



Journal which deals with research, Innovation and Originality



Table of Content

Topics	Page no
Chief Editor Board	3-4
Message From Associate Editor	5
Research Papers Collection	6-34

CHIEF EDITOR BOARD

- 1. Dr Chandrasekhar Putcha, Outstanding Professor, University Of California, USA**
- 2. Dr Shashi Kumar Gupta, , Professor, New Zealand**
- 3. Dr Kenneth Derucher, Professor and Former Dean, California State University, Chico, USA**
- 4. Dr Azim Houshyar, Professor, Western Michigan University, Kalamazoo, Michigan, USA**
- 5. Dr Sunil Saigal, Distinguished Professor, New Jersey Institute of Technology, Newark, USA**
- 6. Dr Hota Ganga Rao, Distinguished Professor and Director, Center for Integration of Composites into Infrastructure, West Virginia University, Morgantown, WV, USA**
- 7. Dr Bilal M. Ayyub, professor and Director, Center for Technology and Systems Management, University of Maryland College Park, Maryland, USA**
- 8. Dr Sarâh BENZIANE, University Of Oran, Associate Professor, Algeria**
- 9. Dr Mohamed Syed Fofanah, Head, Department of Industrial Technology & Director of Studies, Njala University, Sierra Leone**
- 10. Dr Radhakrishna Gopala Pillai, Honorary professor, Institute of Medical Sciences, Kirghistan**
- 11. Dr Ajaya Bhattarai, Tribhuvan University, Professor, Nepal**

ASSOCIATE EDITOR IN CHIEF

- 1. Er. Pragyan Bhattarai , Research Engineer and program co-ordinator, Nepal**

ADVISORY EDITORS

- 1. Mr Leela Mani Poudyal, Chief Secretary, Nepal government, Nepal**
- 2. Mr Sukdev Bhattarai Khatry, Secretary, Central Government, Nepal**
- 3. Mr Janak Shah, Secretary, Central Government, Nepal**
- 4. Mr Mohodatta Timilsina, Executive Secretary, Central Government, Nepal**
- 5. Dr. Manjusha Kulkarni, Asso. Professor, Pune University, India**
- 6. Er. Ranipet Hafeez Basha (Phd Scholar), Vice President, Basha Research Corporation, Kumamoto, Japan**

Technical Members

- 1. Miss Rekha Ghimire, Research Microbiologist, Nepal section representative, Nepal**
- 2. Er. A.V. A Bharat Kumar, Research Engineer, India section representative and program co-ordinator, India**
- 3. Er. Amir Juma, Research Engineer ,Uganda section representative, program co-ordinator, Uganda**
- 4. Er. Maharshi Bhaswant, Research scholar(University of southern Queensland), Research Biologist, Australia**

Message from IJERGS

This is the First Issue of the Seventh Volume of International Journal of Engineering Research and General Science. A total of 3 research articles are published and we sincerely hope that each one of these provides some significant stimulation to a reasonable segment of our community of readers.

In this issue, we have focused mainly on the Young innovative Ideas. We also welcome more research oriented ideas in our upcoming Issues.

Author's response for this issue was really inspiring for us. We received many papers from many countries in this issue but our technical team and editor members accepted very less number of research papers for the publication. We have provided editors feedback for every rejected as well as accepted paper so that authors can work out in the weakness more and we shall accept the paper in near future.

Our team have done good job however, this issue may possibly have some drawbacks, and therefore, constructive suggestions for further improvement shall be warmly welcomed.

IJERGS Team,

International Journal of Engineering Research and General Science

E-mail – feedback@ijergs.org

A Literature Review: Traditional and Advanced Protection Schemes of Power Transformer

Atul Jaysing Patil, Arush Singh

Condition Monitoring, Control and Protection of Electrical Apparatus,

PG Scholar, National Institute of Technology, Hamirpur

Email- atul2322nith@gmail.com, arushsingh.contact@gmail.com

Abstract— Power transformers perform a pivotal role in a power system network in ensuring reliable power supply to electricity consumers. This paper contributes the concept about different types of transformer protection so that will be more helpful for investigating the protection system of the transformer. In this Paper, an effort is made to put together developments in the protection of the transformer. Efforts have been made to cover all the techniques and philosophies used to that end. The article includes the most recent techniques and traditional techniques of the transformer. There are many important parts installed in the transformer which is very costly so these have to be safe in an abnormal condition. Transformer performs a great job in the power system to change voltage and current level so proper protection for the transformer is important to maintain reliability in the system. Usually, a well-designed transformer protection system provides a great life without any uninterrupted power supply. To increase life, efficiency, overall performance then reduces stress on the transformer is the only way so this protection system help here to observe those things properly.

Keywords— Power Transformer, Fault statistics, Fuzzy set method, Artificial Neural Network Approach Overcurrent protection, Differential protection, Inter-turn fault, Earth-fault protection, Traditional method of protection.

I. INTRODUCTION

The function of protective relaying is to initiate the prompt removal of the faulty element from service in order to minimize the damage to the system. Rockefeller first presented the role of digital computers in 1969. Later on, with the development of the microprocessor in early seventies, its role in digital protective relays has become a very attractive option. Among the various elements of the power system, the power transformer is one of the important elements. Due to its importance, its protection needs to be fast and reliable. Hence, significant work has been done in this area [1-2].

The transformer is part of the power system so proper protection system is important for the transformer. Generally, back up protection should be required for protected transformer because if the relay or circuit breaker failed to operate then, there is the chance of the whole transformer can be damaged so this is not economical. Transformer operation can be classified as follows: Normal operation, magnetizing inrush, over-excitation, and fault condition. For the first three operating conditions, the relay should not operate, but for any fault, the relay must operate. Cost and weight of the transformer are high and we cannot transport the transformer to the maintenance department to clear fault clearing purpose so protection system performs a great role here to avoid this condition [2] [32-34].

II. FAULT STATISTICS

Table 1 classifies failures statistics for six categories of faults which is given by IEEE guide in Protective relay system for Power Transformer. Mostly, due to winding and tap changer near about 70% faults occurred in the transformer and other fault occurring possibilities are quite low as possible so winding and tap changer is the main reason to cause the fault in the transformer [28]. So transformer protection under abnormal condition is great challenging part to engineer. Loose connections are involved as the initiating event as well as insulation failures. The different category includes CT failure, external faults, overloads, and damage in shipment. These failures can be identified by sophisticated online monitoring devices (e.g. gas-in-oil analyzer) before a serious incident occurs [24-26].

Due to these failure rate observation, proper transformer protection gear is important to maintain continuity of the power supply. So this paper represents various types of the transformer protection system.

Table 1 Failure rate [27]

Name of Faults	1955-1965		1975-1982		1983-1988	
	Number	% of total	Number	% of total	Number	% of total
Winding failures	134	51	615	55	144	37
Tap changer failures	49	19	231	21	85	22
Bushing failures	41	15	114	10	42	11
Terminal board failures	19	7	71	6	13	3
Core failures	7	3	24	2	4	1
Miscellaneous failures	12	5	21	6	101	26
Total	262	100	1127	100	389	100

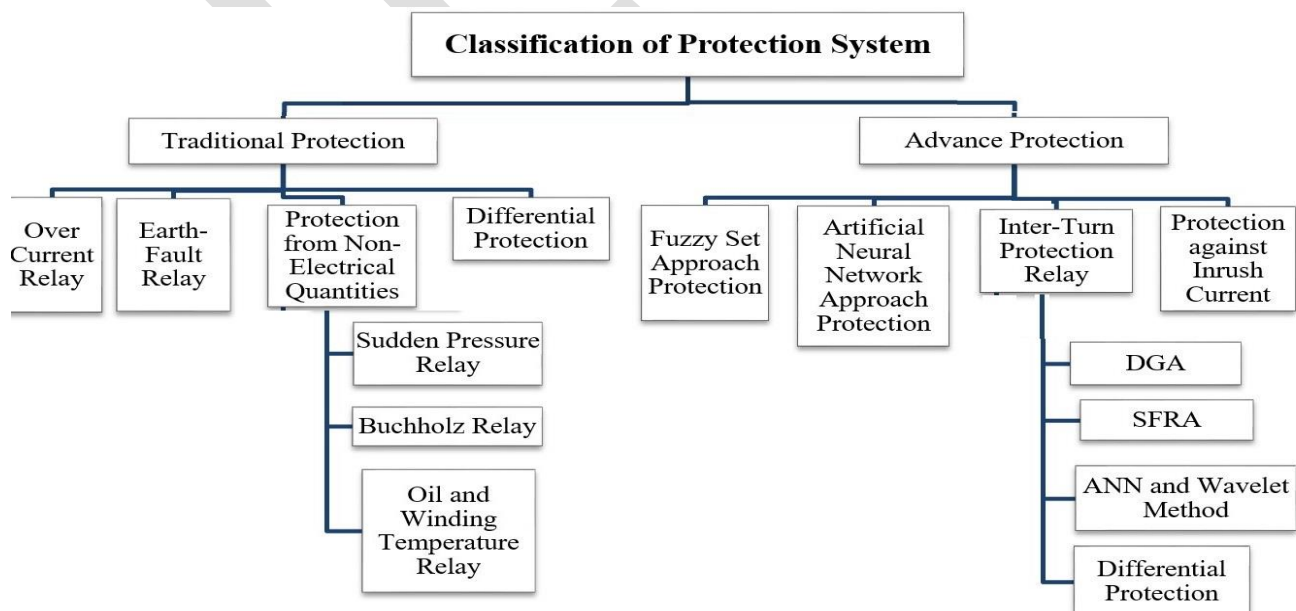
III. CLASSIFICATION OF TRANSFORMER PROTECTION RELAY

In general, the faults occurred in the transformer due to weakening or failure of insulation. This insulation failure causes increases in temperature of the transformer oil and this lead to making the poor performance of the transformer. So for that purpose temperature monitoring system is provided for transformer oil. Sometimes due to a transient situation over voltage and over current occurred so for that purpose overcurrent relay and differential protecting system used [1-3]. There are many faults occurred, but some abnormal fault is not making a big issue in the transformer like magnetic inrush current, over fluxing, low oil level.

Although these abnormal conditions are not faults in the transformer. So for these faults, no protective gear is employed. But one important thing is that if the abnormal fault is prolonged for a long time then it makes a big problem in the transformer [2]. The most important protection system chart is given below. Always this protective gear should be working properly otherwise it will make a big problem in the transformer after the occurrence of the fault [2] [30].

A. ADVANCED PROTECTION SYSTEM

1. Fuzzy Set Approach for Transformer Protection



Fuzzy Set theory concept is firstly founded by Zadeh scientist in 1965 for dealing with uncertain and ambiguous properties of events. And for power system protection fuzzy set concept firstly used in 1979. Accordingly, fuzzy set theory can be counted as a generalization of the standard set theory. In fuzzy set theory, the association of the element can be continuously changed. Since fuzzy logic uses heuristic knowledge, expert knowledge, and experience, it is a very beneficial mathematical medium to solve decision-making problem. So it is a very powerful weapon to express quantitatively uncertain values and the relation between them [4].

