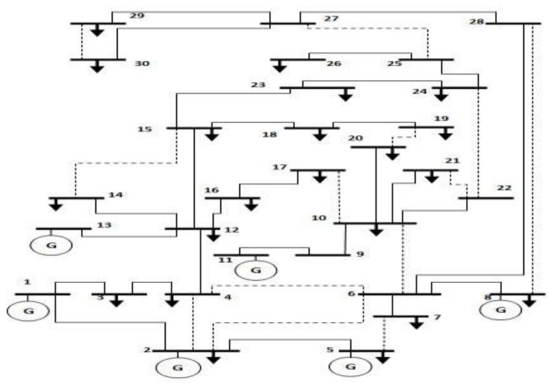

Figure 5: Optimal Configurations obtained from Edmond's algorithm

Table 1: Sectionalizing Switch placement data for 30-bus System

START BUS	END BUS	SWITCH
1	2	S1
1	3	S2
2	4	S3
3	4	S4
2	5	S5
4	6	S6
5	7	S7
6	7	S8
6	8	S9
6	9	S10
6	10	S11
9	11	S12
9	10	S13
4	12	S14
12	13	S15
12	14	S16
12	15	S17
12	16	S18
14	15	S19
16	17	S20
15	18	S21
18	19	S22
19	20	S23
10	20	S24
10	17	S25
10	21	S26
10	22	S27
21	23	S28
15	23	S29
22	24	S30
23	24	S31
24	25	S32
25	26	S33
25	27	S34
28	27	S35
27	29	S36
27	30	S37
29	30	S38
8	28	S39
6	28	S40

Table 2: Comparison of different radial configuration manual configuration (1-3), Kruskal's configuration (4) and Edmond's configuration (5)

Radial configuration no.	Switches Which Are open	Active power loss (p.u.)	Voltage Stability
1	S3,S6,S8, S12,S20, S24,S26, S29,S31, S35,S39, S40.	0.30584	0.75904
2	S3,S4,S9 S10,S14, S17,S21, S23,S32, S33,S38.	0.41121	0.7938
3	S3,S4,S8, S10,S14, S20,S22, S26,S28, S32,S33, S39.	1.22419	0.9461
4 (Kruskal's)	S3,s8,S12, S20,S21, S23,S29, S32,S33, S39,S40.	1.7599	0.2821
5 (Edmond's)	S3,S6,S8, S12,S20, S24,S26, S29,S31, S35,S39, S40	1.45484	0.1685

5. Conclusion

Topology change in Power Distribution Network by means of Sectionalizing Switches to achieve better operating condition was attempted in the paper. An efficient search algorithm is essential, as the number of alternative configuration is usually huge and the normal search takes an unacceptably long time. In our project, Edmond's Maximal Directed Spanning Tree algorithm to render a fast and efficient search for optimal network configuration. The test of Edmond's algorithm in our 30-bus system was found better to reduce system losses and to improve voltage stability condition.

6. Future Research

The research done in this report prevailed over some of the awaiting processes. The proposed algorithm does play a significant and vital role in finding the optimal radial reconfigured network from a large number of feasible configurations, obtaining the highest voltage stability index. In future, the proposed algorithm will be tested on the IEEE 67-bus distribution network aiming to prove the proposed Edmond's algorithm to be feasible for all the available IEEE distribution network.

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Authors' Profiles

Jerrymeo P L Nongkynrih, is pursuing BTECH**,** 8th semester, in Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Rishandonborlang Mawrie, is pursuing BTECH**,** 8th semester, in Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Lyon Ch Marak, is pursuing BTECH**,** 8th semester, Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Pushpanjalee Konwar, is working as Assistant Professor, Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Mriganka Gogoi, is working as Assistant Professor, Department of Electronics and Communication Engineering, School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Analysis of the Problems Occurred Due To Partial Shading of Solar Photovoltaic Array and Probable Solutions

Arnaan Ronghangpi[1], Jyoti Mahanta[2], Joram Henjum[3], Papul Changmai[4]

[1,2,3,4] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]arnaanronghangpi192621@gmail.com, [2]jyotimahanta.jm@gmail.com, [3]foxtailretusa17@gmail.com,*
[4]papul.changmai@dbuniversity.ac.in

Abstract: ***A solar panel is made up of solar cells where semiconductors made to react and give us a potential difference when solar energy falls on it. However, due to the internal and external interferences, many problems are faced by the solar panels like dust, partial shading by leaves or mud, etc. This paper aims at trying to find out the best possible solution for the partial shading problems when solar energy is harvested using a solar panel. The Series-Parallel configuration (SP) and the Total-Cross Tied configuration (TCT) connections of PV module have been analyzed using MATLAB.***

Keywords: Partial shading; solar cells; solar energy; solar panels connections; MATLAB.

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1. Introduction

In the world today, conventional sources of energy faces the probability of dying off, leaving behind an extreme situation where we will not have any sources of energy if we do not come up with alternative ones. Therefore, looking into this matter, people have started coming up with various sources of energy. One such source is the solar energy, efficient and cheap harvesting of which is a major challenge around the world. Solar panel itself faces many problems. Apart from these, the external sources of problem like partial shading and dust also need to be considered. So, in order to understand and tackle such problems, we decided to take up the topic of analyzing and find a really good solution to overcome the problems.

Solar energy has been in use for a long time by human civilizations. But in the past few years, this energy is being used to generate electricity in a direct as well as in an indirect way. If we are to produce electricity directly from the sunrays, then we have to install panels called photovoltaic plates. An indirect way to produce electricity is by heating up the water or salt. The water is turned into steam and this helps in turning the turbines that are attached to the generators. The salt that is used for producing electricity is heated to an extremely high temperature. Then this is used to produce steam [4].

2. Partial Shading Problem

The photovoltaic (pv) plates that are used in the generation of electricity are made up of semiconductors. The semiconductor metal present in the cells has electrons and protons present. The electrons moves form one point to another creating a potential difference. This potential difference is what allows the pv plates to generate DC voltage and in turn, we can use the electricity produced for our own use.

But, the downside to a pv plate is that since it has electrons and protons, the possibility of reverse voltage occurring due to not getting enough light to excite the electrons is also high. So we need to take care of such a situation occurring. This type of situation is especially dangerous for the life of the pv plate if it is not corrected in time. A hotspot forms if the area covered is not uncovered in time. Also, the electrical production of the array is also affected to a large extent. To overcome this problem, we aim at coming up with a new algorithm that can decrease both the problems due to bad connection and the hotspots formed. The new connection will be increase the production efficiency of the solar pv panels and reduce the effect of partial shading in the pv panels.

The research work by Vaishnavi P. Deshpande and Sanjay B. Bodkhe [1] focuses on analyzing the outputs of different existing connections of solar panels under different shading conditions. This paper gives an analysis of how under different shading conditions the module output is and how the output is entirely dependent on the connections done to the module to create an array. In another research H. Samet, S. Kolsi and M. Ben Amar [2] focuses on the irradiance and temperature parameters changes systematically during the day, so the MPP (Maximum Power Point) also changes. This paper gives us an analysis that along with this change if there is any change in the mechanics of the module due to PSC (Partial Shading Condition), the module also can get damaged.

3. Method

The algorithms for partial shading problem that are presently in use provide us not even half of the total power that can be harnessed from the solar rays that is we get. This also in turn gets reduced in half due to factors like shading connections that do not give good output, etc. We plan to come up with an algorithm that can be used to connect the panels in such a manner that we can increase the productivity of the panels to a much larger extent. We analyzed the connections that are in use so far and compared the results of all the new type of connections that we can make with these existing results and conclude a new connection that can give us a better result compared to the new one. MATLAB application has been used to simulate solar cells as well as solar panels to get various results that we compared it with the results of the existing connection models that have been recorded so far. The Series-Parallel configuration (SP) and the Total-Cross Tied configuration (TCT) connections of pv module have been analyzed using MATLAB.

4. Results and Analysis

The MATLAB simulation results of the various probable pv panel connections have been listed below.

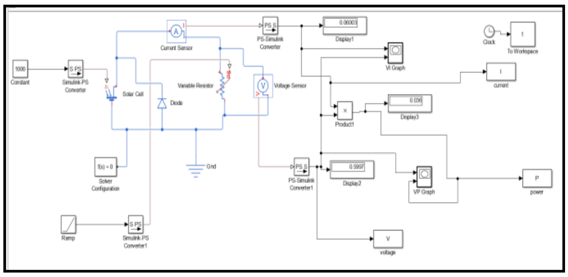

Figure 1: Circuit diagram of a solar cell

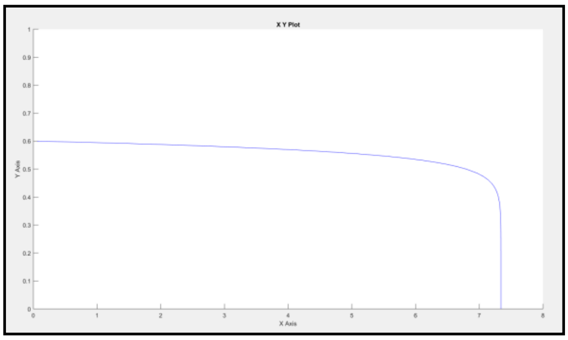

Figure 2: V-I characteristics of a solar cell

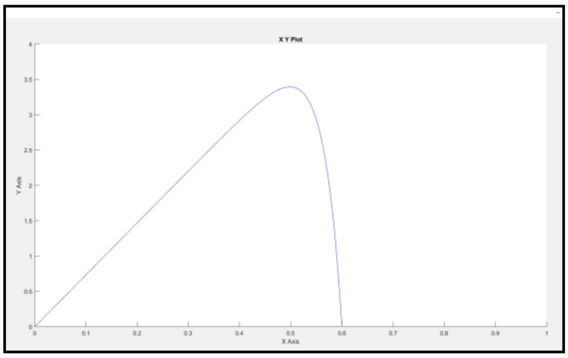

Figure 3: V-P characteristics of solar cell

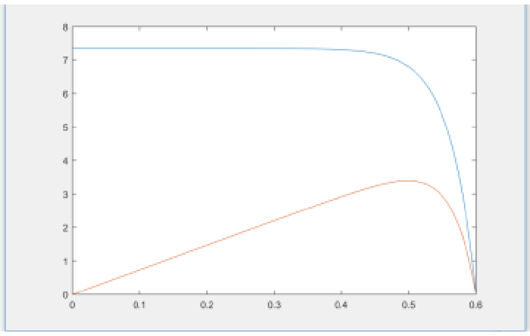

Figure 4: V-I, V-P characteristics of solar cell

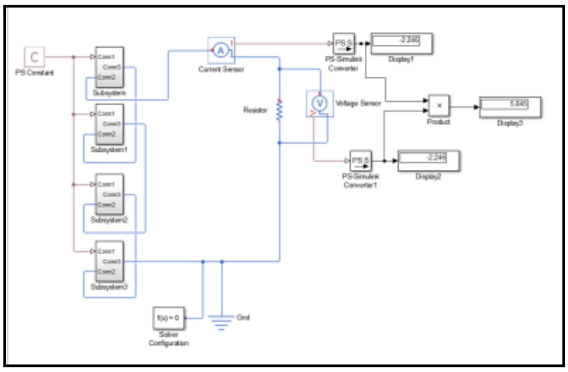

Figure 5: Series-Parallel connection

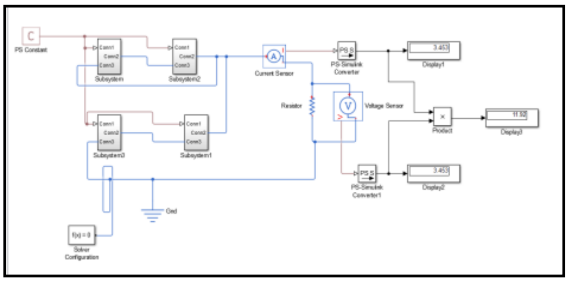

Figure 6: TCT connection

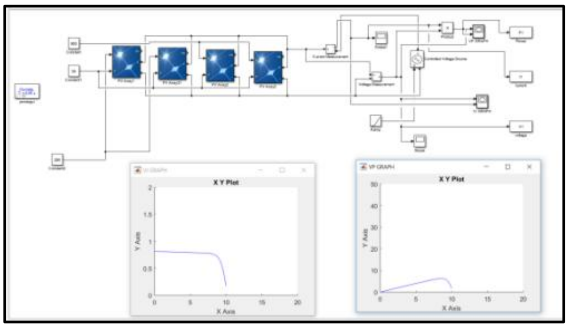

Figure 7: A TCT connection of pv panel along with its graph

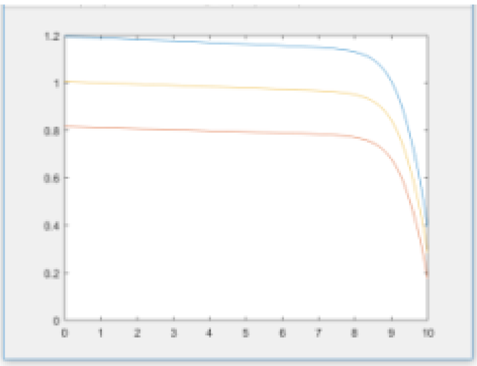

Figure 8: A V-I comparison between the different values obtained during different conditions