The transformer is a critical ingredient of the electrical power system. To magnify the fault detection sensitivity of traditional percentage differential current relaying algorithm, fuzzy logic strategies are used. Fuzzy inference is a method that makes a decision in parallel [4-5]. Because of this property, there is no data destruction during the process and so final fault detection will be far more precise than that of traditional relaying techniques. Fuzzy logic uses linguistic variables rather than numerical variables. The process of converting a numerical variable (crisp variables or real number) into a linguistic variable (fuzzy number) is named as a Fuzzification. Fuzzification performs an extraordinary role in dealing with uncertain information, which might be objective or subjective in nature.

Researchers developed differential power transformer protection after 1990 using a fuzzy logic concept. The fuzzy logic approach can also be with conventional DGA method for fault detection and decision-making. So this paper also shows an improved method for fault detection of transformer parallel with the traditional method [6]. This method gives the self-adjusting characteristic and this will helps in detection faults in the transformer. It has been claimed that the methods are able to detect incipient faults. To make more powerful a combined method of multi-criteria, fuzzy set and wavelet-based method were presenters by Jiao et al [35]. This article summarizes fuzzy based algorithm consisting flux-differential current derivative curve, harmonic restraint, and percentage differential characteristic curve [4].

The following advantages shows the fuzzy logic based approach:

- The fuzzy based relaying algorithm is not allowed to operate unnecessarily operation of the relay in the event of magnetizing inrush with low second harmonic component and internal faults with the high second harmonic component. So these results enhance accuracy and robustness against the change of condition in the power system.
- Due to this fuzzy algorithm relay obtain high sensitivity to detect fault detection and operate with average tripping time of about 3/4 cycles. Therefore, the method is reliable and speedy.

2. Artificial Neural Network Approach Protection

The second most dominant mathematical tool of recent time is an artificial neural network (ANN), which attracts the researcher's to tackle the transformer protection difficulty [7]. The characteristic feature of the ANN is that it considers the accumulated knowledge acquired during training and responds to new events in the most proper manner given the experiences gained during the training process. The model of the ANN is prepared according to network architecture, transfer function, and learning rule. The architecture is concluded by corresponding weights and connection scheme. The objective of the training process is to adjust all ANN weights to obtain minimal deviation between the target and calculated ANN outputs in relation to the mean value of all input samples [7] [9].

The criterion function for the sum square error is minimizing according to the standard gradient procedure. The effectiveness of ANN depends on the quality of the training procedure. In ANN, the waveform analysis method is used to train the neural nets. To implement the neural network, the following three difficulties arise, i.e., a set of training examples must be defined, the multilayer perceptron is small enough to allow the convergence of weight, and the input must be defined and coded with the core so that they are representative of the events to be identified [7] [28] [36].

The following events have to be considered in applying an ANN approach:

- No fault situation,
- Energization,
- External fault,
- Turn to turn internal fault, and
- Turn to earth internal fault.

The relay should operate in the last two situations, but it should identify all the above conditions. The artificial neural network is used for fault diagnosis of the power transformer, and some recent studies report that ANN is used as a classifier along with dissolved gas analysis method, and determined very good results [8]. The nature of the fault is judged by the amount of the gas decomposed from oil present in the tank. In concern of fault diagnosis of the power transformer, recent investigations show that the ANN and expert system tools are the decision-making elements. The performance of trained ANN is tested successfully for the classification of numerous cases. ANN is implemented in the LabVIEW environment for the real-time application [31].

3. Protection Against Inrush current

The transformer is a critical ingredient of the electrical power system. Usually, by utilizing differential protection transformers are being protected. But whenever a transformer is energized, sometime malfunctioning may take place in the differential protection due to inrush current. Some techniques are used to depreciate the fault [11]. Those techniques are like per-phase method, the cross-blocking method, Percent average blocking method, and harmonic sharing method. Then the fuzzy logic system has been adopted to divide the internal fault from magnetizing inrush current. After that, differential protection has been adopted which was based on the wavelet packet transform. Then Mathematical morphology based inrush blocking scheme has been used [10] [29].

In this paper, the comparison is made between per-phase method, cross-blocking method, percentage average blocking method, harmonic sharing method, fuzzy logic, wavelet packet transform based technique and Then Mathematical morphology based inrush blocking scheme [29] [35]. Following methods shows the different protection schemes against magnetic inrush current:

a) Per-Phase Method

The per-phase method is the uncomplicated and traditional method to restraint harmonics. In every phase, the restraint algorithm is parallel and independent. In the Per – Phase Method, this criterion applies to each phase separately. In each phase, the residual flux is different. So in each phase, the magnitude of 2nd harmonic will be different. This method works on the threshold value. Thus, if the 2nd harmonic content is low in a phase while energizing, the differential protection may trip. That's why this technique is very reliable but not very secure [10].

Since different residual flux belongs to each phase energization of each phase has been done at a different angle, every phase will have a different level of harmonics. When the ratio value of the second harmonic for a specific phase is greater than a preset level, the percent differential operation will be inhibited on that phase. There is a possibility of having a ratio of low second harmonic for each phase at the time of transformer energization. If there is a small ratio of the second harmonic in a phase during differential operation, the undesirable the trip may occur in the three-phase transformer [10].

b) Cross-Blocking Method

This technique is very highly correlated with Per-Phase Method, the single dissimilarity is that the signal which is restraint from a phase will restrain differential operation for all another phase. Differential protection will trip at above the pre-set value of the second harmonic for other phases also. In the case of the symmetrical fault, this technique works properly. But if there is a single unsymmetrical fault, the differential protection will trip [10].

This method prevents the possibility of erroneous tripping by improving the security because this technique allows the phase with a ratio of low harmonic to be cross-blocked by a phase with a higher ratio. The insulation usually bears huge mechanical stress at the time of energization and the inrush current is usually a few times greater than the rated current. This cross-blocking technique is well secure but not so trustworthy. Two-out-of-three restraint method is similar to a cross-blocking method. In this method, blocking of differential operation needs minimum 2 phases to detect the adequate level of harmonics. But this method also has the same basic drawback of the simple cross-blocking technique [10].

c) Percent Average Blocking Method

For percentage average blocking method, harmonic ratio means the average of the 2nd harmonic ratio of three phases the security of the differential protection has been enhanced by this percentage average blocking method. So this method is more secure than the

two-out-of-three method and cross-blocking method. If there is a large harmonic ratio in the remaining phases, it is highly possible that the differential operation will be restrained owing to a true single-phase fault during energization. There arises a concern relating to the dependability in the differential protection [10].

d) Harmonic Sharing Method

A single harmonic signal has been created by summing all the magnitudes of all 2nd harmonics from three phases. The resultant value is shared to calculate the ratio of 2nd harmonic for every phase. If there is even a very low 2nd harmonic in any phase, the shared harmonic calculated from will be large, and the 2nd harmonic ratio will become larger enough to restrain the differential protection system from maloperation. If an internal fault is found in a phase at the time of energization. If the value of the fundamental current surges very high the consequence is a low harmonic ratio. Therefore there is less chance to arise a problem from a faulted phase. So the tripping of a three-phase transformer will occur during an internal fault. The security against maloperation has improved with the help of this harmonic summing technique [10].

4. Inter-Turn Fault Protection

Among the detection of numerous faults in the transformer detection of winding inter-turn fault is crucial since its effect is not easily comprehensible at the lower magnitude in the signatures of terminal voltages and currents. Among these faults, winding inter-turn fault is challenging to monitor and detect, especially at a lower magnitude of the fault current. As per the survey of the faults in a transformer is calibrated, which shows that 19% of the total faults occur in the windings [12] [39].

Fig. 1 shows the schematic of winding inter-turn fault in the three-legged transformer. The fault is shown on R-phase of the primary winding by connecting fault-impedance (Z_f) across the short-circuited turns. At a lower magnitude of fault-current (I_f), the terminal voltages and currents are less sensitive to I_f since it distributes through the short-circuited turns through Z_f [13] [37].

The impedance Z_f acts as a supplementary load on the winding, which performs as an autotransformer. The winding current supplies additional current drawn by Z_f . However, if the severity of I_f is not important, the increase in the winding current cannot be observed. This poses the difficulty in the detection of winding inter-turn fault, especially at a lower magnitude of I_f . The fault is mostly launched by insulation failure of the turns in the vicinity to each other [13].

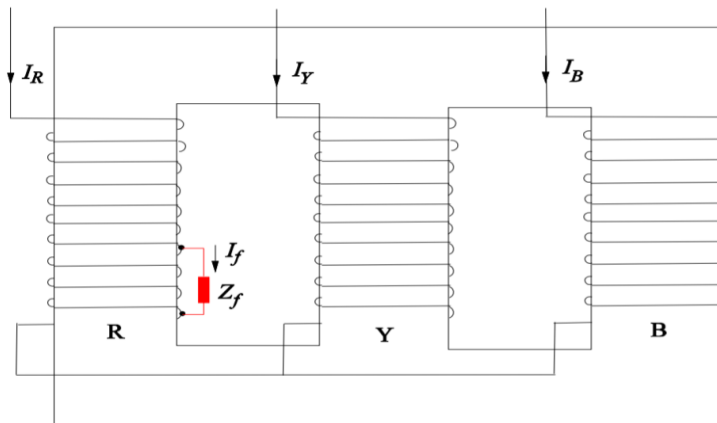


Fig. 1 Schematic for inter-turn fault in transformer [13]

There are various methods available to check the winding condition. The following subsection shows detection method for inter-turn fault for the transformer:

a) Dissolved Gas Method (DGA):

These are a very popular diagnostic method. The transformer winding and oil are made of cellulose and mineral oil. Whenever any fault or thermal stress or electrical stress occurred on them then some amount of gas is produced. These observed gas we take it as the sample for DGA analysis and comparing to these observed gas to normal condition gas. If this gas is found in the range of 0-500 ppm (parts per millions) then the transformer can be said to be the normal condition [13] [38]. The mixture of individual gas compositions

is used to predict the actual fault. The composition of Ethane is found to be more than 35 ppm then observed data is suffering from the localized overheating problem. To check the presence of circulating current then the flowing composition is required in the gas.

b) SFRA Scheme:

Sweep Frequency Response Analysis (SFRA) is an effectual and sensitive method to estimate the mechanical integrity of core, windings, and clamping structures within power transformers by calibrating their electrical transfer functions over a broad frequency range. SFRA is a certified method for frequency measurements. SFRA is one of the best and accurate methods among all method [13].