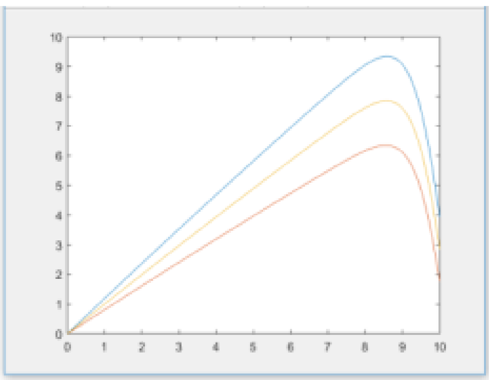

Figure 9: A V-P comparison between the different values obtained during different conditions

5. Conclusion and Future Prospects

We concluded the findings by doing various simulations for various connections and found that there is a huge difference between the result for a TCT connection and a series parallel connection.

To make a more reliable results for a better output, we can collect more raw data and try to make a model out of the connection we may consider as best so that a confirmed physical output can be made.

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Authors' Profiles

Arnaan Ronghangpi, currently pursuing Bachelor degree in Electrical and Electronics Engineering, final semester, Assam Don Bosco University (India).

Jyoti Mahanta, currently pursuing Bachelor degree in Electrical and Electronics Engineering, final semester, Assam Don Bosco University (India).

Joram Henjum, currently pursuing Bachelor degree in Electrical and Electronics Engineering, final semester, Assam Don Bosco University (India).

Papul Changmai, M.Tech., is working as an assistant professor in Assam Don Bosco University, India. He received his Bachelor degree in Electrical Engineering from Jorhat Engineering College (India) in 2008. He received his Master degree in Electronics and Communication Engineering from Assam Don Bosco University (India) in 2015. He is currently pursuing PhD in Electronics and Communication from NIT, Arunachal Pradesh (India). His areas of interest are Design of Solar Photovoltaic System and Partial Shading Analysis of Solar Photovoltaic Array.

Smart Vehicle System using Arduino

Parveen Kaur[1], Animesh Das[2], Manash P. Borah[3], Smriti Dey[4]

[1,2,3,4] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
*[1]parveenkaurk10@gmail.com, [2]dasanimesh774@gmail.com, [3]mborah1996@gmail.com, [4]smriti.nita@gmail.com**

Abstract: ***Transportation is a basic need of society and with the increasing population; indirectly there is an increase in the vehicle density, which may lead to many road accidents resulting in injuries and sometimes lead to death. To prevent this particularly, a system has been designed for accident location detection, accident prevention due to the upper issue of the dipper and anti-collision system. In this system, the shock sensor, ultrasonic sensor and temperature sensor are used as an input to the system along with GPS and GSM for real-time analysis and corresponding responses are analyzed; if any hazard occurs, the processing unit (Arduino) will take the appropriate action.***

Keywords: Arduino; GSM; GPS; Shock sensor; Temperature sensor; Ultrasonic sensor.

 Article history: Received: 1 March 2019 and Accepted: 10 April 2019.

1. Introduction

In the proposed project, accident location detection system, anti-collision system and accident prevention due to the upper issue are incorporated. In the accident location detection system, if any hazard occurs, a message containing the location of the accident is sent to the reference contact who can take necessary steps to control the situation. The execution of the system is simple as it makes use of GSM and GPS technologies. GPS takes the coordinates of the site of the accident and GSM sends the coordinates to the reference contact. All the controls are made using Arduino as it is the main control unit of the system.

The Arduino-based collision detection system is a kind of system that is the fastest growing safety feature in the automotive industries. Such a system enables vehicles to identify the chances of collision and give visual and audio warning to the driver so that the driver can take necessary action to avoid a collision. For the implementation of this system, the ultrasonic sensor is used to provide the estimation of the distance between two vehicles.

While driving it is always recommended to use the dipper more often, and the upper should be used only if necessary. The reason is that while driving at night, visibility is low on roads without streetlights and to counter these, the drivers tend to use upper, which also means high beam. The car headlight bulb has two modes high beam and low beam, also known as upper and lower. On low beam, the reach of the light is less and the brightness is also low, but sufficient to drive with. Whereas, in upper or high beam, the light is much more intense and the reach is much better as the light is projected at a higher height, which affects the car drivers coming from the opposite direction. This can cause them to have poor visibility because of the excess light hitting their eyes. This generally leads to too many road accidents, in order to eliminate this problem accident prevent due to upper issue is designed.

2. System Design

2.1 Block Diagram

The block diagram of the system can be represented as:

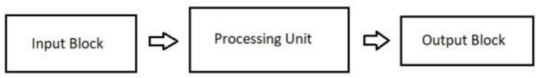

Figure 1: Block Diagram

The input block comprises of the vibration sensor, temperature sensor, ultrasonic sensor and GPS, which provides the digital input to the Arduino. The vibration sensor i.e. SW420 is used for detecting the shock whose sensitivity can be adjusted using the potentiometer on the board, the temperature sensor is used for keeping track of temperature, and the ultrasonic sensor is used to sense the distance between the vehicles. The GPS provides the input location to Arduino in latitudes and longitudes to track the real-time location.

The processing block comprises of Arduino, which acts as the main brain to the system. It accepts the input, i.e. from the vibration sensor, temperature sensor, ultrasonic sensor and GPS and processes the data according to the requirements and provides the necessary action. The output block comprises of the LCD, buzzer, GSM. Depending upon the output received from the Arduino, the different units of the output block will be triggered.

2.2 Circuit Operation

The circuit diagram shown is the feasible diagram for this project.

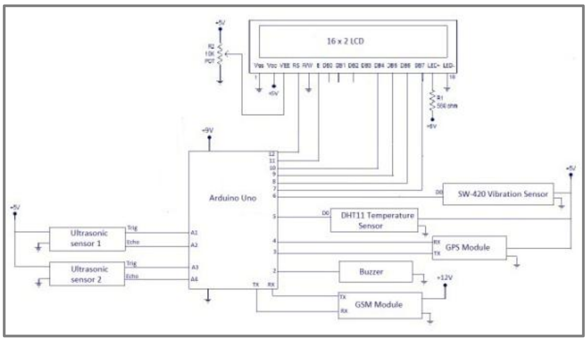

Figure 2: Circuit Diagram

Here the digital output pin of the vibration sensor and temperature sensor is connected to the digital input pin-6 and pin-5 respectively of the Arduino. The V_{cc} of the sensor is connected to +5V supply from the Arduino and ground pin common with Arduino. The RX (receiver) pin and TX (transmitter) pin of the GPS module is connected to pin 4 and 3 of the Arduino respectively. The GPS is power by +5V supply from the Arduino. The RX and TX pin of the GSM module is connected to the TX and RX pin of the Arduino. The GSM module requires a power supply of +12V, which will be provided by using the adaptor. The buzzer is connected to A1 pin of the Arduino. The RS pin of the LCD module is connected to digital pin 12 of the Arduino. R/W pin of the LCD is grounded. Enable pin of the LCD module is connected to digital pin 11 of the Arduino.

In this project, the LCD module and Arduino are interfaced in the 4-bit mode**.** This means only four of the digital input lines (DB4 to DB7) of the LCD are used. Digital lines DB4, DB5, DB6 and DB7 are interfaced to digital pins 10, 9, 8 and 7 of the Arduino. The 10K potentiometer is used for adjusting the contrast of the display. 560 ohm resistor R1 limits the current through the backlight LED. The Arduino can be powered through the external power jack provided on the board. A +5V supply required in some other parts of the circuit can be tapped from the 5V source on the Arduino board. The ultrasonic sensor is powered using +5V supply from Arduino, have a common ground. The Trig and Echo pins of the ultrasonic sensor are connected to the pins, as shown in the circuit diagram. The Arduino can also be powered from the PC through the USB port.

2.3 List of Components

We have designed a system using the given components listed below. The system was designed to keep the cost at a bare minimum as well as efficient in performance. Here we tried to design the system, which is simple yet compact.

Table 1: List of components

Sl. No.	**Components**	**Specification**	**Quantity**
1.	Arduino Board	Uno	1
2.	GPS	---	1
3.	GSM	800	1
4.	Vibration Sensor	SW420	1
5.	Temperature Sensor	DHT11	1
6.	Ultrasonic Sensor	---	2
7.	Buzzer	----	1
8.	LEDs	Yellow, Red, Blue	1(each)
9.	Resistor	470Ω, 1K (pot)	1(each)
10.	Adaptor	12V	1

2.4 Flow Charts

2.4.1 Flow Chart for Accident Location Detection System

The flow chart for the accident location Detection system is shown below in Figure 3(a).

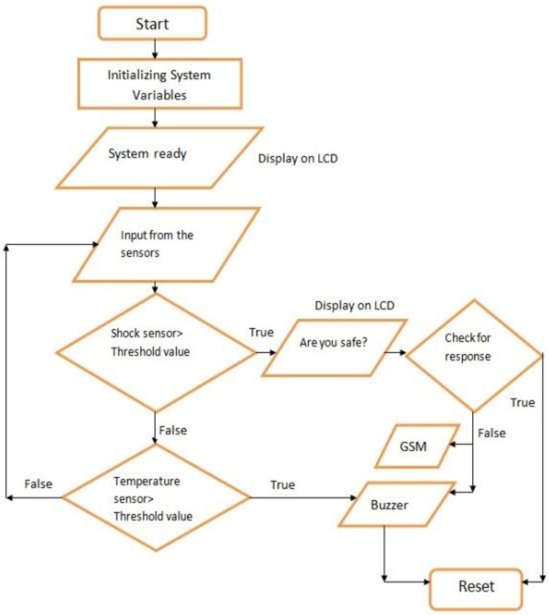

Figure 3(a): Accident Location Detection System

According to the flow chart, the code instructions will be as follows:

1. We will initialise the input pins, output pins and the variables that will be used to store data at different intermediate steps.
2. After the initialization phase is over, there will be a message displayed on the LCD (System ready).
3. Then the system starts reading data from the sensors. The data reading from the sensors is done using the polling technique.
4. After fetching the input from the vibration sensor, the value is first compared with the threshold value of the vibration sensor, if the condition is true, i.e. vibration sensor reading is greater than the threshold value then it will go to next step or else it will go to step 8.
5. It will display “Are you safe?” on the LCD for a certain period of time, if the driver is under the condition to take action by themselves then he/she can press the reset button within the appropriate time delay, the system will reboot, and no action will be taken.
6. If the driver fails to press the reset button within the appropriate delay, then after the delay automatically the buzzer and GSM will be triggered.
7. To stop the buzzer, the system has to be rebooted by pressing the reset button.
8. If the value of the vibration sensor is within the limit, the system then compares the input value of the temperature sensor with the threshold value. If the value of the temperature is higher than the threshold, the buzzer is triggered automatically, and if the value lies below the limit, then it goes back to step 3.

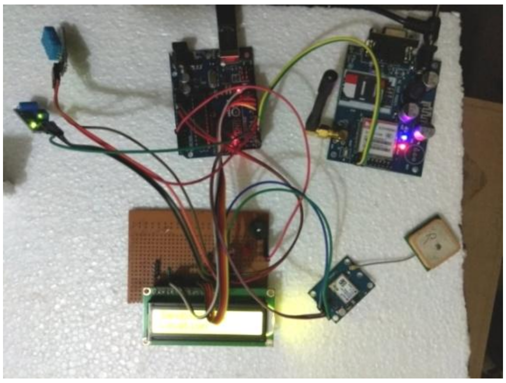

Figure 3(b): Implemented Circuit of Accident Location Detection System

2.4.2 Flow Chart for Anti-collision and Upper Issue of Dipper System

The flow chart for the anti-collision system and the upper issue of the dipper system is shown below in Figure 4(a).

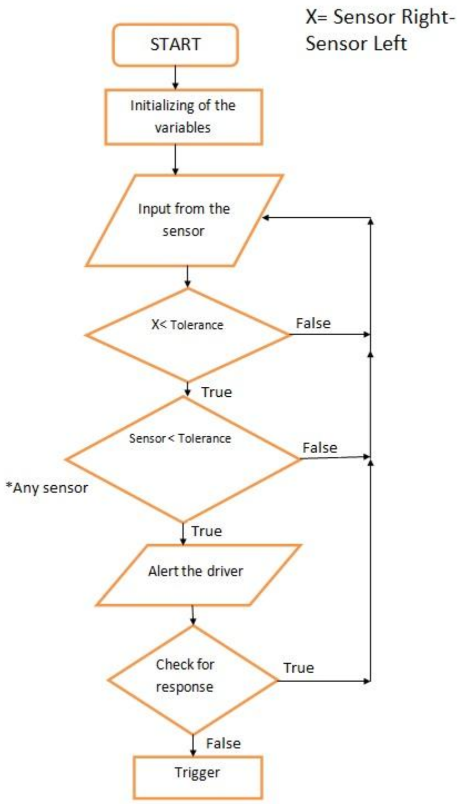

Figure 4(a): Anti-Collision and Upper Issue Flow Chart

According to the flow chart, the code instructions will be as follows:

1. We will initialise the input pins, output pins and the variables that will be used to store data at different intermediate steps.
2. Then the system starts reading data from the sensors. The data reading from the sensors is done using the polling technique.
3. Then the system will compute the difference between the two sensors, which is stored in the variable ‘x’. If the value of ‘x’ is greater than the tolerance value, it will go back to step 2 or else it will go to the next step.
4. If the sensor reading is less than the tolerance, then it will go to the next step, or else, it will go to step 2.
5. The buzzer will beep to alert the driver that the safe distance limit is being exceeded. The system will check for a response from the driver, if the driver doesn’t want the system to take any action, he/she can reset the system by pressing the reset button within the proper delay. If the drive fails to do so in the given time, the system will trigger the speed control circuit.

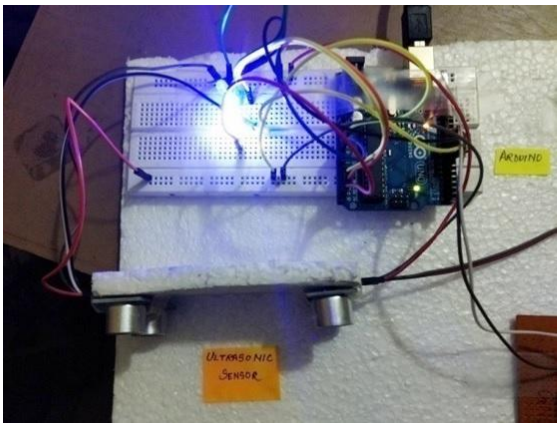

Figure 4(b): Anti-Collision and Upper Issue of Dipper Implemented circuit

3. Results and Analysis

The output reading of the vibration module is as follows:

Table 2: VIBRATION MODULE

Sl. No	Vibration Sensor Reading (mV)	LED	Triggering
1	< 1000	Yellow (ON)	---
2	≥ 1000	Red (ON)	GSM, Buzzer

The normal vibration in a car varies from (2000- 3000) mV. But, for analysis purpose, the threshold value is set to 1000mV. In a practical situation, the vibration that will be observed in the case of an accident will be much higher.

Under normal conditions, the sensor reading is less than 1000 mV, which is indicated by the yellow LED, which represents the normal functioning. Under critical circumstances, the value of the vibration sensor is equal to or greater than 1000mV, which is represented by the red LED. In addition, GSM and Buzzer are triggered depending on the conditions specified in the code.

The output reading of the temperature module is as follows:

Table 3: TEMPERATURE SENSOR

Sl. No	Temperature Reading(°C)	LED	Triggering
1	<30	Yellow (ON)	-----
2	≥30	Red (ON)	GSM, Buzzer

The temperature sensor module is used to monitor the temperature of the system installed since excessive heat produced in the vehicle can damage the system. The threshold of the temperature sensor from the analysis is taken as 30 degrees Celcius.

Under normal situation, the yellow LED is ON representing that the temperature is below 30 degrees, whereas under the abnormal condition the red LED is turned ON representing that the temperature of the system has exceeded the threshold value and the buzzer and GSM is triggered respectively.

The output reading of the ultrasonic sensor is as follows:

Table 3: ULTRASONIC SENSOR

Sl. No	Ultrasonic Reading (cm)	LED	Triggering
1	x<40, Sensor reading<40	Green (OFF)	System Controller
2	x>40	Red (ON)	Intensity controller

The Ultrasonic sensor is used to detect the vehicle. The 'x' in the table represents the difference between the two sensor readings. If the sensor reading is less than 40 (threshold value), and the difference between the sensor reading is also less than 40, then it represents that there is a vehicle is in front of the system, and the distance between both the vehicle is less than the specified safety distance. As a result, the system will initialize the system controller to avoid a collision.

Again, if the difference between the readings of the sensor is greater than the specified value, it represents that the vehicle is coming from the opposite direction, and it will initialize the intensity controller circuit if the light is at high beam, to control the intensity of light for a specific period of time. After that, it will return to the original value once the required time delay is over.

4. Conclusion

The main objective of the proposed system is to design a smart vehicle system using Arduino. Here a prototype of the smart vehicle is developed which can be integrated to form an application for installing in smart vehicles in future. This system will help people receive emergency services on time and will reduce the causes of road accidents.

Since smart India is the new trend, every working system is being upgraded to an automatic or smart system, then why not a smart vehicle system. In the proposed project we have taken up only three parameters, the system can further be modified by addition of more sophisticated designs. Some of such sophisticated designs that can be added in future are:

(i) Speed controller system
(ii) Pollution control
(iii) Ignition Control
(iv) Audio Controllable system etc.

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Authors' Profiles

Ms. Smriti Dey, is working as an Assistant Professor in the department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, India. She is currently pursuing Ph.D. from Gauhati University. Her areas of research interest are Power & Energy Management and FACTS Networking Pricing, Power Quality.

Animesh Das, is Pursuing B.Tech degree (8th semester) in the department of Electrical and Electronics Engineering, School of Technology, Assam

Don Bosco University, Guwahati, India.

Parveen Kaur, is pursuing B.Tech degree (8th semester) in the department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Guwahati, India.

Manash Pratim Borah, is pursuing B.Tech degree (8th semester) in the department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University, Guwahati, India.

Automatic Cable Fault Distance Locator using Arduino

Baskhemlang Rynjah[1], Ferdinand Lyngdoh[2], Marqueen Mary Sun[3], Bikramjit Goswami[4]

[1,2,3,4] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]baskrynjah@gmail.com, [4]bikramjit.goswami@dbuniversity.ac.in*

Abstract: ***This paper presents the method of design of a cable fault location sensor for underground cable fault detection. The aim was to detect the fault location from transmitting or receiving station up to few meters accuracy using an Arduino based kit. The underground cable-based supply system is a common practice in urban areas. As explained in the paper, the system uses the principle of a Varley loop to determine the exact distance of the fault in the underground cable up to the accuracy of a meter. When any fault, e.g. short circuit and earth fault occurs, the length of the fault of the cable can be determined from the fault resistance using the bridge in the Varley loop. A microcontroller is used to make the necessary calculations and display the fault distance after that. After necessary calibration and testing, an accuracy of about 85% is achieved in locating the fault using the method.***

Keywords: Arduino; ADC; Varley loop; Underground Cable Fault.

 Article history: Received: 25 Feb 2019 and Accepted: 10 April 2019.

1. Introduction

For the low voltage and medium voltage distribution lines, underground cables have been used for many decades worldwide. To reduce the effects of distribution networks on the environment, underground high voltage cables are used more and more now. Underground cables have been widely used in power distribution networks due to the advantages of underground connection, involving more security than overhead lines in bad weather, less liable to damage by storms or lightning. It is less expensive for a shorter distance, eco-friendly and required less maintenance [1].

But, if any fault occurs in an underground cable, then it is difficult to locate the fault. Therefore, this paper explains one such method developed to detect the location of a fault in a digital way. There is a great requirement of locating the fault point in an underground cable in order to facilitate quicker repair, improvement of the system reliability and reduced outage period [2].

From the works of literature reviewed, it is seen that different designs are proposed by different authors for using various methods to locate the faults in underground cables. Variety of methods such as the techniques using Megger, Optical sensing, Electromagnetic Field and Varley loop sensing are being used for fault detection and pinpointing. The accuracy levels and complexity of the set-up used vary along with the cost of the equipment in various such methods. The earliest techniques recorded in pieces of the literature suggest the use of Megger based techniques for the purpose of locating the fault. The use of optical and electromagnetic methods is relatively new, mainly developed during the last decade [3, 4].

The automatic underground fault locator systems have a higher level of acceptance as compared to manual ones [5]. The automatic fault locator has perceived benefits of protection against any underground faults, i.e., short circuit and open circuit faults. The present system, as described in subsequent sections, is therefore designed to give the exact distance reading from the feeder end to where the fault occurs in underground cable automatically. In addition, it can be taken to any location for operation, whenever the fault occurs and is basically made to serve for the need for a simple and cheap cable fault locator.

2. Theoretical Background

In the present work, the Varley loop based testing method is used for locating short-circuit and earth faults in underground cables. This test employs the principle of the Wheatstone bridge [8].

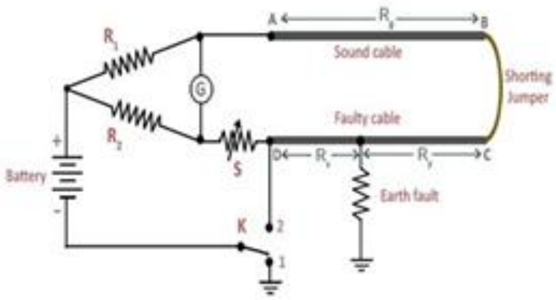

Figure 1: Varley loop method for earthed fault

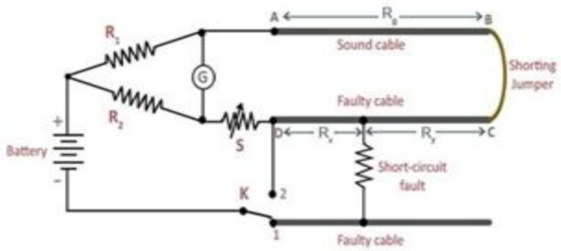

Figure 2: Varley loop method for short circuit fault

To locate fault using the Varley loop, connections are made as shown in the circuit diagram of Figure 1 and Fig. 2. Resistors R_1 and R_2 are fixed, and the resistor S is variable. A stepper motor is to be used to vary the resistance to bring the bridge to a balanced condition. The balanced resistance value will be given to the microcontroller for applying that value to the program to be developed. The program will automatically calculate the distance of fault, based on the algorithm to be developed during the project.