In this method from one side of winding we apply pulse wave and in another side of the winding, we observe frequency response for the given input. And analyse these results there are three methods:

- Time-based – current SFRA results will be compared to past results of the same unit.
- Type-based – SFRA of one transformer will be compared to an identical type of transformer.
- Phase comparison – SFRA results of one phase will be compared to the results of the different phases of the same transformer.

If any change observed in the output frequency response then it clear that transformer is suffering from some fault condition. For each part of the transformer, the different frequency range is allowed. So observed response should lie on that particular range [13].

c) ANN And Wavelet Method

Artificial Neural Network (ANN) and Wavelet transform is advanced technology used for transformer diagnostic. ANN technology is also used in conjunction with the SFRA technique.

In this technique, we compare winding transfer function at a healthy and faulty condition case and their difference is delivered to the ANN input. ANN is prepared for various differences in the winding transfer function and then, it performs as a decision-making tool to identify the fault in the winding. A Maxwell Hat Wavelet (MWH) or Morlet Wavelet is convoluted with the detecting signal of the faults. Their convolutions with the neutral current of the transformer under the impulse test can demonstrate an indication of the inter-turn fault [13-14].

ANN scheme for detecting inter-turn fault can deal with the complex situation and it is robust with respect to the missing data. In order to use ANN for detecting inter-turn fault then a large number of fault cases needs to be simulated or practically performed to train the neurons. For ANN and Wavelet method requires a large number of processors and instruments [14].

d) Differential Protection Scheme

The differential relay can detect internal faults easily. The principle of Differential Protection scheme is simplistic conceptual technique. The basic block diagram is shown in figure 9. The differential relay actually distinguishes between primary current and secondary current of the power transformer if any unbalance noticed in between primary and secondary currents the relay will actuate and trip both the primary and secondary circuit breaker of the transformer. Differential protection is based on balancing current on both sides of the winding. As per classical method, primary and secondary phase current are measured, converted to common base value and compared to compute differences in the currents [13].

The Difference is observed continuously as a parameter for the fault conditions. Under the normal operating condition fault current is small and in the abnormal condition, it becomes too high so that can be detected by the relay [20-21]. However, they achieve a larger value during the internal faults, which recognizes them as the detection parameters for winding inter-turn fault. However, the sensitivity of this method for winding-failure detection depends largely on the accuracy of measurements by the instrument transformer [25].

Table 2 Summary of Inter-turn Methods [13]

Methods Name	Advantages	Limitations
DGA	Detection of any abnormality at incipient level	Expensive, Not suitable for air-cooled transformer, Ambiguity in the analysis
SFRA	Capacitive effect can be detected at high frequency	Needs expert's opinion, Require additional sophisticated instruments
ANN And Wavelets	Detect minute fault during impulse test robust for missing data	Based on neutral current not always accessible, Memory and computation intensive
Differential Protection	Classical and Robust method	Sensitive to instrument transformer

B. TRADITIONAL PROTECTION SYSTEM

i. Non-Electrical Protection

In order to preserve the transformer against incipient fault, the special protective gear arrangement is required. Overheating, the over fluxing or sudden increase in pressure that outcomes show incipient faults. The cause for this type of is mainly due to deterioration of insulation. These faults introduce arcing to the transformer which can be detected by the protective relay. This non-electrical protective consist of three relay:

a) Buchholz Relay

Buchholz relay is used for detect fault in the transformer with help of heating monitoring. This device detects the small produced gas in the oil by low-energy arcs, insulation decomposition, overheating. This relay also detects heating due to increased power transferred, increased ambient temperature, high eddy current between lamination, arcing, overloading [15]. Buchholz relay is connected between conservator and transformer tank.

Whenever any fault occurred in the transformer then the temperature of the oil is increasing then on that principle Buchholz relay works. Location arrangement can also be displayed in figure 2 and the operation principle of this relay is very simple. Construction is given below figure 2. Relay is mounted in such way that this arrow point towards the conservator and is at an angle of 5 degrees. There are multiple ways to analyze fault in the transformer. But by observing oil temperature method also one the reliable method among another method [25-26]. Whenever a fault has occurred then production of gas is started in the oil. There are two mercury switches used in the relay and one belongs to trip alarm switch and second is to trip the circuit breaker.

Following condition is responsible for activation of the alarm circuit:

- i. Oil leakage
- ii. High resistance inter-turn faults or other winding faults
- iii. Faulty joints
- iv. Failure of core insulation
- v. Formation of hot spots on the core due to the short circuit of laminated insulation

Mainly to trip mercury switch major internal fault is initiated in the transformer. Following condition is responsible for activation of the trip circuit:

- i. All severe winding faults (solid inter-turn or turn-earth fault)
- ii. Fall in the transformer tank oil resulting from either continues decomposition of oil due to higher operating temperature or faulty sample collection tap.

In normal working condition, these switches are in open condition and they mounted with a 40-degree angle. Whenever any fault has occurred then in that condition these mercury switches is shifted 40- degrees to the horizontal state position. When the fault is initiated then bubbles are formed in the transformer oil tank and then it will go towards buchholz relay through pipe. Initially, the severity of fault is less so limited quantity of bubbles is formed in the oil [15].

After entering bubbles in the relay zone, it will try to rotate that alarm mercury switch in horizontal position. When alarm mercury switch circuit is closed then it sends the signal to monitor engineer transformer is under small fault condition zone. If fault severity increases further then the trip circuit is closed then from this necessary action has been required to minimize that fault as soon as possible. This switch normally will operate a circuit breaker to isolate the apparatus before the fault creates additional injury [25].

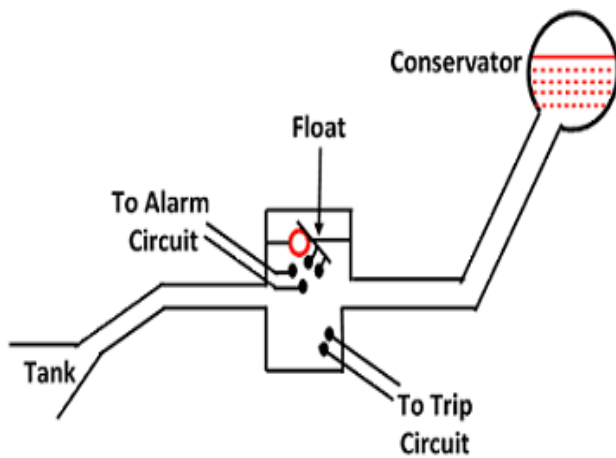


Fig. 2 Arrangement of Buchholz relay [25]

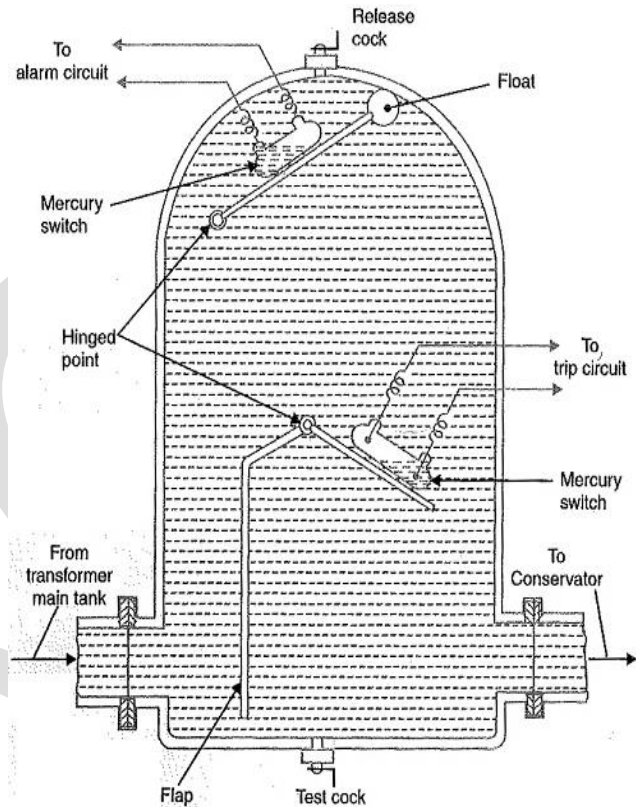


Fig. 3 Construction of Buchholz relay [25]

b) Sudden Pressure Relay

The gas pressure relay facilitates the protection of a transformer merely in conjunction with a simple differential relay. Main advantages of this relay it will perform the stable operation against the inrush current. This relay can be used as the back up the protected relay for Buchholz relay. This relay operates immediately when any large production of gas in the transformer tank. The working principle for this type of relay is the rate of rise of the gas in the transformer [16-17].

Whenever any high current is passing through winding then heat is generated. So that winding heat is responsible for increases oil temperature, introduce arcing in the oil. So it will result in increases pressure in the transformer oil. A sudden increases gas pressure can be detected by a sudden pressure relay [25]. This type of relay is installed at the top of the oil-filled transformer. It performs two functions and these detect the slow accumulation of gases, providing an alarm after a given amount of gas has been collected [16].

A typical transformer gas relay consists of two chambers, each giving a distinctive function. It reacts to a sudden pressure change that accompanies a high rate of gas production. A simplified sudden pressure relay is shown in figure 4. The relay arrangement consists of a gas accumulation chamber installed directly over a pressure chamber. The accumulation chamber accumulates slowly produced gases. A float positioned in this partially oil-filled chamber moves as the gas volume increases. It operates an alarm switch when the amount of gas collected touches a particularized level [16-17].

Operating time of this relay is varies over large span depending upon the rate of gas formation. Design of this relay can be made such way that it can operate at dynamics pressure changes. The main difference in buchholz relay and sudden pressure relay is,

buchholz relay can handle light internal faults and pressure relay can handle heavy internal faults. This type of relay is suitable for above 5 MVA rated transformer [16-17] [25-26].

Only one drawback of pressure relay is it can operate whenever high current is passing through the winding. Due to this disadvantage, some user prepares it for only alarm purpose only.