3. System Designs

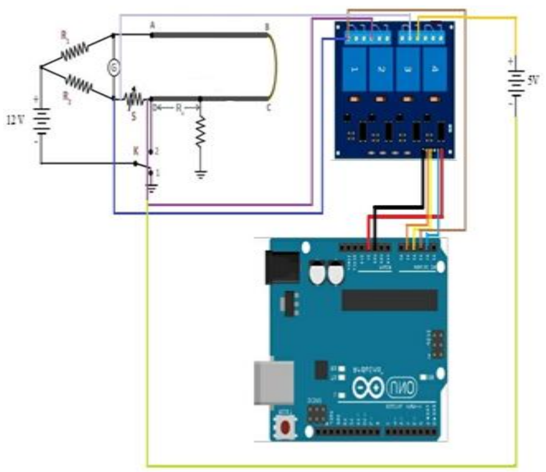

Figure 3: Circuit diagram of automatic cable fault distance locator

The fault detector system is designed to utilize the bridge balance technique. In this test, the switch K is first thrown to position 1. Then the variable resistor S is varied until the galvanometer shows zero value (i.e., the bridge is balanced).

Let us say; the bridge is balanced for the value of S equal to S_1. Then,

$$\frac{R_1}{R_2} = \frac{R_g + R_y}{R_x + S_1}$$

Let, $R_g + R_y = R_3$

$$\frac{R_1 + R_2}{R_2} = \frac{R_3 + R_x + S_1}{R_x + S_1}$$

$$R_x + S_1 = \frac{R_2 (R_3 + R_x + S_1)}{R_1 + R_2}$$

$$R_x = \frac{R_2 (R_3 + R_x) - R_1 S_1}{R_1 + R_2} \quad \text{........ eq. (i)}$$

Now, the switch K is thrown to the position 2, and the bridge is balanced by varying the resistor S. Say, the bridge is balanced at the value of resistor S is equal to S_2. Then,

$$\frac{R_1}{R_2} = \frac{R_3 + R_x}{S_2}$$

$$R_1 S_2 = R_2 (R_3 + R_x) \quad \text{........ eq. (ii)}$$

Now, putting the result of eq.(ii) in eq.(i),

$$R_x = \frac{R_1 (S_2 - S_1)}{R_1 + R_2}$$

Since the values of R_1, R_2, S_1 and S_2 are known, R_x can be calculated. When R_x is known, the distance from the test end to the fault point L_x can be calculated as,

$$L_x = R_x / r$$

Where, r = resistance of the cable per meter.

Now, when the bridge is in a balanced condition, the relay module consisting of 3 relays will be interfacing with the Varley loop circuit. The relay 1 and relay 2, which is connected between the two ends of the terminal of variable resistor S, trip when the galvanometer reads zero value. Therefore, the relays 3, which is connected as shown in Figure 3, will then extract the balanced resistor, which will then be fed to the Arduino for distance calculation from the equation $L_x = R_x / r$.

3.1 Block Diagram

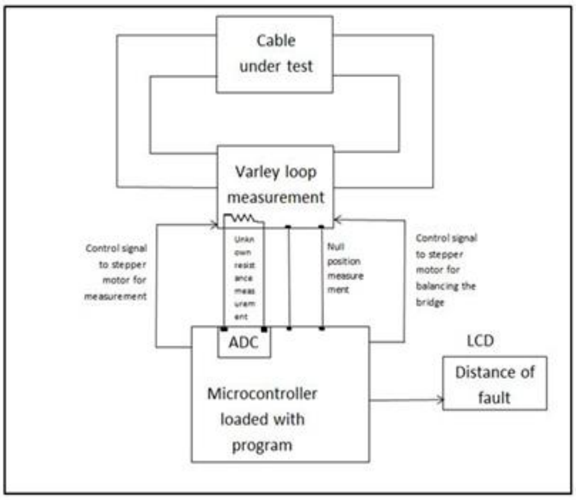

Figure 4: Block diagram of automatic cable fault distance locator

At first, the Varley loop bridge is brought into a balanced condition. The variable resistor is used to vary the resistance to bring the bridge to the balanced condition.

The relays are connected across the terminals of the variable resistor S. The relays will be operated (tripped) by a signal sent from the microcontroller when the bridge is in a balanced condition. The balanced resistance value will then be given to the microcontroller. The change in resistance will then be converted automatically to the faulty distance of the cable. The program has been developed for making the system automatic.

3.2 Automatic Cable Fault Distance Locator Algorithm and Components

The microcontroller is interfaced with the relay module circuit. The analog pins of the microcontroller are connected with the input pins of the relay module, which consists of three relays to be operated. The V_{cc} pin of the relay module is supplied from the Arduino board. Accordingly, the contacts of the relays are connected, as shown in the above circuit diagram. These contacts operate according to the program being fed from the Arduino microcontroller, and therefore the required operation works satisfactorily.

The algorithm for the program is as the following:

Step 1: Start.
Step 2: Initialize the pin modes and variables (pot resistance), and flag variables.
Step 3: Voltage analog read by the ADC.
Step 4: Check for voltage value.
Step 5: When voltage = 0, set pin A1, A2, A3 high and low to pin A4 and read analog voltage across the resistance (pin A4).
Step 6: Converting voltage to the resistance value.
Step 7: Print resistance value.
Step 8: Else if voltage > 0, set A1, A2, A3 low and make A4 high.
Step 9: Halt.

The components used for the work are shown in Table 1.

Table 1: Components Used in Automatic Cable Fault Distance Locator Using Arduino

Sl. No.	Name of components	Ratings	Quantity
1	Microcontroller	ATMEGA328P	1
2	Battery	12 V	1
3	LCD	16x2	1
4	Resistors	470 Ω, 100 Ω, 220 Ω, 47 Ω, 330 Ω	1 each
5	Variable Resistors	10 Ω	1
6	Relay	5 V	3

4. System Analysis and Implementation

The output results obtained from the microcontroller are shown in Figure 5 when the voltage across the galvanometer goes higher than zero value, which implies that it is in an unbalanced condition.

The output result of the voltage when the bridge is in the balanced condition is shown in Figure 6. During a balanced condition, the voltage value is zero, and therefore the Arduino reads the resistance value from the Varley loop circuit and displays in the serial monitor of the Arduino.

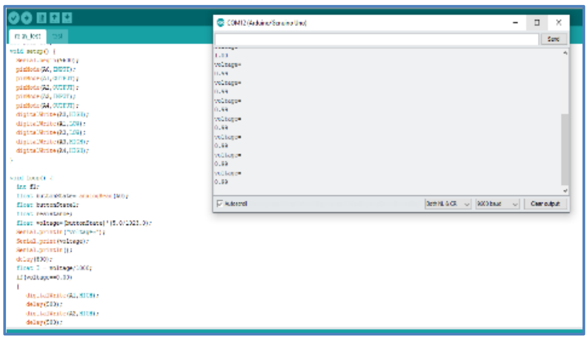

Figure 5: Output result during the unbalanced condition

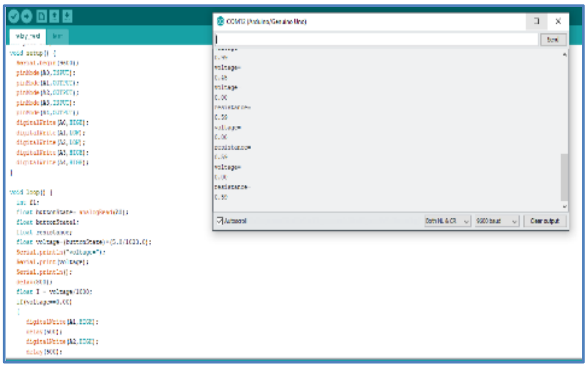

Figure 6: Output result during a balanced condition

During the testing of the project, it was found that if the unknown resistance value is very small, then it is difficult to bring the bridge to the balanced condition. The bridge is very sensitive, and the voltage deflects randomly if the unknown resistance is very small. But, through much continuous trial, the voltage could be made stable, by choosing proper ratings of standard arm resistances. After that, the bridge could be interfaced with the Arduino for making the system automatic.

The relay module is interfaced with the microcontroller, and when the voltage across the galvanometer is higher than zero value, the relays do not trip. But, as soon as the Arduino reads zero value, it automatically sends signals for tripping the relays.

5. Conclusion

In the present project, it was intended to study the process of detection of the exact location of circuit fault in the underground cables from the feeder end in few meters by using an Arduino microcontroller. The Arduino microcontroller is used to detect the changes in the output voltage of the bridge circuit. As soon as a fault occurs in the cable, the bridge is balanced at some other resistance than the normal condition. That resistance is then used to produce the voltage across the analog input ports of the microcontroller, and thus the fault location is determined using an algorithm.

The project using the Varley loop test is expected to detect the fault by detecting the resistance, which in turns can be translated into distance using an algorithm. Then the microcontroller is used to display the fault distance from the source end in the LCD display.

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Authors' Profiles


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[1]Baskhemlang Rynjah

[2]Ferdinand Lyngdoh

[3]Marqueen Mary Sun[3]

[1,2,3]B.Tech, 8^{th} Semester, EEE, School of Technology (Don Bosco College of Engineering and Technology), Assam Don Bosco University.

Bikramjit Goswami is working as an Assistant Professor in the department of Electrical and Electronics Engineering of Assam Don Bosco University, Guwahati, India. He received his master degree in Electronics and Communication Technology from Gauhati University (India) in 2012. He has published more than 20 papers in areas of Antenna, Microwaves, Sensors, Microwave Remote Sensing etc.

Arduino Based Automatic Irrigation System

Sandeep Minz[1], Ankit Saha[2], Mrinmoy Ranjan Dev[3]

[1,2,3] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]sandeepminz16@yahoo.in, [2]ankitsaha198@gmail.com, [3]mrinmoyranjan123@gmail.com*

Abstract: ***In the present days, the farmers are suffering from severe drought like condition throughout the year. The main objective of this paper is to provide a system leads to automatic irrigation thereby saving time, money & power of the farmers, gardeners in greenhouses etc. Manual intervention is common in traditional farm-land irrigation techniques. This paper presents a technique for Arduino based Automatic Irrigation System. With this automated technology of irrigation, human intervention can be minimized. The moisture sensors will be bed in on the field. Whenever there is a change in water concentration, these sensors will sense the change and gives an interrupt signal to the micro-controller. Soil is one of the most fragile resources whose soil pH property used to describe the degree of the acidity or basicity, which affects nutrient availability and ultimately plant growth. Thus, the system will provide automation, remote controlling and increased efficiency. Humidity sensor is connected to internal ports of microcontroller via comparator; whenever there is a fluctuation in temperature and humidity of the environment, these sensors sense the change in temperature and humidity and give an interrupt signal to the micro-controller and thus the motor is activated. A buzzer is used to indicate that the pump is on.***

Keywords: Arduino; Moisture Sensor; Automatic Irrigation; Xbee.

 Article history: Received: 1 Feb 2019 and Accepted: 1 April 2019.

1. Introduction

In the present senerio, irrigation systems are manually operated. To use the water efficiently and effectively, a concept of automated irrigation is introduced. Sensor-based irrigation system is based on soil moisture sensor that will measure the level of moisture in the soil and propel the signal to the Arduino and accordingly it will irrigate the crops. The Arduino plays the role of Micro-controller. This will compare the values received from the moisture sensor with the predefined moisture levels already stored in the system. Based on the values received from the sensors, the Arduino will turn the irrigation system ON/OFF. The Arduino will also provide the functionality of calculating the pH value of soil. pH is a term that is used to describe the degree of acidity or basicity. In addition, the moisture sensor is attached so that the water content of the soil is detected. Automatic irrigation system proves to be very helpful for those who travel. If designed and coded properly, the automatic irrigation systems can be very cost effective and can do a lot of water conservation. Watering with a pipe or with oscillator wastes water and none of these method aim plant roots. Automatic irrigation systems can be designed in such a way that gives the required amount of water in a targeted area, and which will promote water conservation too.

1.1 General

This project is about a moisture-sensing automatic irrigation system under closed environment using Arduino UNO. This system reads the moisture content of the soil using a soil moisture sensor and switches on the motor when the moisture is below the set limit of the designated soil under consideration. When moisture level rises above the set point, the system switches off the pump. The status of the motor and the moisture level will be displayed on a 16×2 LCD display.