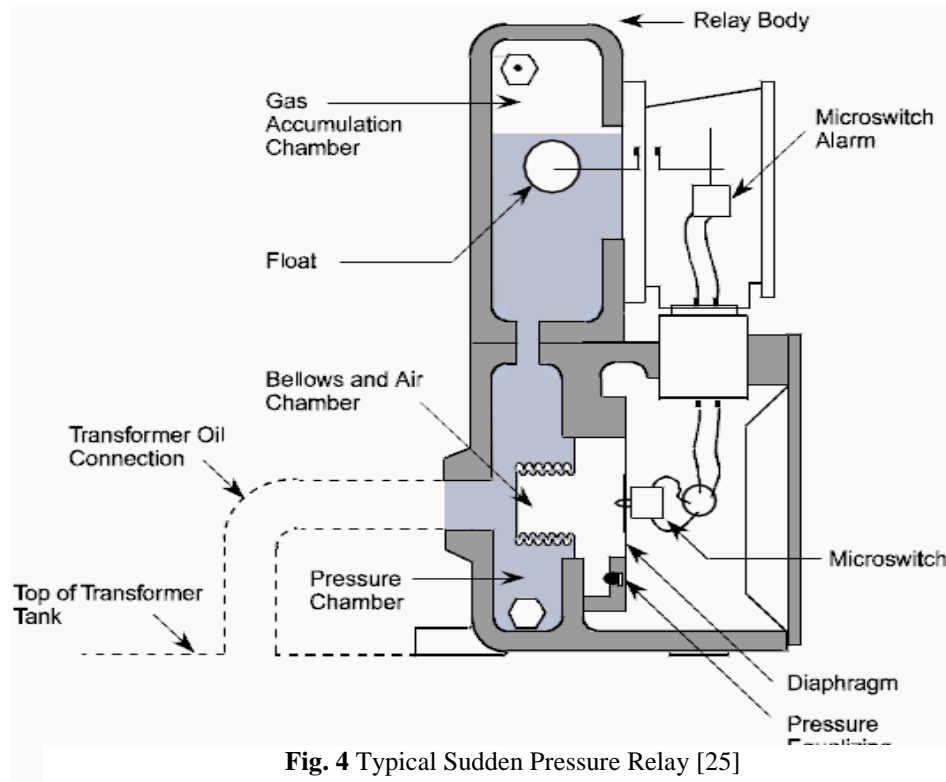


Fig. 4 Typical Sudden Pressure Relay [25]

c) Oil and Winding Temperature Relay

Transformer designed to operate for the various range of temperature depending upon the type of insulation is used in the transformer. To maintain the transformer temperature at a particular level cooling system arrangement is provided. Any abnormal temperature commencement of the winding leads to weakening of insulation either between the turns or from turn to the core. These hot spot should be carefully observed and timely inspected because it will leads to a major fault in the transformer [25].

Sometimes the resistance temperature detector (RTD) is used to detect hot spot the temperature of the winding. The temperature information from RTD is given to temperature scanner so temperature scanner will display the temperature of the winding [25].

Here winding temperature is calibrated by connecting the current transformer (CT) in series with the main winding of the transformer. The secondary side of the CT is joined to the heaters inside the transformer tank and it will represented in figure 5. The sensing bulb is situated near to heaters and will glow depending upon current will circulate in the transformer main winding. The output of the sensing bulb is connected alarm/protective gear system and temperature indicator. When the temperature of any RTD is exceeded its threshold value then the alarm protective circuit comes into the picture. Depending on alarm action, operator engineer will take the decision. If the temperature is increased further then one sensing device is used so that will open all necessary contact of the transformer [25-26].

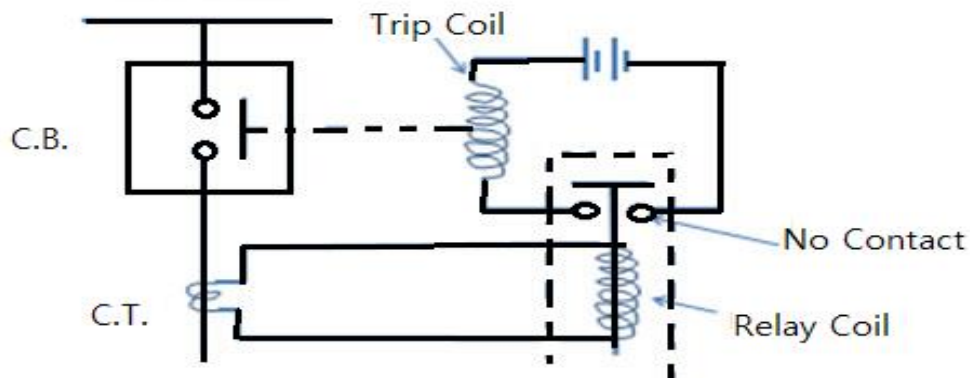


Fig. 5 Connection of WTI and alarm unit with transformer [25]

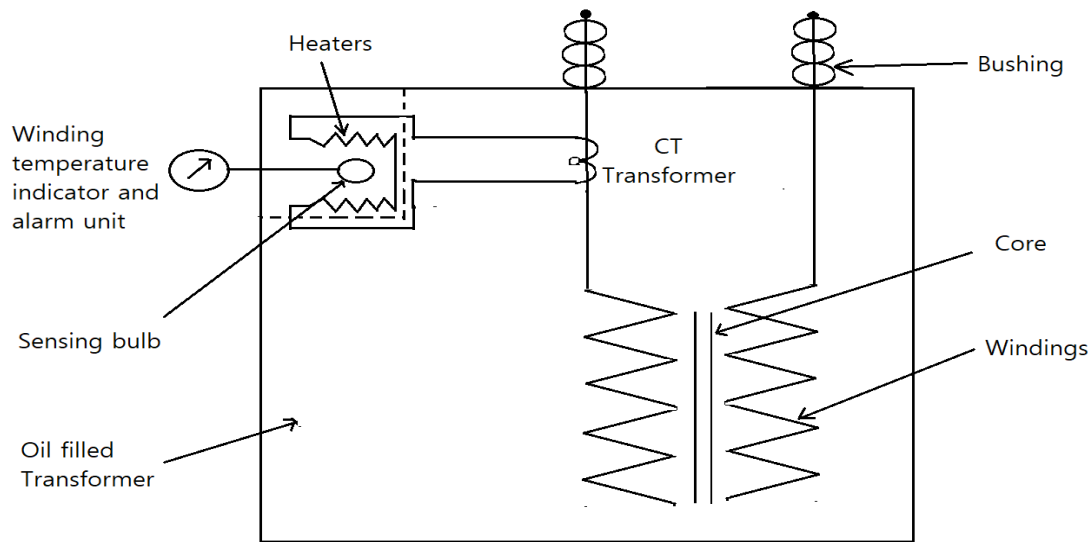


Fig. 6 Basic Overcurrent Protection System [25]

ii. Overcurrent Protection

For the small rated transformer, overcurrent relay is best for protection purpose. This overcurrent relay is suitable for 100-500 KVA transformer. This relay is also suitable for large rating transformer as the backup protection.

In general, this relay is set by above normal rated current so that a short time rating is allowed by the relay. Sometimes during the low-level fault, pickup overcurrent value is not exceeded so in such cases, the instantaneous overcurrent relay will let this fault continue indefinitely. In general, this relay is set at 2-3 times above rated of the transformer. One important thing is that the pickup value of this relay is always higher than magnetic inrush current. To afford primary protection for against heavy internal faults, instantaneous overcurrent relay employed [18].

Overloaded transformer results in increasing rating size of the transformer and mechanical force are also generated. These mechanical force will try to increase winding hot spot temperature and movement of the transformer. This movement results in mechanical damage to insulation which results in hot spot temperature. Therefore, the transformer should not operate for a long time in overloading state [18].

A relay is a controlled switch. Normally, the tiny output of a Current Transformer (CT) is utilized for the relay's input. The relay typically has a shorter size and smaller rating for input. When the contact is closed, then the battery is joined to the trip coil of the Circuit Breaker and the circuit is tripped. We are basically using it as a switching transistor, to elaborate the small output of CT to the large battery voltage of Trip coil [25].

iii. Earth-fault Protection

In earth fault, the current extracted from the source terminate its path without contributing to the load. The main intention for this protection is to limit ground fault current. When the fault occurs, the short-circuit currents flow over the system, and this current is returned through the earth or any electrical equipment. This fault current degrades the equipment of the power system and also interrupted the continuity of the supply. The earth fault can be dispersed by using the restricted earth fault (REF) protection design [19].

Figure 7 represents for operating characteristics of restricted earth fault relay. High impedance restricted earth fault protection system can be employed for protecting transformer winding exactly like bus bar protection. Primary protection for high rated transformer against earth fault is achieved by differential protection relay. For small transformer differential relay is not used, so here instantaneous overcurrent relay used as a primary protection relay for earth relay [20].

A star side external faults will results in current flowing in the line current transformer of the affected phase and at the same time a balancing current flows in the neutral current transformer, hence the resultant current in the relay is consequently zero. So this REF relay will not operate for external earth fault. But during an internal fault, the neutral current transformer only offers the unbalance fault current and operation of Restricted Earth Fault Relay takes place. This scheme of restricted earth fault protection is very sensitive for internal earth fault of the electrical power transformer. The protection scheme is relatively cheaper than the differential protection scheme. Three CT's are connected together so, only one residual current is available at the output. This residual current is balanced at the secondary side of CT's. The Operating element is a high impedance relay, and a region of operation is the star winding of the transformer. The degree of protection is magnified not only because of the use of the instantaneous element but also because the entire fault current is used as the operating quantity. So this main reason this protection system is capable to detect closer value fault current near to neutral end of the winding. Operating quantity is residual current, so relay will remain stable for any fault outside its zone [25-26].

Restricted earth fault protection is afforded in electrical power transformer for sensing internal earth fault of the transformer. In this scheme, the CT secondary of each phase of an electrical power transformer are connected together as shown in figure 8. Another main advantage is it will also provide protection of transformer with the solid grounding of neutral. The REF design is quite simpler and is used alone on either side of the transformer for affording high-speed earth-fault protection [20] [25].

iv. Differential Protection

A fuse protection system quite simple and less costly, but differential protection provide several advantages over another protection system so that why we use differential protection and these are:

- a) Differential protection provides faster detection as compared to another method and reduces damage due to the flow of fault

Fig. 7 Operating Characteristics of Earth Fault Relay [25]

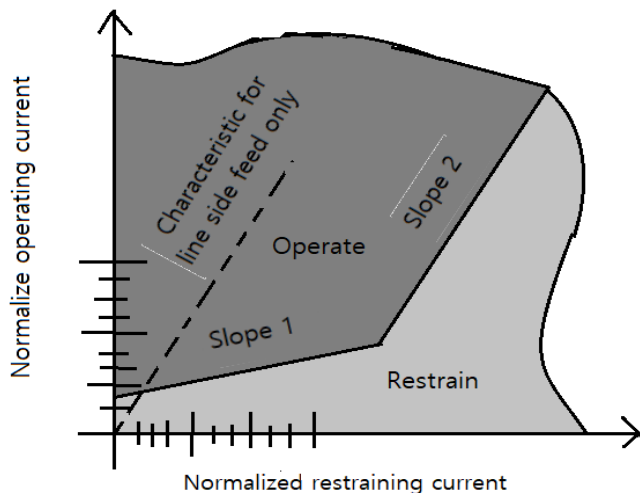
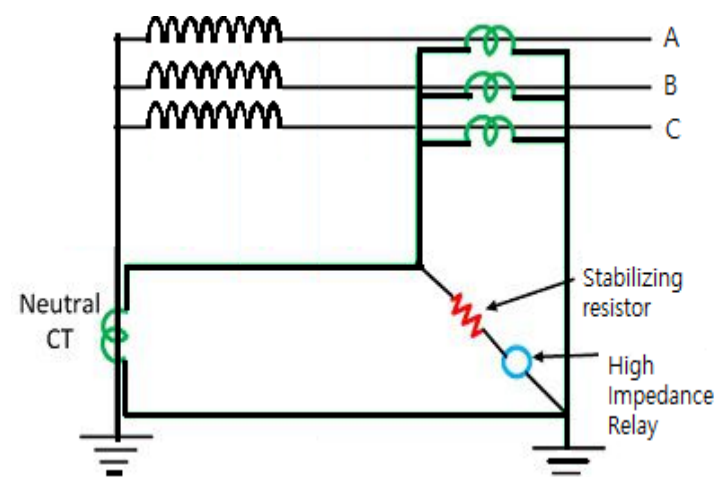


Fig. 8 Restricted Earth-fault Protection for a star winding [25]



current.