For continuously increasing demand and decrease in the supply of food necessities, it is important for rapid improvement in the production of food technology. Agriculture is only the source to provide this. This is an important factor for human societies to growing and dynamic demand in food production. Agriculture plays an important role in the economy and development, like India. The farmers use to irrigate the land due to lack of water. Irrigation may be termed as the science of artificial submission of water to the dry land or soil for making it suitable for plant growth. Moreover, depending on the soil type, the plant is to be provided with water for better production and yield.

1.3 Literature Survey

In the work by Authors A. N. Arvindan and D. Keerthika [1], the Android smartphone was used as a remote control to make Arduino-based automated irrigation system easy-to-use and an economical one. The design of this system includes a soil moisture sensor that provides a voltage signal proportional to the moisture content in the soil, which is compared with a predetermined threshold value. On the basis of this comparison result, the appropriate data are fed to the Arduino Uno processor, which is linked by the HC-05 module to an Android phone. Android smartphone allows the user easy remote control for the irrigation system to switch on, to the drive motor. The system has the potential to be used in the real-time precision agriculture application.

In the research by the Chandan Kumar Sahu and Pramitee Behra, the authors present a prototype for full automation accessing of irrigation motor where Prototype includes numbers of sensor placed in different directions of the farm field. Each sensor is integrated with a wireless networking device and the data received by the "ATMEGA-328" microcontroller, which is an ARDUINO-UNO development board. The RASPBERRY-Pi is used to send messages through internet correspondence to the microcontroller process. The objectives of this paper were to control the water motor automatically and select the direction of the flow of water in a pipe with the help of soil moisture sensor. The information, which is considered as the operation of the motor and direction of water of the farm field, is finally sent to the user using mobile message and e-mail account.

In the paper by D. Baghyalakshmi, Jenimah Ebenezer and S. A. V. Satyamurty [3], the authors have presented the implementation details of WSN based temperature monitoring application. The main feature for the authors' proposed network is to continuously monitor the temperature in the 128 nodes High-Performance Computing Cluster for its smooth functioning. The wireless sensor node sense and transmit the current value of temperature to the base station. This paper explains about performance analysis of the network and the various steps involved in the experimental implementation and maintenance of the temperature monitoring network for High Performance Computing cluster.

In another research by A. K. Tripathy, A. Vichare, R. R. Pereira, V. D. Pereira, and J. A. Rodrigues [4], the authors proposed systems main aim is to implement a cost-effective automated gardening system. This system helps in solving the above problem by being efficient and using fewer resources. The system exploits cost efficient soil moisture, light and temperature sensors to decide when and how much water will be provided for a specific type of plant under consideration.

In the paper by R. M. Aileni [5], the author presents a mobile application for healthcare, which process data from humidity and temperature sensors. The mobile app is based on cloud computing SaaS (software as a service) cloud computing model. The cloud-computing infrastructure based on sensors is used in this paper for deploying an application, which provides patients monitoring (moisture, temperature or blood pressure). The data is sent and stored in a dedicated server for being analyzed later by doctors or caregivers. The advantages of sensor-cloud also come from using PaaS (platform as a service) and IaaS (infrastructure as a service) models.

In another research by P. Archana and R. Priya [6], the authors proposed a technique in which the humidity and soil moisture sensors are placed in the root zone of the plant. Based on the sensed values, the microcontroller is used to control the supply of water to the field. However, their system does not intimate the farmer about the field status.

In the paper by Sonali D. Gainwar and Dinesh V. Rojatkar [7], the authors proposed a fully automated system in which soil parameters such as pH, humidity, moisture and temperature are measured for getting a high yield from the soil. In this system, the motor pump switches ON/OFF as per the level of moisture in the soil. However, the current field status is not intimated to the farmer.

In another paper V. R. Balaji and M. Sudha [8], the authors proposed a paper in which the system derives power from sunlight through photo-voltaic cells. This system doesn't depend on electricity. The soil moisture sensor has been used and based on the sensed values PIC microcontroller is used to ON/OFF the motor pump. Weather forecasting is not included in this system

In the research by C. H. Chavan and P. V. Karnade [9], the authors proposed a smart wireless sensor network for monitoring environmental parameters using Zigbee. These nodes send data wirelessly to a central server, which collects data, stores it, and allows it to be analyzed then displayed as needed and also be sent to the client mobile. Weather forecasting and nutrient content is not determined in this system

In the paper by G. Parameswaran and K. Sivaprasath [10], the authors proposed a smart drip irrigation system using IOT in which humidity, temperature and pH sensors are used. Irrigation status is updated to the server or localhost using a personal computer. However, the farmer can't access the field condition without internet.

2. Theoretical Background

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall. When a zone comes on, the water flows through the lateral lines and ultimately ends up at the irrigation emitter (drip) or sprinkler heads. Many sprinklers have pipe thread inlets on the bottom of them, which allows a fitting and the pipe to be attached to them. The sprinklers are usually installed with the top of the head flush with the ground surface. When the water is pressurized, the head will pop up out of the ground and water the desired area until the valve closes and shuts off that zone. Once there is no more water pressure in the lateral line, the sprinkler head will retract back into the ground. Emitters are generally laid on the soil surface or buried a few inches to reduce evaporation losses. Healthy plants can transpire a lot of water, resulting in an increase in the humidity of the greenhouse air. A high relative humidity (above 80-85%) should be avoided because it can increase the incidence of disease and reduce plant transpiration. Sufficient venting or successive heating and venting can prevent condensation on plants surfaces and the greenhouse structure. The use of cooling systems during the warmer summer months increases the greenhouse air humidity. During periods with warm and humid outdoor conditions, humidity control inside the greenhouse can be a dare task. Greenhouses located in dry, desert environments benefit greatly from evaporative cooling systems because large amounts of water can be evaporated into the incoming air, resulting in significant temperature drops.

2.1 System Design

The microcontroller based system is designed in such a way that it turns the motor on and off on detecting the moisture content of the soil. A GSM module acts as a transmitter and receiver, which can be used to view the readings and stats of the sensors and the moisture level of the soil.

The aim of the system is to monitor the moisture content of the soil using a soil moisture sensor. The objective is to turn the pump ON when the soil moisture falls below a certain reference value. Next objective is to display the status of the soil and the tank using a 16×2 LCD.

3. System Design

3.1 Block Diagram

The block diagram of the proposed system can be represented as shown in Figure 1.

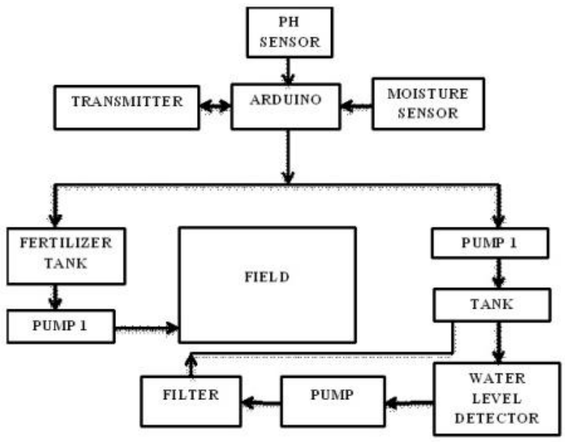

Figure1: Block Diagram

Here Arduino is the main control centre. From where moisture sensor, Xbee transmitter and pH sensor are connected .The values shown by the moisture sensor is calculated, and if the value is less than the reference value, the pump will start; otherwise, it will not perform. The Xbee is used to control the system remotely. Again, if the water level in the tank is low, it will be refilled back.

3.2 Circuit operation

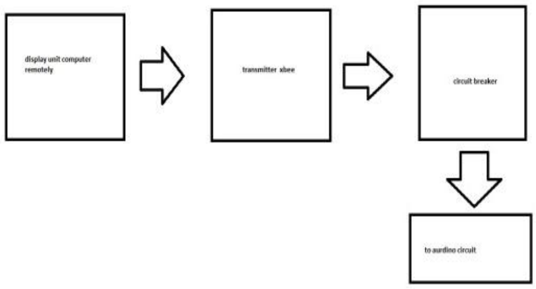

Figure 2: Block Diagram of Xbee

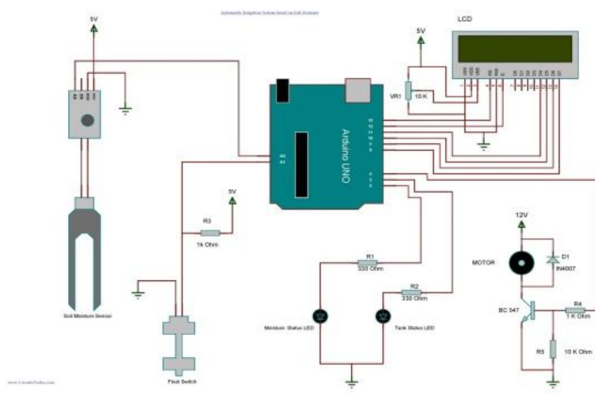

Figure 3: Circuit Diagram

1. The moisture sensor, pH sensor, Xbee transmitter, are connected to the analog inputs of Arduino.
2. Then, from the digital inputs of Arduino, an LCD is connected to display the results.
3. The pumps are connected by a motor drive circuit using diodes IND40007 and BJT. They are connected in reverse bias mode and resistance grounded for protection and to flow current only in one direction only.
4. A float switch and LED are used to indicate the water level of tanks.
5. If the water level of the tank is not sufficient, then with the help of level detector another pump will pull water from underground and allow it to pass through a filter which will purify the water and make it free from impurities and store it in the tank
6. Then as the tank gets filled up, the pump will automatically turn off by another Arduino working independently of the 1st Arduino connected to the main circuit.
7. Then with the help of Xbee the transmitter sends the data to a remote location for references and evaluations.
8. The moisture sensor will collect the data from the soil and feed it to Arduino, and if the moisture level is low, the pump will activate and water the area. If the moisture level is high; the pump won't turn on.
9. Similarly, the pH sensor will collect the percentage of nitrogen in the soil and will work by providing fertilizer.

We designed a system using the given components. The system was designed to keep the cost at a bare minimum as well as efficient system. Arduino is the central to the whole system. Table 1 shows the component list.

Table 1: List of Components

Sl. No.	Components	Range	Quantity
1	Arduino Uno Xbee transmitter	ATmega328P, 5v	1
2	LCD	25C, 64Hz, 5.0V	1
3	Resistor		5
4	BC547	45v, 100mA, 625mW, 300MHz	1
5	Diode		1
6	Pump		1
7	Potentiometer		1
8	LED		2
9	Float Switch		1
10	Moisture Sensor		1
11	Xbee	2.4 GHz, 250 Kbps	2

4. Result and Analysis

4.1 Soil testing

To measure and set the base value for the pump to be activated, we have calculated the resistances of various types of soils. Soils with high water contents will have low resistance as compared to soil with less water. Then we calculated the water content % of each sample of 50gm using wet-dry soil testing as shown in Table 2. It is given by the formula %water = wet soil(weight) - dry soil(weight) / 1000gm per cubic cm.

Table 2: Water content testing of different soils

Soil Type	Water Content	Moisture Level
sandy	0.1	Low
low clay loam	3.5	High
wet soil	5	High
loam	0.2	low

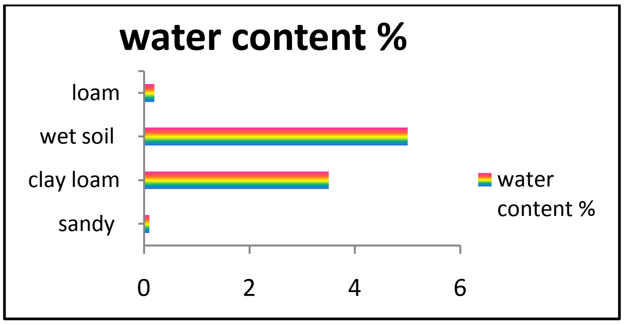

Figure 4: Graph representation of soil testing results

5. Conclusion and Future Scope

The Cultivation Management System based on cloud is a very effective system for the user, which cultivates the plants on the farm field by this farmer can examine their farm field information and detail from anywhere in between range The proposed monitor tool gives soil moisture details, water level details which can help to increase in productivity by using such automated irrigation system.