- b) The location can precisely be located by using the differential protection system depending upon the size of the protected zone.

- c) Accurate faults location provides the application of automation techniques, such as rapid isolation of faulted components and restoring load.
- d) The faults occur in the transformer inside the insulating oil can be identified by Buchholz relay. But if any fault occurs in the transformer but not in oil then it cannot be identified by Buchholz relay. Any flashover at the bushings is not adequately covered by Buchholz relay. Differential relays can detect such type of faults.

The principle of Differential Protection scheme is simplistic conceptual technique. The basic block diagram is shown in figure 9. The differential relay actually differentiates between primary current and secondary current of the power transformer if any unbalance noticed in between primary and secondary currents the relay will actuate and trip both the primary and secondary circuit breaker of the transformer [21-22]. Differential protection is based on balancing current on both sides of the winding. To design, the differential protection system makes the adjustment in such a way that it can compensate for the phase difference between the line current on each side of the power transformer whenever it becomes necessary [23].

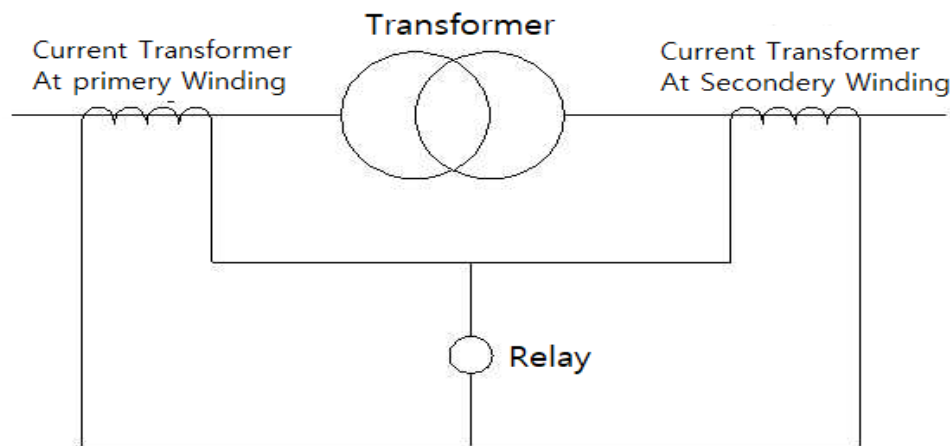


Fig. 9 Principle of Transformer Differential Protection [25]

IV. ACKNOWLEDGMENT

Preparing a paper of different protection relays for the transformer is a really challenging work for anyone. Being the student of condition monitoring and to prepare a paper on the specified topic, we accept it with challenge, opportunity and also became successful to present the report with our full endeavor. We owe a deep of gratitude to **Mr. O. P. Rahi** lecturer at National Institute of Technology Hamirpur. We got valuable guidance at every stage of paper.

V. CONCLUSION

This paper represents the basic, advanced level information and provides an overview of the different type and schemes of the transformer protection. This paper contributes to different advanced and traditional based protective relay used for the transformer. There are many issues are occurred in the transformer, so to protect transformer proper protective gear arrangement is required.

The protection schemes so far designed can successfully protect the transformer and mitigate the risk of enormous destruction. The benefit of this methods is, it is an automatic protection method no manual work is required. In practice, this concept can be manipulated without any difficulty.

REFERENCES:

- [1] Manoj Tripathy, R.P. Maheshwari, H.K. Verma (2005) "Advances in Transformer Protection: A Review" Electric Power Components and Systems, 33:11, 1203-1209, August 16th 2006
- [2] E. A. Goodman, "A new approach to distribution transformer protection", Proceedings of the American Power Conference, vol. 34, pp. 984-992, 1972
- [3] C. H. CLARRIDGE, "New Monitor System Guards Generator Transformers", Electrical World, May 1966
- [4] K. Ramesh, M. Sushama, "Power Transformer Protection using Fuzzy Logic Based-Relaying", International Conference on Advances in Electrical Engineering, pp. 1-7, 2014
- [5] A. Wiszniewski, B. Kasztenny, "A Multi-Criteria Differential Transformer Relay Based on Fuzzy Logic", IEEE Trans on Power Delivery, vol. 10, pp. 1786-1792, Oct. 1995
- [6] B. Kasztenny and E. Rosolowski, "A self-organizing fuzzy logic based protective relay an application to power transformer protection," IEEE Trans. Power Delivery, vol. 12, pp. 1119-1127, July 1997
- [7] Mr S.B.Parmar, Mr. B.S.Shah "Transformer Protection using Artificial Neural Network", International Journal of Novel Research and Development, ISSN:2456-4184, Vol.2, Issue 5, page no.108-111, May-2017
- [8] Pihler, B. Grcar, D. Dolinar "Improved operation of power transformer protection using artificial neural network", IEEE Transactions on Power Delivery. 12 (3), 1128- 1136, 1997
- [9] D. Niebur, "Artificial neural networks for power systems," ELECTRA, no. 159, pp. 77-101, April 1995
- [10] Satyaki Biswas, Rudra Narayan Dash, KVVSR Choudhury, Sarada Prasanna Sahoo "A review paper on Inrush Fault Isolation Methods of a Three-Phase Transformer" IEEE International Conference March 28-30, 2018, Bhubaneswar, India
- [11] R. Hamilton "Analysis of transformer inrush current and comparison of harmonic restraint methods in transformer protection", IEEE Trans. Ind. Appl., vol. 49, no. 4, pp. 1890-1898, Jul. 2013
- [12] N.C. Joshi, R.K. Jarial, Y.R. Sood, Rakesh Thapliyal "Transformer Internal Winding Faults Diagnosis Methods: A Review", MIT International Journal of Electrical and Instrumentation Engineering, Vol. 2, No. 2, Aug. 2012, pp. 77-81
- [13] R. S. Bhide, M. S. S. Sreenivas, A. Banerjee, and R. Somakumar, "Analysis of winding inter-turn fault in transformer: A review and transformer models," in Proc. ICSET'10, Dec 2010
- [14] H. Firoozi, M. Kharezi, and H. Bakhshi "Turn-to-turn fault localization of power transformer using neural network techniques," in Proc. ICPADM'09, July 2009, pp. 249-252
- [15] M. Buchholz, "The Buchholz protection system and its application in practice," E. T. Z., vol. 49, no. 34, 1928, pp. 1257-1262
- [16] Bean, R. L., and Cole, H. L., "A sudden gas-pressure relay for transformer protection," AIEE Transactions, vol. 72, pt. III, pp. 480-483, 1953
- [17] Anderson, R. N., "A new fault-pressure relay provides fast, effective power transformer protection," Distribution, vol. 21, no. 3, pp. 8-9, July 1959
- [18] C. L. WAGNER, "Overexcitation Problems and Protection of Generators and Transformers", Georgia Institute of Technology, May 1967
- [19] M. Davarpanah, M. Sanaye-Pasand, R. Iravani, "Performance enhancement of the transformer restricted earth fault relay", IEEE Trans. Power Del., vol. 28, no. 1, pp. 467-474, Jan. 2013
- [20] Sachdev, M. S., and Shah, D. V., "Transformer differential and restricted earth fault protection using a digital processor," Transactions of the Canadian Electrical Association, Engineering and Operating Division, vol. 20, pt. 4, 1981, Paper no. 81-SP-155
- [21] E. Vazquez, I.I. Mijares, O.L. Chacon, A. Conde, "Transformer differential protection using principal component analysis", IEEE Transactions on Power Delivey. 23 (1), 67- 72, 2008
- [22] Mathews, C. A., "An improved transformer differential relay" Electrical Engineering, pt. III-A, pp. 645-649, June 1954
- [23] "Fundamentals of Power System Protection" book by Y. G. Paithankar, S. R. Bhide
- [24] ABB, "Power Transformer Protection Application Guide", 1988
- [25] "Power System Protection and Switchgear" book by Badri Ram
- [26] "Electrical Power System Protection" book by C. Christopoulos, A. Wright
- [27] Talha Ali Qasmi "Power Transformer Protection" research gate, 17 April 2005
- [28] Symon Haykin. "A text book on Neural Networks", 2nd ed. Prentice Hall:1998
- [29] Li-Cheng Wu, Chih-Wen Liu, Shih-En Chien, Ching-Shan Chen "The Effect of Inrush Current on Transformer Protection" in IEEE Carbondale, IL, USA, 15 May 2007
- [30] P. Muddit, R. Niven, "Developments in Transformer Protection", Developments in Power Protection 1989 Fourth International Conference on, pp. 61-65, 1988

- [31] M. Kezunovic, "A Survey of Neural Net Applications to Protective Relaying and Fault Analysis", Engineering Intelligent Systems, vol. 5, December 1997
- [32] Li Wei, "Design method of fault analysis expert system in relay protection and fault information system [J]", Relay, vol. 33, 2005
- [33] M. A. Rahman, B. Jeyasurya, "A state of the art review of transformer protection algorithms", IEEE Trans. on Power Delivery, vol.3, no.2, April 1988, pp. 534-43
- [34] A. T. Johns and S. K. Salman "Digital Protection For Power Systems", ser. IEE Power Series 15. London, U.K, 1995
- [35] M. Gomez-Morante and D. W. Nicoletti, "A wavelet-based differential transformer protection," IEEE Trans. on PWRD, vol. 14, pp 1351-1359, October 1999
- [36] Drasko Furundzic, Zeljko Djurovic, Vladimir Celebic, Iva Salom, "Neural Network Ensemble for Power Transformers Fault Detection", 11 th symposium on Neural Network Applications in electrical Engineering NEUREL, Serbia, January 2012
- [37] T.K. Saha, "Review of modern diagnostic techniques for assessing insulation condition in aged transformers", IEEE Trans. Dielectr. Electr. Insul., vol. 10, no. 5, pp. 903-917, 2003
- [38] M. Duval, "Dissolved gas analysis: It can save your transformer", IEEE Elect. Insul. Mag., vol. 5, no. 6, pp. 22-27, Nov./Dec. 1989
- [39] Nima Farzin, Mehdi Vakilian, Ehsan Hajipour "Transformer Turn-to-Turn Fault Protection Based on Fault-Related Incremental Currents" IEEE Conference Power & Energy Society, January 2019

Characterization of Physical Properties of Biomass Waste Materials in Kenya for Gasification: Rice Husks and Coffee Husks

Kilaka Mutuku

Department of Energy Engineering, Kenyatta University, Kenya
Email- mutukukilaka@gmail.com

ABSTRACT— This work presents characterization of coffee husks and rice husks based on their calorific value, percentage moisture content, volatile matter, ash content, fixed carbon, bulk density and porosity for gasification. Calorific value of rice husks and coffee husks was 15.9kJ/g and 18.1kJ/g respectively. Bulk density of sampled rice husks and coffee husks was 127.4kg/m³ and 218.0kg/m³ respectively. Porosity of sampled rice husks and coffee husks was 87.4% and 71.9% respectively. A moisture content of sampled rice husks and coffee husks was 8.0% and 8.8% respectively. The percentage volatile matter of sampled rice husks and coffee husks was 62.8% and 78.4% respectively. The percentage ash content of sampled rice husks and coffee husks was 20.2% and 3.9% respectively. The percentage fixed carbon of sampled rice husks and coffee husks was 17.0% and 17.7% respectively.