The proposed system can be extended in future by adding the feature for remotely monitoring sensors that can detect crop growth and livestock feed levels. In the future, adding the features that can remotely manage and control their smart connected other irrigation equipment in the proposed system can be investigated.

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Authors' Profiles

Sandeep Minz, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester), in the School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Ankit Saha, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester), in the School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Mrinmoy Ranjan Dev, is currently pursuing B.Tech in Electrical and Electronics Engineering (final semester), in the School of Technology, Assam Don Bosco University, Airport Road, Azara, Guwahati -781017, Assam, INDIA.

Review on Design and Simulation of Electricity Theft Detection and Protection System with their techno-economic Study

Moitreyo L. Handique[1], Queen Kalita[2], Gitu Das[3]

[1,2,3] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]moitreyolakhyahandique@gmail.com, [2]kim.kalita.1@gmail.com, [3]gitu.das@dbuniversity.ac.in*

Abstract: ***Theft of electricity is a major problem faced by both developed as well as developing countries. It affects both the power as well as economic situation. It also at times is the root cause of blackouts. The objective of this paper is to design and simulate a system that can detect, which in turn, will help in protection from electricity theft.***

Keywords: Electricity theft; Electricity protection; Smart meter, MATLAB Simulink; Smart-grid.

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1. Introduction

Modern life cannot be possibly imagined without electricity. From a simple light to computers to even vehicles, now it has grown into such a necessity that it has been declared as a fundamental right. Such is the importance of electricity in modern life. The value of electricity cannot be undermined in the technology-driven world where our daily lives are dominated by appliances and gadgets. Yet there are still places where electricity is not available yet, and their people are still who do not enjoy this fundamental right as we do. There are various reasons for this, such as the insufficient power generation, losses, various geographical terrains etc. But, among these, one of the major reasons is electricity theft. With the advent of automobiles that run on electricity and needs charging, the electricity theft situation is expected to worsen further. This is a huge challenge faced by the whole world, where one side we are talking about carbon emission and need to use renewable clean energy for sustainable growth, we are not being able to manage the situation in an efficient manner.

The motivation of this study is to come up with a measure to detect, prevent and counter the problem of electricity theft in an efficient and robust manner such that it can be tackled and therefore, help the power as well as economic situation.

1.1 Literature Survey

In the research work done by P. Jokar *et al.* [1], the authors presented a consumption pattern-based energy theft detector, find suspicious usage pattern. Areas with a high probability of malicious usage pattern are marked, and by monitoring abnormalities in consumption patterns, suspicious customers are identified. Classification and clustering techniques are used. Also, the use of transformers and anomaly detectors, make the algorithm robust against no malicious changes in usage pattern and provide a high and adjustable performance with a low sampling rate.

In the research work done by M. Tariq *et al.* [2], a stochastic Petri net formalism is used in this paper to detect and localize the occurrence of theft in grid-tied MGs. The disturbance in any of time in the form of resistance above a threshold in the accumulated data of a smart meter, irrespective of the mode of operation, initiates a transition assigned to the arc, which notifies the transmission module. The affected transition and suspected user information are sent to the Meter Data Management System (MDMS) for localization of the theft. In experiments, it calculates the technical and non-technical losses with absolute accuracy without having the knowledge of the exact topology of the power distribution network.

In the research work done by A. J. Dick [3], the researcher looks at revenue protection activities within the UK to combat the problem of theft of electricity, which is estimated to cost the electricity industry (EI) some #50 m per annum. The nature and scale of the problem are first analyzed, with comments on the relative incidence of the various types of theft and interference, and the legal framework is indicated. A report is then made with the mentioned procedure.

In the research done by N. Mohammad *et al.* [4], the researchers proposed a prepaid energy metering system to control electricity theft. Smart meters are used and installed at every customer unit and server is maintained. Both the meter and the server are equipped with GSM module, which allows bidirectional communication. A few techniques to counter malpractices related to electricity are stated. Electricity theft can be reduced using these methods.

In the research work done by A. Jindal *et al.* [9], the authors concentrated on Nontechnical losses, particularly due to electrical theft, have been a major concern in power system industries for a long time. There is a gap between demand and supply and therefore creates energy constraints. Thus, there arises the need to develop a scheme that can detect these thefts precisely in the complex power networks. So, keeping focus on these points, this paper proposes a comprehensive top-down scheme based on a decision tree (DT) and support vector machine (SVM). This system is unique as it can detect theft in both transmission and distribution. The proposed scheme is based on the combination of DT and SVM classifiers for rigorous analysis of gathered electricity consumption data. In other words, the proposed scheme can be viewed as a two-level data processing and analysis approach, since the data processed by DT are fed as an input to the SVM classifier. Furthermore, the obtained results indicate that the proposed scheme reduces false positives to a great extent and is practical enough to be implemented in real-time scenarios.

In the research work done by J. Nagi *et al.* [10], the authors worked on finding efficient measurements for detecting fraudulent electricity consumption has been an active research area in recent years. This paper presents a technique to deal with non-technical losses using a novel intelligence-based technique, Support Vector Machine (SVM). The main motivation of this study is to assist Tenaga Nasional Berhad (TNB) in Malaysia to reduce its NTLs in the distribution sector due to electricity theft. The proposed model preselects suspected customers to be inspected onsite for fraud based on irregularities and abnormal consumption behavior. Here customer consumption patterns are recorded. It detects using abnormal usage pattern. Suspicious users are shortlisted. This method is proved better when simulated in comparison to existing techniques,

In the research work done by J. Nagi *et al*. [11], the authors worked on finding efficient methods for detecting electricity fraud that has been an active research area in recent years. This paper presents a hybrid approach towards non-technical loss (NTL) analysis for electric utilities using genetic algorithm (GA) and support vector machine (SVM). The main motivation of this study is to assist Tenaga Nasional Berhad (TNB) in Malaysia to reduce its NTLs in the distribution sector. This hybrid GA-SVM model preselects suspected customers to be inspected onsite for fraud based on abnormal consumption behavior. The proposed approach uses customer load profile information to expose abnormal behavior that is known to be highly correlated with NTL activities. GA provides an increased convergence and globally optimized SVM hyper-parameters using a combination of random and repopulated genomes. The result of the fraud detection model yields classified classes that are used to shortlist potential fraud suspects for onsite inspection. Simulation results prove the proposed method is more effective compared to the current actions taken by TNB in order to reduce NTL activities.

In the research work done by T. B. Smith [12], he worked on the aspect that electricity theft can be in the form of fraud (meter tampering), stealing (illegal connections), billing irregularities, and unpaid bills. Statistics of electricity theft in 102 countries were collected. Electricity theft and various ways to counter are discussed.

In the research work done by R. F. Ghajar *et al.* [13], the authors worked on the aspect that one of the largest pitfalls for any distribution network is the level of energy losses suffered by the system. Two types of losses being technical and non-technical, technical losses depend largely on the physical properties of the network, while non-technical losses (sometimes a more significant form of losses) are the result of theft or fraud caused by meter tampering, false reading, illegal connections or unpaid bills. The results of this study and a cost/benefit analysis of the proposed system are summarized in this paper.

In the research work done by K. L. Joseph *et al.* [14], the authors worked on the aspect that ongoing theft, corruption, and an artificially decreased pricing structure have made it nearly impossible for the state utilities in India to improve power service. As a result, industrial consumers across India exit the state-run system and rely on their own on-site power generation in order to ensure a consistent and reliable source of electricity. The 2003 Electricity Act encourages further power production from these captive plants through its open access clause. By encouraging the growth of these captive power plants, politicians in India set up a dual-track economy, whereby state-run and market-run production exist side-by-side. This strategy allows politicians to encourage private sector involvement in the electricity market, without jeopardizing the support of key political constituencies at the state level.

2. Theoretical Background

2.1 Indian Scenario

Power theft in India is a critical issue that the country has been trying to deal with for years. The problem is found not simply within the rural areas; however, it's conjointly rampant within the cities likewise. Even though the government has claimed to achieve village electrification in all the villages in India [16], power theft is something that the Indian Govt. has failed to address properly.

As per the Central Electricity Authority, over 27 pc of all power produced in India is either lost due to dissipation from wires or theft. That's about 261,130 GW/HR of power annually- enough to light up New York for nearly two years. It is valued nearly bureau one trillion at a median electricity rate of bureau four per unit.

2.2 World Scenario of power theft

When we hear the phrase "electricity theft," we may automatically picture places like India or Brazil where the number of power outages is astounding. However, unfortunately electricity thieves can be found in nearly every country across the globe, including the U.S. Whether it's performing illegal hookups, tampering with meters, or stealing copper wire from substations, over $200 billion in electricity is lost each year due to equipment failure or electricity thieves. In the U.S. alone, this crime costs roughly $6 billion annually, which makes it the third most stolen commodity following credit card information and vehicles [15].

2.3 Micro Grid

Micro grid technology is especially good at managing and storing natural resources at the point of consumption, meaning they can incorporate clean renewable energy from the sun, wind, waves etc. On Robben Island, the former apartheid prison and now a world heritage site, diesel use have been cut by 75%; while Kodiak Island gets 99% of its power from renewable sources. The ability to be self-sufficient means micro grids can be vital even where larger grids already exist. That is why Red Cross installed a solar micro grid at their Logistics Center in Nairobi to make sure they are covered even during national power outages. Cities at risk from extreme weather conditions can also benefit from having these islanded grids. Micro grids have emerged as one of the key technologies in the ongoing energy revolution helping to make power cleaner and available to more people than ever before.

2.4 Smart Grid

A grid is a network of power lines and substations, which carry electricity from the power station to homes and businesses. Today the grid is in problem, it needs updating and is running at capacity. When power lines break, our power stations cannot generate enough power, blackouts can occur, which is a problem that can cause fatalities. Grids often rely on a single power source and do not provide detailed information on the utilization or consumption, making electricity difficult to manage. To address these problems in the past, simply new power plants were built, but now we need to work towards sustainability and reduce our dependency on fossil fuels by using a smarter grid.

A smart grid suggests that adding sensors and package to the present grid that may offer utility people new info that may facilitate them to perceive and react to changes quickly. For example, if a tree falls on a power line, 1000 homes loose power supply. With the current grid system, .utility employees often physically reroute power, which takes time. With the smart grid, sensors and software would identify and immediately rout the power around the problem, limiting the issue to fewer homes. And there is more, the price of electricity changes throughout the day, but we cannot see it with the current meters in our homes. It may be expensive at peak hours and cheap at nights, with new smart meters we could set heavy power appliances such as dishwasher to run when power is cheap. This provides individuals with more control over their power bills and helps prevent blackout during peak hours. The smart grid also means new ways to use renewable energy. Power generation can now be distributed among multiple sources, so the system is more stable and efficient. This provides the ability to communicate and manage electricity that helps the grid in a smarter way and helps us avoid burning more fossils fuels in the future. The smart grid will help us manage our power bill, help the environment and also help the economy by making a more informed decision about how we use electricity.

3. System Design

3.1 Power Summation Method

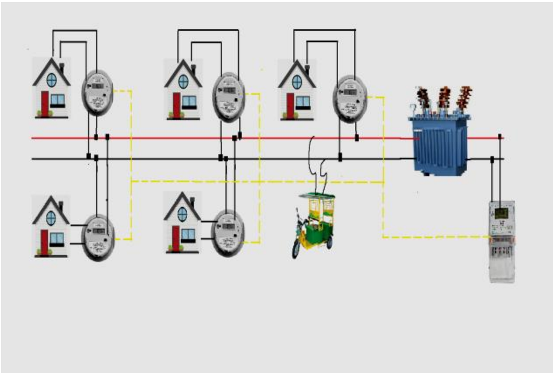

Figure 1: Power Summation Method

The block diagram is one of the two methods intended to work on in this study. One of the two methods is being discussed here.