Keywords— biomass gasification; rice husks; coffee husks; biofuels

1.0 INTRODUCTION

About 45.2% of Kenya's population lives below the poverty line. Low income has forced most of the Kenyans to opt for the cheapest available sources of energy. Biomass fuels are the most important source of energy in Kenya with wood-fuel (firewood and charcoal) accounting for over 68% of the total primary energy consumption (MOE, 2014). In spite of past efforts to promote substitutes for wood-fuel, the number of people relying on them is not decreasing. Consequently, it is projected that biomass will continue to be the main source of energy for the majority of the rural population and urban poor. As a result of deforestation, biomass resources (fire wood and charcoal) are getting scarce. Waste products from agro-processing industries such as coffee husks and rice husks have been a major challenge in disposal. Biomass gasification is one of the few technologies that can potentially generate carbon negative energy with pollution-free power and also turn these wastes into energy through gasification. Unlike other countries in the developed world, gasification technology is still new in Kenya and Africa in general so its adoption can help in recycling bio waste materials and reduce deforestation (Practical Action, 2012). According to Rajvanshi (1986), the choice and design of a gasifier is dependent on fuel properties. Yang *et al.* (2005) also reports that the properties of biofuels affects their combustion in a gasifier reactor. The findings of this study can therefore be used to inform the design of gasifiers in the country and help in utilization of these bio-waste materials in gasification. This study used Arabica coffee husks and long grain rice husks obtained from Thika Coffee Mills Ltd and Nice Rice Millers Ltd respectively, all located in Central Kenya.

2.0 METHODOLOGY

2.1 Determination of Bulk Density

A graduated glass cylinder of volume V , 0.005m³ was completely filled with the sample and the material was slightly compacted to ensure there are no large void spaces. The glass cylinder and the sample were then weighed to obtain the combined weight, W_2 . (Zhang *et al.*, 2012). Three replicates were carried out and the mean obtained. The bulk density of the sample was calculated using equation (1).

$$\rho_b (\text{kg/m}^3) = (W_2 - W_1) / V \quad (1)$$

Where:

ρ_b = bulk density of fuel sample

W_2 = weight of the glass cylinder container +sample

W_1 = weight of the glass cylinder container

V = volume of the glass cylinder container

(Zhang *et al.*, 2012)

2.2 Determination of Porosity

The porosity of biomass was determined by using a sample of Volume V_s 0.0030 m³ in a 0.005m³ graduated cylinder. A wire mesh screen was placed on the top of the sample to prevent material getting suspended when water is added. Water was gently added over the sample until the water level went above the level of the sample. The cylinder was gently rocked from the sides to remove any air bubbles and then the final water level was recorded. Then the amount of added water to the cylinder and the water level were recorded (Zhang *et al.*, 2012). The cylinder was emptied and cleaned thoroughly after each test. The test was done in triplicates and the porosity of biomass fuel was calculated using equation (2).

$$P(\%) = (V_i - V_f)/V_s \quad (2)$$

Where:

P = porosity of the sample

V_i = combined volume of the sample and water separately

V_f = final total volume of the sample and added water

V_s = volume of the sample

(Zhang *et al.*, 2012)

2.3 Determination of Particle size distribution

The samples of rice husks and coffee husks were separated into different particle sizes using a sifting column. This was done by placing the 4 sieves with different mesh sizes on a mechanical shaker. The weight of sample residues in each test sieve were determined using a digital weighing balance of model Stanton St01 made in Great Britain with accuracy of 0.1g and recorded in table A.1 and table A.2. Three replicates were carried out and the mean obtained. The individual fractions were then calculated and assigned as a percentage of the sum of all the individual fractions (Zhang *et al.*, 2012).

2.4 Determination of Moisture content

The moisture content was determined in accordance to ASTM Standard D 1762-84(2007). Dishes containing fuel samples were placed in drying oven at 105°C for duration of 2 hours. The dish was then weighed using a digital weighing balance of model Stanton St01 made in Great Britain to the nearest 0.01g. Three replicates were carried out and the mean obtained. The percentage moisture content was then obtained using equation (3) below.

$$MC(\%) = (W_{ad} - W_{od})/W_{ad} \quad (3)$$

Where:

MC = moisture content

W_{ad} = weight of sample before drying in oven at 105°C for duration of 2 hours

W_{od} = weight of sample after drying in oven at 105°C for duration of 2 hours

(Zhang *et al.*, 2012)

2.5 Determination of Volatile Matter

The volatile matter (VM) determination was done in accordance to ASTM Standard D 1762-84(2007). 5 grams of fuel sample was put in a ceramic crucible and weighed using a digital weighing balance of model Stanton St01 made in Great Britain with accuracy of 0.01g. The samples were first heated at 105°C for 2 hours to drive out moisture. The crucibles were then heated inside a muffle furnace maintained at 950°C for 6 minutes after which they were left to cool and weighed. Three replicates were carried out and the mean obtained. The percent volatile matter was calculated using equation (4) below.

(4)

$$VM (\%) = (W_{od} - F_g) / W_{od} \times 100$$

Where:

VM =volatile Matter

F_g = weight of sample after heating in furnace for 6 minutes at 950°C

W_{od} = weight of sample after drying in oven at 105°C for duration of 2 hours

2.6 Determination of Ash Content

The ash determination was done in accordance with ASTM Standard D 1762-84(2007). 5 grams of fuel sample was weighed using a digital weighing balance of model Stanton St01 made in Great Britain with accuracy of 0.01g and taken in an empty ceramic crucible. The samples were first heated at 105°C for 2 hours to drive out moisture. The crucibles along with the samples was placed in a muffle furnace at 750°C for 6 hours after which the crucibles were left to cool and weighed. Three replicates were carried out and the mean obtained. Calculation of the percent ash content was done as per equation (5) below.

$$\% \text{ Ash percent} = (W_R / W_{od}) \times 100 \quad (5)$$

Where:

VM =Volatile Matter

W_R = weight of sample after heating in furnace for 6 hours at 750°C

W_{od} = weight of sample after drying in oven at 105°C for duration of 2 hours

2.7 Determination of Percentage Fixed Carbon

Fixed carbon (FC) was calculated using the following equation according to Mckendry (2002).

$$\% FC = 100 - (\% VM + \% \text{ Ash}) \quad (6)$$

Where:

VM=Volatile Matter

FC =Fixed carbon

2.8 Determination of Energy Content

The calorific value of the briquettes was determined using the P.A. HILTON bomb calorimeter, Model C200 made in United Kingdom. Benzoic acid with a known calorific value of 26.5kJ/g was used as a calibration material. The experiments were conducted at Kenyatta University Mechanical Engineering department from the 6th of October to 13th October, 2017. Three replicates were carried out and the mean obtained. Figure B.1 shows how the equipment was set up for the experiment.



Figure B.1 Experimental set up for energy content test



Figure B.2 Photographs of test fuels used in the study

3.0 RESULTS AND DISCUSSION

3.1 Porosity and bulk density

Rice husks presented the highest value of porosity of 87.4% while coffee husks had the lowest porosity of 71.9%. Coffee husks had the highest bulk density of 218.0kg/m³ while rice husk was the lowest with 127.4% kg/m³. According to Belonio (2005), the bulk density of both compacted and non-compacted rice husks ranges from 100 to 120 kg/m³ while Zhang *et al.* (2012), found the porosity of rice husks to be in the range 64%-73%. From table A.1 and table A.2, Rice husks were mainly composed of particles in the range of 2.36-4.75 mm which accounted for 81.0% of the sample while coffee husks were mainly composed of particles in the range 2.36-4.75mm accounting for 67.1% of the sample.

3.2 Proximate Analysis

The percentage moisture content, volatile matter, carbon content and ash content were obtained for the two fuels. Coffee husks presented the highest moisture content of 8.8% whereas rice husks had the lowest moisture content of 8.0%. Rice husks had the highest percentage ash content of 20.2% whereas coffee husks presented the lowest value of 3.9%. Coffee husks had the highest percentage of volatile matter of 78.4% while rice husk had the lowest value of 62.8%, coffee husks presented the highest percentage of fixed carbon of 17.7% while rice husks gave the lowest value of 17.0%.

3.3 Energy Content

Rice husks showed the lowest heating values of 15.9kJ/g. This could be attributed to the fuel's high ash content. Coffee husks presented the highest calorific value of 18.1kJ/g. This could be attributed to the fuel's high fixed carbon content and low ash content.

Physical properties obtained from other researches in literature are presented in table A.3. Comparing the values obtained from this study and those of previous researches, they are within the same range.

Table A.1 Particle size distribution of rice husks in a 150g sample

Particle size(mm)	Average (g)	Fraction by weight (%)
>4.75	0	0.0
2.36-4.75	121.5	81.0
1.18-2.36	13.8	9.2
0.6-1.18	8.9	5.9
<0.6	5.8	3.9

Table A.2 Particle size distribution of coffee husks in a 150g sample

Particle size(mm)	Average (g)	Fraction by weight (%)
>4.75	23.1	15.4
2.36-4.75	100.6	67.1
1.18-2.36	13.9	9.2
0.6-1.18	7.4	4.9
<0.6	5.2	3.4

Table A.3 Typical properties of coffee husks and rice husks from literature

	Rice husks	Coffee husks
Bulk density (kg/m ³)	96-160	185-300
Porosity (%)	77-89	64-73
Moisture content (%)	6-10	9-12
Ash content (%)	15-24	0.8-6
Fixed carbon (%)	14-19	13-19
Volatile matter (%)	58-68	78-89
Gross calorific value (kJ/g)	15-17	18-20

(Kumar *et al.*, 2015; Zhang *et al.*, 2014; Quaak *et al.*, 1999; Lam *et al.*, 2014; Belonio, 2005)

4.0 CONCLUSION

The properties of biomass test fuels had the following physical properties: Calorific value of rice husks and coffee husks was 15.9kJ/g and 18.1kJ/g respectively. Bulk density of sampled rice husks and coffee husks was 127.4kg/m³ and 218.0kg/m³ respectively. Porosity of sampled rice husks and coffee husks was 87.4% and 71.9% respectively. The moisture content of sampled rice husks and coffee

husks was 8.0% and 8.8% respectively. The volatile matter of sampled rice husks and coffee husks was 62.8% and 78.4% respectively. The ash content of sampled rice husks and coffee husks was 20.2% and 3.9% respectively. The fixed carbon of sampled rice husks and coffee husks was 17.0% and 17.7% respectively.

ACKNOWLEDGEMENTS

The author thanks his research supervisors, Prof. Thomas F.N. Thoruwa and Dr. Jeremiah Kiplagat for their guidance and input into this work.

REFERENCES:

1. ASTM D1762-84, 2007. American Society for Testing Materials Standard test method for chemical analysis of wood charcoal, ASTM international, West Conshohocken, PA, 2007.
2. Belonio, A.T, 2005. Rice husk gas stove handbook, Appropriate Technology Centre. Central Philippine University. Philippines.
3. Kumar, B., Shrestha, R.K, Ale, B.B., (2015). Performance evaluation of Chinese model (HX-20) updraft institutional gasifier stove in context of Nepal. *2015 Proceedings of IOE Graduate Conference*, 155–159
4. Lam, P.S., Sokhansanj, S., 2014. Engineering Properties of Biomass. *Engineering and Science of Biomass Feedstock Production and Provision*, 17-35. doi:10.1007/978-1-4899-8014-4_2
5. Ministry Of Energy Kenya, MOE. *National energy Policy Final Draft*. 48. Web. Oct. 2014. <http://www.energy.go.ke/downloads/National%20Energy%20Policy%20-%20Final%20Draft.pdf>.
6. Practical action, 2012. Biomass Gasification working Paper: The East African Study
7. Quaak, P., Knoef, H., Stassen E. H., 1999. *Energy from Biomass-A Review of Combustion and Gasification Technologies*. World Bank Technical Paper No.422-Energy Series. 2-5.
8. Rajvanshi, A.K., 1986. Biomass Gasification. In: Goswami, D.Y., Ed., *Alternative Energy in Agriculture*, Vol. II, CRC Press, Boca Raton, 83-102.
9. Yang, Y., Ryu, C., Khor, A., Yates, N., Sharifi, V., Swithenbank, J., 2005. Effect of fuel properties on biomass combustion. Part II. Modelling approach—identification of the controlling factors. *Fuel*, 84(16), 2116-2130. doi:10.1016/j.fuel.2005.04.023
10. Zhang, Y., Ghaly, A. E., Li, B., 2012. Availability And Physical Properties Of Residues From Major Agricultural Crops For Energy Conversion Through Thermochemical Processes. *American Journal of Agricultural and Biological Sciences*, 7(3), 312-321. doi:10.3844/ajabssp.2012.312.321

Quantization in Nanomaterials

S.S.Manaktala¹

¹Research Scholar ,Dept. Of ECE , JECRC University , Jaipur

ssmanaktala.ece@jecrec.ac.in

K.M.Singh 2

2 Professor , Department of ECE
JECRC University ,Jaipur
Kmsingh2005@rediffmail.com

Kanika Jain 3

Student III Year , ECE
JECRC, Jaipur

3 Kanikajain7099@gmail.com

Abstract—This paper is a review of quantization phenomena in nanomaterials. Dimensions of nanomaterial are reviewed and Quantum concept is analyzed. The influence of band structures on the physical properties of quantized structures is studied. Energy level and effective mass calculation through equations are understood. Finally quantized electronic structure of semiconductor is studied.

Keywords—nanomaterial,quantization, emiconductor,quantum ,band structure.

INTRODUCTION

The physical properties of the material significantly depend on their size when reduced to Nano dimension. In bulk system, most of the atoms are the interior atoms, so the properties of the materials are determined by them. But in the case of nanoparticles, the fraction of surface atoms cannot be neglected. The nonmaterial are the elements that have at least one spatial measurements in size range 1 to 100 nanometers. The quantum number determines a set of discrete energies which the electron can have, since the energy is directly related to the electron's momentum. Quantum confinement is responsible for the increase of energy difference between energy states and band gap. Nanomaterials are generally characterised as zero dimensional nanomaterials and one dimensional nanomaterials. Low dimensional structures having quantum confinement of one, two, and three dimensions such as

- quantum wells
- quantum wires
- Quantum dots

To predict the confined energy levels of nanostructures Schrodinger equations are used. In recent years, with the advent of MBE, MOCVD and other experimental techniques, the influence of quantization of band states on the different physical properties of nanostructured materials such as quantum wells, quantum well wires, quantum dots, inversion layers, magnetic quantization, and different field added dimensionally reduced systems. The influence of band structures on the physical properties of quantized structures is becoming increasingly important

INTRODUCTION TO NANOMATERIALS

There are different kinds of materials of different size around us. Some materials are natural e.g. silver, gold, and garnet etc. and some materials are manmade e.g. cement, CD and pigments etc. Human eye can see the materials with naked eye using visible rays 350 nm to 700 nm. Human eye resolution is 0.07mm. If we want to see the material below 0.07 mm size then we have to use different microscopes according to the size of material.

What is Nanoscale?

It can be used to refer to one billionth of any measure.

Nanometer

Nanosecond

Nanogram

Nanomole

The diameter of one human hair is about 10,000 to 80,000 nanometers. The diameter of atom is 0.1 nm to 0.2 nm. A crystal of 0.1 mm size contains approximately 1021 atoms. Nanoscale materials have size less than 100 nm. Nanoscale materials can be seen using light rays of wavelength in the range of 0.1 nm to 10 nm which can be achieved using electrons. So electron microscopy is very important in analysis of nanoscale materials.

Unusual properties are seen at nanometer size. For example- electrons which are delocalized becomes confined so the properties depending on localization of electron will change. Metal becomes non-metal due to this. Similarly reactivity will change due to change of surface to volume ratio. Disorder of dipoles increases with decrease of size which will result in transition from magnetic to nonmagnetic material.

Different size of gold particles appears in different colors which can be explained with the help of nanoscience.

Gold cluster < 1nm Orange gold

Gold nanoparticles: 3 to 30 nm Red color gold

More than 50 nm size: Crimson to blue color gold

Bulk gold film: Yellow color gold.

Different type of microscopes used in nanoscale analysis is

- 1- TEM- Transmission Electron Microscope(1931)
- 2- SEM- Scanning Electron Microscope(1937)
- 3- STM- Scanning Tunneling Microscope(1981)
- 4- AFM- Atomic Force Microscope(1986)

Nanotechnology gives new array of properties which are not possible with bulk material. Eric Drexler has written a book in 1981 with title "molecular manufacturing" and another book in 1986 with title "Engine of creations". These books have given the direction to nanoscale manufacturing. Atomic manipulation of Xe atoms is done in 1989 at IBM.

In electronics size is very important. Nanoscale miniaturization will lead to reduction of effective electron path and reduction in electron scattering which will lead to faster operation of electron devices but it will require more complicated manufacturing process and it will lead to increase in the fabrication cost.

Electronic and optical properties of materials can be controlled by controlling their size and shape.

III ENERGY LEVEL IN ATOMS

The sum of the kinetic and potential energies of an electron moving around a nucleus can only assume a set of discrete values for the simplest atom (hydrogen). This is due to wave like properties exhibited by electrons.

The electron wave must repeat itself exactly when followed around any circular path enclosing the nucleus to become stable. It leads to the conclusion that an integral number of wavelengths must fit into the path, and is termed as 'quantization condition'.

The electron's wavelength (λ) is inversely proportional to its momentum (p) as defined by De Broglie's relation of the wave-

particle duality:

$$\lambda = \frac{h}{p} \quad (2.1)$$

Where h is called Planck's constant and it has the value 6.6×10^{-34} Js. The quantization condition fixes the electron momentum to one of a set of discrete values depending on the number of wavelengths fitting the circular path. The quantum number determines a set of discrete energies which the electron can have, since the energy is directly related to the electron's momentum.

IV EFFECTIVE MASS:

The concept of mass of the carriers occupies a central position in the whole field of solid-state electronics. This mass is different than that of free electron mass and is called the effective mass of the carrier whose expression changes under different physical conditions. The effective carrier mass, in general, can be expressed as

$$\text{effective carrier mass along a particular direction } (m^*) = \frac{\text{momentum}(p) \text{ along this direction}}{\text{velocity}(v) \text{ along the same direction}} \quad \text{eqn. (2.2)}$$

From eqn. (2.1) we can write,

$$p = \frac{h}{\lambda} = \left(\frac{h}{2\pi} \right) \left(\frac{2\pi}{\lambda} \right) \quad (2.3)$$

The term $\left(\frac{h}{2\pi} \right)$ is called \hbar and is called the normalized Planck's constant or the Dirac's constant and the term $\left(\frac{2\pi}{\lambda} \right)$ is known as the carrier wave vector (\vec{k}) . Therefore the eqn. (2.3) can be expressed as,

$$\vec{p} = \hbar \vec{k} \quad (2.4)$$

The velocity as written in eqn (2.2) must be the group velocity $\left(\frac{\partial \omega}{\partial k} \right)$, where the frequency $\omega = \frac{E}{\hbar}$ in which E is the total energy of the carrier and

not at all the phase velocity. Therefore the velocity of the carrier is $\frac{\partial \omega}{\partial k}$. Thus the mass of the carrier should, in general, be written as

$$m^* = \frac{\hbar k}{\frac{\partial \omega}{\partial k}} = \frac{\hbar k}{\frac{1}{\hbar} \frac{\partial E}{\partial k}} \quad (2.5)$$

Therefore the effective mass of the carriers can be expressed as,

$$m^* = \hbar^2 k \frac{\partial k}{\partial E} \quad (2.6)$$

From eqn. (2.6), we observed that effective mass changes with the slope of the E-k curve. This E-k relation is called the dispersion relation which changes from semiconductor to semiconductor, and consequently the m^* also changes. The momentum effective mass is

$$m_f^* = \hbar^2 \left/ \frac{\partial^2 E}{\partial k^2} \right.$$

the most fundamental. Acceleration effective mass

This is also called the curvature effective mass. These two definitions yield the same result when $E \propto k^2$ i.e. E-k relation is parabolic. For any deviation from the parabolicity these two definitions of the effective mass will not converge to the same expression. The effective momentum mass of the carriers as given by eqn. (2.6) affects all the properties of semiconductors such as electronic heat capacity, diffusivity to mobility ratio, the Hall co-efficient, all types of transport co-efficient and changes with electron concentration and other externally controllable parameters.