In this method, the concept of micro grid as well as smart grid is considered along with smart meters. The whole concept of the method is based on the smart meters and the two-way communication they are capable of. The concept is that a micro grid is connected to say a power supply source, which will have a transformer with its own smart meter, connected between it and the loads. Each of the load or houses will have their own smart meters, which will both communicate among themselves as well with the transformer. The whole concept is built on the idea that if the summation of all the power received by individual smart meters considering the possible losses is less than the power supplied by the transformer, there must be electricity theft somewhere in the grid.

This method though on the surface, may seem a very simple one, yet the main and big challenge is that of distinguishing between the losses and the electricity theft. It is basically the main hurdle in the method. Another hurdle in this method has been to come out with ways to localize the theft; we're still studying and trying to come up with ways, which can localize and give us a location regarding the theft.

4. System Implementation (Simulation)

The concept was implemented in MATLAB Simulink. A radial system of transmission is designed showing a 3-phase power Source. A 3-phase transformer was connected to this source while attaching a power measuring unit to it. Then, with a transmission line having inductance and resistance. Power is supplied to three load units, each with its own current measuring unit. The idea is to compare the real power quantities of the supply transformer and the summation of the loads. We have given power measuring units to two of the three loads to consider the one without theft. If the comparison of the real power between the transformer and summation of loads comes off equal, there is no theft and vice versa.

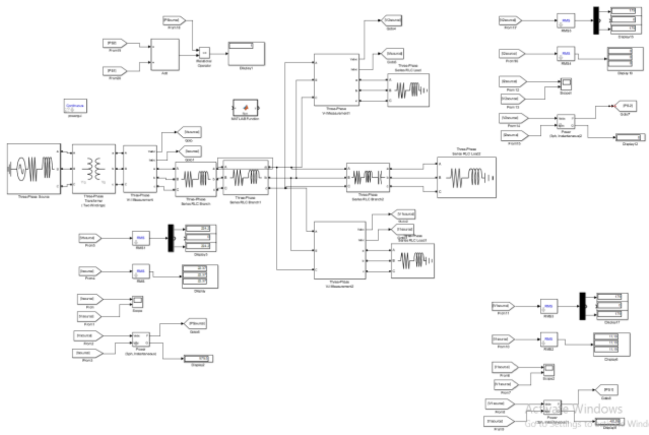

Figure 2: Matlab Simulation

5. Results

The comparator compares the real power of the supply transformer and the real power summation of the loads. If the result of the comparison is equal, then there is no theft and vice versa. Then the result is shown on a display block.

Table 1: Results on the Display Block

Output	Result
1	Theft
0	No Theft

6. Conclusion & Future Scope

The expected outcome of this study is to have various methods to counter the huge problem of electricity theft and to provide a comprehensive and comparative study between these methods based on the economic as well as various aspects. The expected end product of the study is to design and simulate these methods and therefore come up with practical solutions to help the power and economic situation of our country as well as the world.

We managed to detect electricity theft successfully. Localization is the prospect that can be worked on to make the method more robust.

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Authors' Profiles

Gitu Das, M.Tech., is working as an assistant professor in Assam Don Bosco University, India. He has 1.5 years of industrial experience (in Philips health care as service engineer & T&T Projects Ltd. as site engineer for various substation, overhead lines, electrical wiring etc. His areas of research interest are Renewable Energy, Embedded Systems.

Moitreyo L. Handique, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University (India). His areas of interest are Power Plants Engineering, Renewable Energy.

Queen Kalita, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University (India).Her areas of interests are Renewable Energy, Power Systems.

Transformer Oil Quality Diagnostic Using Spectroscopy Techniques - A Review

Hironmay Deb[1], Javin Nunisa[2], Mun moon sun Naiding[3], Superdao Jidung[4], Dipankar Sarmah[5]

[1,2,3,4,5] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]deb.hironmay@gmail.com, [2]javinnunisa@gmail.com, [3]naiding29@gmail.com, [4]superdao23@gmail.com,*
[5]sarmahdipankar3@gmail.com

Abstract: ***Transformer serves as a vital component in the electrical energy supply system. In order to have an uninterrupted power supply, it is essential to timely monitor the condition of the transformer. A transformer has many components, out of which the transformer oil is one of the most crucial. It provides insulation and keeps the transformer cool. With ageing, the quality of the transformer oil degrades, and it loses its insulation properties that become a threat to the supply system. Optical Spectroscopy has gained a lot of attention in monitoring the quality of transformer oil in the past few years for various advantages. This paper reviews some of the commonly applied Spectroscopy techniques to monitor the various components of transformer oil by which we can predict the quality of the oil.***

Keywords: Optical method; Spectroscopy; Transformer oil; DGA (Dissolve Gas Analysis); CLRS.

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1. Introduction

Power Transformers are one of the most vital elements in the transmission and distribution network. It is also the costliest instrument in the power system. To continue the power supply system, it is essential to monitor the condition of transformers continuously. Oil in a transformer serves as a coolant and provides insulation between the different parts [1-2]. Under continuous working conditions and with ageing the quality of transformer oil degrades [3]. Therefore, it becomes very crucial to timely monitor the quality of oil to prevent any kind of catastrophic failure. Quality monitoring of transformer oil involves the testing of various parameters of transformer oil such as moisture content, acidity, breakdown voltage, dielectric dissipation factor and interfacial tension [4]. Dissolved Gas Analysis (DGA) is one of the most widely used techniques [5]; however due to need in expertise and complex setup requirement, optical techniques are considered as an alternative. Optical fibre system is used as an alternative to electrical techniques [6-7]. Recently, various spectroscopy techniques are under research to develop other optical techniques to access the various parameters of transformer oil [8-9]. This paper describes the various spectroscopy techniques used to study the various parameters considered to monitor the quality of transformer oil.

2. Fundamental of Optical Spectroscopy

Optical Spectroscopy technique studies the interaction between a matter and electromagnetic wave (EM) [10].The matter reflects, absorbs, diffuses, refracts or emits at particular wavelengths whenever an EM wave interacts with a matter. The readings obtained using spectroscopy techniques are accurate. In the UV-VIS-NIR spectroscopy techniques, light is passed through a sample under test and is detected in terms of optical signal, transmittance or reflectance. The results are then converted to absorbance as a function of wavelength given by Beer-Lambert Law [11] as

$$A_\lambda = -\log_{10}\left(\frac{S_\lambda - D_\lambda}{R_\lambda - D_\lambda}\right) = \varepsilon_\lambda . c . l \qquad (1)$$

where, A_λ is the light absorbance, S_λ is the sample intensity, R_λ is the reference intensity D_λ is the dark intensity, ε_λ is the absorbance coefficient of the absorbing species at wavelength λ, c is the concentration of the absorbing species (gram/liter) and l is the path length traversed by the light.

The spectrum of spectroscopic techniques is divided into Ultraviolet region, Visible Region and Infrared Region. This paper describes the spectroscopy techniques one by one.

Types of Spectroscopic Techniques used for monitoring transformer oil quality are:

- UV-VIS Spectroscopy
- NIR Spectroscopy
- Conical Laser Raman Spectroscopy (CLRS)

2.1 UV-Vis Spectroscopy

UV-VIS Spectroscopy is used commonly nowadays to monitor the change in various parameters in transformer oil .The system used is simple, robust and user-friendly methods compared to conventional Dissolved Gas Analysis (DGA) methods that require special expertise for testing. In literature, numerous methods have been described using UV-VIS Spectroscopy [12-13]. In this paper, some of the common setup use for spectroscopy is described.

In a method, the quality of inhibitors present in transformer oil was studied using UV-VIS Spectroscopy [14]. The organic chemical compounds known to retard oxidation in insulating oil are known as inhibitors [15]. There are various inhibitor such as 1,2,3-Benzotriazol (BTA), 2,6-ditertiarybutyl-para-cresol (DBPC), Nphenyl-1-naphthylamine and methylated-BTA, 2-tert-butyl-p-cresol (2-t-BPC), dibenzyl disulfide (DBDS), 2, 6-ditertiarybutyl phenol (DBP).Out of these DBPC is the most universally accepted and desired inhibitor material in transformer oil. These inhibitors deplete over a period of time, which results in a degradation in transformer oil quality. Therefore, it becomes very necessary to timely monitor these inhibitor contents with proper sensing techniques.

Spectroscopy technique determined the weight percentage of inhibitor in the transformer oil. Different weights of Inhibitor content in oil was studied using the spectrometer setup shown in Figure 1.

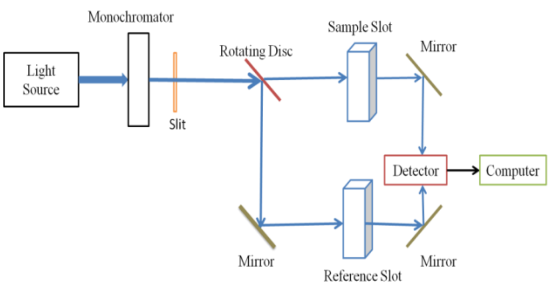

Figure 1: Block diagram of double beam spectrometer [14]

Optical absorbance was studied using the above setup. Using a rotating disc light was allowed to pass through the sample slot and reference slot. The ratio between the sample absorbance and reference gave the absorbance for various samples tested. It was found that the sample at 1403nm gave the best absorbance, so a single wavelength source photodetector was aimed to make the system low cost and portable [14]. The system model designed showed a correlation between %IC in transformer oil and the peak absorbance wavelength.

In another work, the interfacial tension (IFT) of insulating oil was studied using UV-VIS spectroscopy [16]. IFT value is a marker for products of degradation and soluble polar contaminants [17]. These affect the physical and electrical properties of transformer oil by reducing the insulating properties. IFT value is determined by the amount of force required to separate a planar ring of platinum wire one centimetre through water/oil interface as stated in ASTM D971 (Interfacial Tension of Oil against Water by the Ring Method). The setup to calculate IFT value is a mechanical process that requires many precautions and standard procedures to be followed. As the setup is highly sensitive, there are high chances of mechanical errors. Instead of mechanical setup, the optical procedure provides a powerful and non-destructive technique for ITF measurement. A UV-spectroscopy setup, as shown in Figure 2, was used to measure the absorbance of 50 different samples of transformer oil [16]. The method eliminates the use of mirrors, making the system flexible and compact. Light from the source is allowed to pass through the oil sample, which is then collected by an optical fibre as input to the spectrometer. The light then interacts with the oil sample, due to the presence of various contaminants some of the light at particular wavelengths is absorbed by the oil sample. The absorbance is calculated by the Beer-Lambert Law.

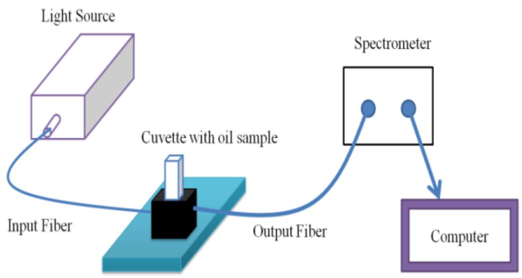

Figure 2: Experimental setup for UV-Vis Spectroscopy [16].

The absorbance of oil samples for different IFT was plotted and found that a correlation was found that with increasing absorbance, there is a decrease in IFT number.

Artificial Neural Network (ANN) was used to calculate the correlation between IFT of transformer oil and its spectral response parameters like bandwidth and peak absorbance. The bandwidth and peak absorbance of oil spectral response are extracted and provided to the proposed ANN estimation model. The results show that UV-VIS spectroscopy technique gave comparable results when compared to commercial ASTM D971 (Interfacial Tension of Oil against Water by the Ring Method) standard. The UV-VIS spectroscopy method is found to be accurate, cheaper and user-friendly as compared to ASTM D971 standard method.

UV-VIS Spectroscopy conducted gave data about the physical condition of transformer oil along with dissolved decay products generated in the oil samples. However, no information could be extracted about the functional groups and molecular structure of the organic compounds in the transformer oil. In this regard, Alshehawy *et al*. used UV-VIS spectroscopy along with FTIR spectroscopy for condition assessment of transformer oil [18]. UV-VIS spectroscopy and FTIR spectroscopy were compared by using aged samples of oil. The UV-VIS spectroscopy covers a wavelength range from 200nm to 800nm whereas the FTIR spectroscopy extends the range from 2.5µm to 25µm. Mineral transformer oil consists of a complex of paraffins, naphthenes and aromatic hydrocarbon. Out of them, aromatic hydrocarbon absorbs energy in the UV range from 200nm to 380nm. The peaks that appear in the spectrum were resulted due to conjugated C=O bond and C=C d=bonds that show response at two different wavelength values. The absorbance peaks shifted to higher wavelengths with the ageing of the transformer oil. Whereas, FTIR spectra are used to identify the difference in the functional groups.

S. Karmakar *et al*. used UV-VIS spectroscopy techniques to study the insulation properties of transformer oil [19]. There are various factors such as electric arcing, partial discharge (PD), thermal ageing, which contribute to the degradation of oil quality. In this method, they studied the degradation due to PD, which were marked by sharp peaks at nearly 293nm and 306nm.The schematic of the setup is shown in Figure 3.

PD is generated in the setup using needle-flat electrode. The magnitude of PD is varied according to the supplied voltage. Four samples of transformer oil were prepared namely S1,S2,S3,S4 where S1 for new transformer oil,S2 for transformer oil aged by PD and S3 transformer oil aged by electric arcing with 500 numbers of shots, and S4 transformer oil aged by thermal effects by heating new transformer oil at 120°C for 1h respectively.

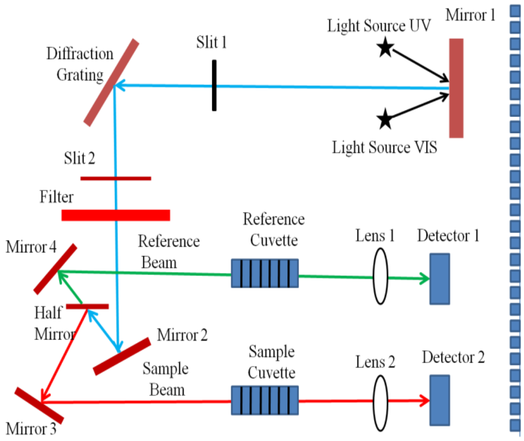

Figure 3: The schematic diagram of the optical absorption measurement in the UV-VIS spectrometer [18].

The ageing of transformer oil increases the aromatic content and acidity, which gives rise to C=O and C=C double bond. Due to ageing the paraffin compounds of the transformer oil dehydrogenate and result in the formation of naphthenic compounds. Further, dehydrogenation of the naphthenic compounds forms conjugated C=C double bonds. These chemical processes also result in colour change in the transformer oil. The changes in the characteristic of the transformer oil are depicted easily using the UV-VIS spectroscopy method, which results to be an effective way of monitoring the quality of oil with ageing.

The above literature studies of methods to monitor transformer oil quality with ageing shows a similar trend in the absorption spectrum where typically in a wavelength range from 280nm to 400nm the absorption peak appears. So, designing a setup with a far UV light source or targeting a single source of light for studying the oil quality may be taken into account to make the setup more compact and low cost.

2.2 NIR Spectroscopy

NIR Spectroscopy has been implemented to study the degradation of transformer oil. Borges *et al*. proposed a method to analyze the chemical degradation of mineral insulation oil [20]. A prototype that adapts on Buchholz transformer relay using the Near Infrared Spectroscopy with chemometrics techniques is used to analyze light gaseous hydrocarbons (methane, ethane, ethylene and acetylene). The test was performed using 29 different samples and absorbance spectrum for all these samples was studied. High-intensity absorbance peak at 2300nm for all the samples showed the regularity in the response of the samples. The magnitude of samples for different concentration of gases is different, but the peak wavelength remains almost the same. Therefore, an intensity-based prototype can be designed that used to monitor the gaseous contents in transformer oil.

In another method, Attenuated Total Reflectance Tool (ATR) was used to detect the effect of Thermal Oxidation and Nitration in the deterioration of quality of transformer oil [21]. The principle of ATR technique is shown in Figure 4.

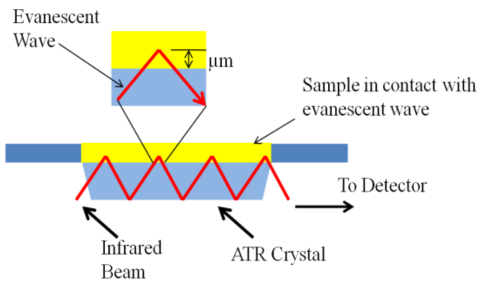

Figure 4: Principle of ATR technique [21]

The sample under test is placed on a detection crystal and a part of IR ray causes absorption in the sample when passing through the crystal sample interface (evanescent wave) and weakens this part in the resultant spectrum. A peak intensity is shown in the NIR wavelengths where the absorption is due to Thermal Oxidation and Nitration.

2.3 Laser Raman Spectroscopy

Laser Raman Spectroscopy (LRS) is based on the Raman Effect, which was discovered by C. V Raman in 1928. The structures and properties of matter can be estimated by directly measuring the Raman scattering light produced by matter due to irradiation. Photons of incident light are absorbed by the electron in a gas molecule with $h\nu_o$ energy, which is the Rayleigh scattering light without any change in frequency. An energy of $h(\nu_0 + \Delta\nu)$ is released by another part of the electrons that return to the vibration excited state. This is the Raman scattering light with the frequency change. The transition is shown in Figure 5.

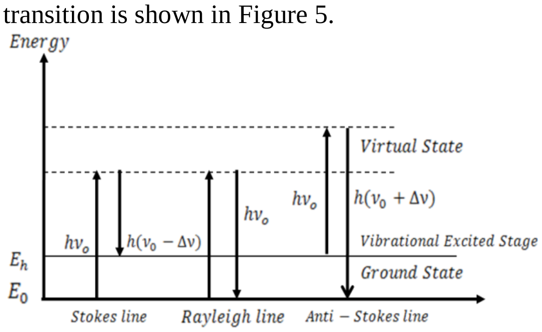

Figure 5: Raman scattering process

The change in frequency $\Delta\nu$ of the Raman scattering is called Raman shift. The structural information of the molecules can be predicted from this Raman shift, which corresponds to the fundamental frequency of the vibration mode of the molecule. The gas concentration is proportional to the peak intensity of the Raman spectrum. So, without separating the mixture of gases we can get the composition and concentration of the gas by analyzing the Raman shift and peak intensity.

The intensity of the Raman scattering is given by the formula

$$I_R = \frac{2^4\pi^3}{45 \times 3^2 C^4} \times \frac{hI_L N\,(v_0 - v)^4}{\mu v\left(1 - e^{-\frac{hv}{KT}}\right)} \times [45\,(\alpha_a')^2 + 7\,(\gamma_a')^2] \quad \dots (2)$$

where c is the speed of light, h is the Plank's constant, I_L is the excitation light intensity, N is the number of molecules scattering light, ν is the vibration frequency of the molecule in Hz, ν_0 is the laser frequency in Hz, µ is the reduced mass of vibration atom; K is the Boltzmann's constant, T is the absolute temperature, α'_a is the average invariant of polarizability tensor, Υ'_a is the isotropic invariant of polarizability tensor.

Laser Raman Spectroscopy technique was adapted to measure the dissolved C_2H_2 gas concentrations present in transformer oil [22]. As shown in Figure 4, a frequency doubled Q-switched Nd:YAG laser (532nm) was used as a source and the signals were detected 1.972µm originating from C_2H_2 gas.

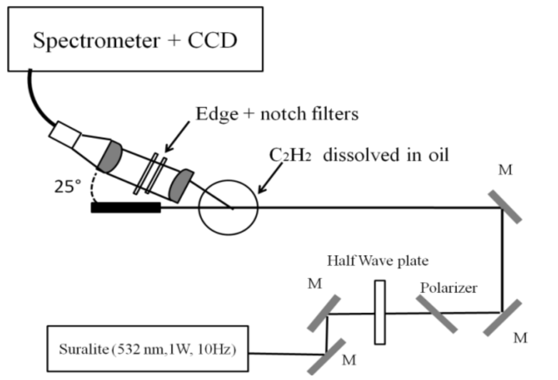

Figure 6: Schematic diagram of experimental setup [22].

The intensity peaks were detected at 1450cm^{-1}. These were due to CH_3-CH_2 bonds, peaks at 1302 and 1350 cm^{-1} correspond to paraffin C-H twisting modes, peaks at 1610 cm^{-1} is due to an aromatic C=C stretching mode. The various peaks can be selectively chosen to get a better response for any particular component of bonds. The Raman Spectroscopy opens new techniques, which are very sensitive methods to detect changes in the components of transformer oil.

In practical applications, the sensitivity of the current LRS detection method cannot meet the required efficiency in engineering applications [24]. To meet this requirement, Conical Laser Raman Spectroscopy (CLRS) was adopted. The setup of CLRS using a Raman probe, as shown in Figure 7.

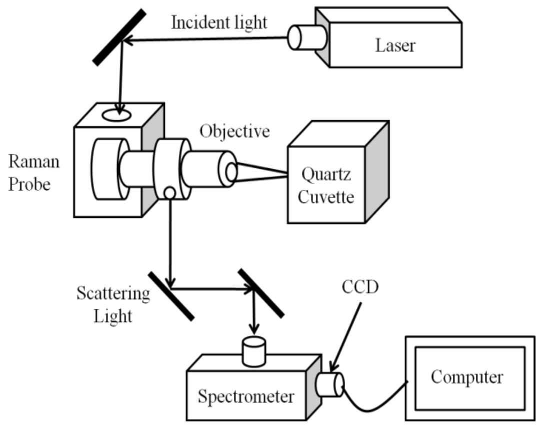

Figure 7: Schematic of CLRS Experimental Setup [25].

Gu *et al.* proposed a method for Conical Laser Raman Spectroscopy (CLRS) detection characteristic of acetone dissolved in transformer oil [25]. The figure below shows the setup using a 532 nm solid-state laser along with a CCD based spectrometer. A quartz cuvette was filled with different oil samples, and the response was analyzed for Raman peaks. Multiple Raman Peaks were observed along the spectrum, out of which a peak at 780 cm^{-1} had the highest intensity for acetone. Different samples of acetone dissolved in transformer oil were studied at 780 cm^{-1}.This process opened a new approach of using CLRS method that is simpler and provides faster, non-touch and non-destructive detection compared to conventional methods.

Another compound in the transformer oil, Furfural (Furan 2-carbaldehyde) that is regarded as an important marker for the thermal and mechanical degradation in oil-paper insulation can be monitored using CLRS [25].

Raman peaks at five different wavelengths at 1371, 1399, 1471, 1677 and 1699 cm^{-1} were detected for Furfural.

Conventional Raman enhancement methods, such as Resonance Raman Spectroscopy [26], Tip-Enhanced Raman Spectroscopy [27], and Surface-Enhanced Raman Spectroscopy [28] appear to be inadequate for monitoring gases in transformer oil. Compared to conventional methods CLRS has high intensity and better efficiency. CFLS also makes the system compact and accurate.

Raman Spectroscopy was applied to analyze many other compounds in transformer oil like methyl formate [29], Oil-paper insulation [30], and methanol [31].

3. Conclusion

Even though DGA is one of the most popular methods of transformer fault diagnostic but as it is laboratory-based testing system that required a certain amount of time for analysis, along with the expertise of testing, Optical Spectroscopy methods have taken the lead in overcoming these difficulties. Due to high sensitivity and ability to make a compact and low-cost detection system using optical components, Spectroscopy techniques are now more researched for application in transformer fault analysis.

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Authors’ Profiles

Hironmay Deb, is working as an Assistant Professor in the department of Electrical and Electronics Engineering at Assam Don Bosco University.

Javin Nunisa, is currently Pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University.

Mun moon sun Naiding, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University.

Superdao Jidung, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University.

Dipankar Sarmah, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University.

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ASSAM DON BOSCO UNIVERSITY

Azara Campus, Airport Road, Guwahati - 781017
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