V FERMI-DIRAC STATISTICS

The Fermi-Dirac statistics expresses the probability with which the electron will occupy the energy level E and is extremely important in the whole field of solid-state electronics.

This equation is called the functional equation and can be satisfied if and only if we substitute f(E) as

$$f(E) = \frac{1}{1 + e^{(E-E_F)/k_B T}}$$

where E_F is the fermi energy (a quantity defined later on), k_B in the Boltzman constant (8.62×10^{-5} eV/K) and T is the absolute temperature in Kelvin (K) .

The total energy E of a conduction electron is given by

$E = \text{Kinetic energy} + \text{Potential energy}$

$$= \frac{p^2}{2m_c^*} + \text{P.E. (where } m_c^* \text{ is the effective mass of the electron in the conduction band)}$$

$$= \frac{p^2}{2m_c^*} \quad (\text{assuming the energy is measured from the edge of the conduction band } E_C)$$

$$E = \frac{\hbar^2 k^2}{2m_c^*} \quad (2.8)$$

Since we have already proved that $p = \hbar k$ therefore we can write that

This indicates a parabolic dependency between the energy and wave vector as shown in the fig below and is termed as electron parabola. In this figure the horizontal line EC indicates the edge of the conduction band, the horizontal line EV is called edge of valence band, the dotted horizontal line near EC is called the donor level ND, the dotted horizontal line near EV is called the acceptor level NA. Ed is called the donor energy level, Ea is the acceptor energy level. The energy is measured from the edge of the conduction band EC in the vertical upward direction. The band gap E_g is defined as $E_g = E_C - E_V$. For positive band gap $E_C > E_V$, for negative band gap $E_C < E_V$ and for zero band gap $E_C = E_V$.

Below the line EV the heavy hole, light hole and split-off hole parabolas have been drawn, since, only three types of holes exist experimentally. The effective masses of the three types of holes are m_{hh} , m_{lh} , and m_{soh} respectively.

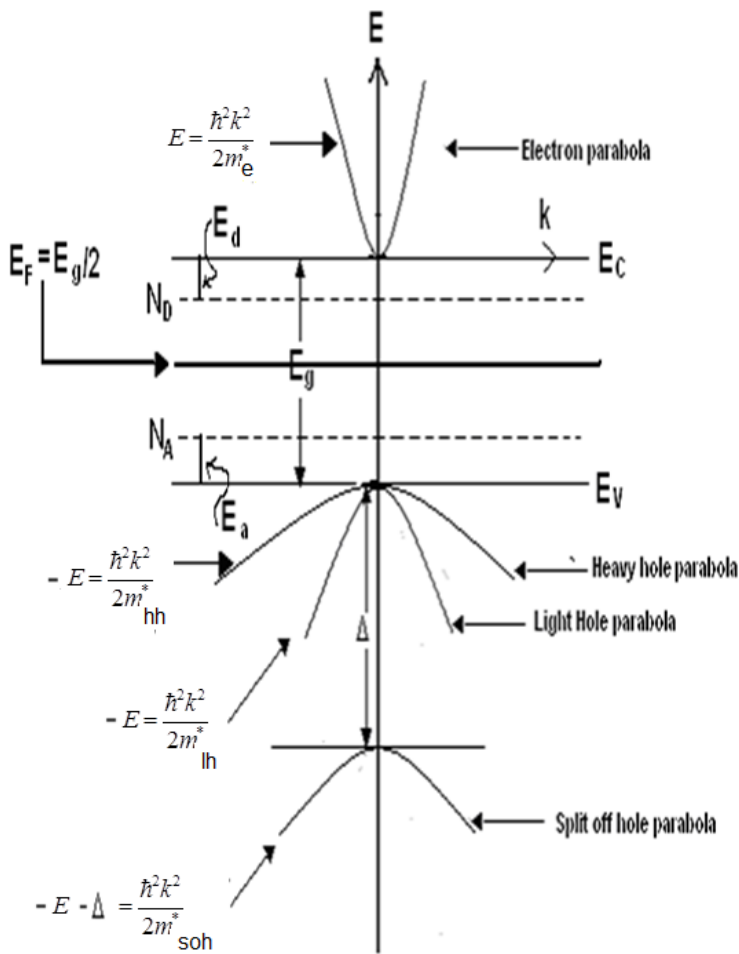


Figure 2.1 Typical model of an energy band structure of the crystalline material (Δ is called spin orbit splitting constant of valance band) Semiconductors ($E_g \leq 2.34\text{eV}$)

VI QUANTIZED ELECTRONIC STRUCTURE

Quantum confinement leads to collapse of the continuous energy bands of bulk material into discrete, atomic like energy levels. The discrete structure of energy states leads to a discrete absorption spectrum, which is in contrast to the continuous absorption spectrum of a bulk semiconductor as shown in Fig.3.1

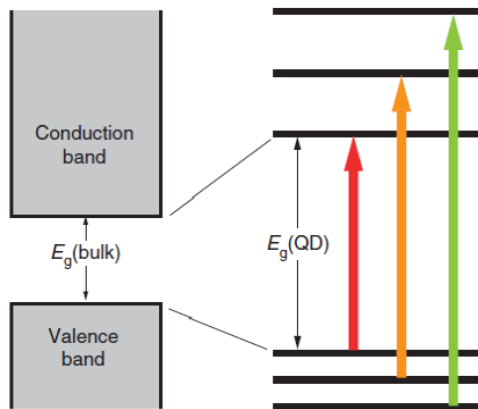


Fig. 3.1: A schematic of the discrete energy level of a semiconductor.

In semiconductors, the quantization effect that enhances the optical gap is routinely observed for clusters ranging from 1 nm to almost 10 nm. Metal particles consisting of 50 to 100 atoms with a diameter between 1 and 2 nm start to lose their metallic behavior and tend to become semiconductors.

Low dimensional structures having quantum confinement of one, two, and three dimensions (such as quantum wells, wires, and dots) have, attracted much attention in uncovering new phenomena and their interesting applications in nanotechnology.

Table 3.1 Classification of quantum confined structures.

Structure	Quantum confinement	Number of free dimension
Bulk	0	3
Quantum well/superlattices	1	2
Quantum wire	2	1
Quantum dot/Nanocrystals	3	0

In general, quantum wires, wells and dots are grown by advanced epitaxial techniques in nanocrystals produced by chemical methods or by ion implantation, or in Nano devices made by state of- the-art lithographic techniques.

In QWs, the restriction of the motion of the carriers in the two directions may be viewed as carrier confinement by two infinitely deep 1D square potential wells, leading to quantization [known as quantum size effect (QSE)] of the wave vectors along the two directions, allowing 1D electron transport representing new physical features not exhibited in bulk semiconductors.

The allowable energy levels, motion, and optical properties of the electrons are strongly affected by the quantum-mechanical effects. These artificially synthesized quantum structures find major application in high-performance transistors such as the microwave high-electron-mobility transistor (HEMT), and in high-performance solid-state lasers such as the semiconductor quantum-well laser.

Zero-dimensional materials: Nanocrystals absorb light then re-emit the light in a different colour. The size of the nanocrystal (at the Angstrom scale) determines the colour. A quantum dot is a semiconductor whose excitations are confined in all three spatial dimensions. As a result, they have properties that are between those of bulk semiconductors and those of discrete molecules.

In an unconfined (bulk) semiconductor, an electron-hole pair is typically bound within a characteristic length called the Bohr excitation radius. If the electron and hole are constrained further, then the semiconductor's properties change. This effect is a form of quantum confinement, and it is a key feature in many emerging electronic structures. Specifically, the effect describes the phenomenon results from electrons and electron holes being squeezed into a dimension that approaches a critical quantum measurement. For 0-D nanomaterials, where all the dimensions are at the nanoscale, an electron is confined in 3-D space. Quantum confinement is responsible for the increase of energy difference between energy states and band gap. Quantum dots offer great potential in the form of QLEDs which are made out of networks of quantum dots and can also build on, yet dramatically improve, existing LED technologies.

Quantum dots are essentially nanometer-size crystals of semiconductor materials (e.g., silicon or germanium) for which the electronic properties are strongly dependent on their size.

Wavelengths in quantum dots can be controlled in nanocrystalline materials. The energy separation between valence and conduction bands can be altered in nanocrystalline quantum dots by changing the size of the nanoparticles. Resulting energy levels can thus be varied.

One-dimensional nanomaterials: The diameters of the nanostructures are comparable to the sizes of biological and chemical species being sensed, and thus intuitively represent excellent primary transducers for producing signals that ultimately interface with macroscopic instruments.

The size-tunable colours of semiconductor nanocrystals, together with their highly robust emission properties, are opening up opportunities for labelling and optical-based detection of biological species that offer advantages compared with conventional organic molecular dyes widely used today.

The underlying mechanism for nanowire sensors is a field effect that is transduced using field effect transistors (FETs), the ubiquitous switches of the microelectronics industry. The electronic characteristics of nanowires are well controlled during growth in contrast to carbon nanotubes. Si nanowires can be prepared as single-crystal structures with diameters as small as 2-3 nm.

The Einstein relation for the diffusivity (D) to the mobility (μ) ratio (DMR) of the carriers in electron devices is very useful since the diffusion constant can be obtained from this ratio by knowing the experimental values of the mobility. It is more accurate than any of the individual relations for the diffusivity or the mobility, which is the two widely, used quantities of carrier transport of modern semiconductor devices. The classical value of the DMR is equal to $(k_B T / e)$, (k_B , T , and e are Boltzmann constant, temperature and the magnitude of the carrier charge respectively) which represents the well-known Einstein relation. The relation is valid for both the electrons and the holes. In this conventional form it appears that, the DMR increases linearly with T and is independent of carrier concentration. This relation holds only under the condition of carrier non-degeneracy although its validity has been suggested erroneously for degenerate materials. Besides, the performance of the electron devices at the device terminals and the speed of operation of modern switching transistors are significantly influence by the degree of carrier degeneracy present in these devices. The simplest way of analyzing such devices taking into account of the degeneracy of the band is to use the appropriate Einstein relation to express the performance at the device terminal and switching speed in terms of the carrier concentration.

The photo-current density depends on the density-of-states function which significantly affects the different physical properties of electronic materials having various band structures. Photoemission from electronic materials having degenerate electron concentration is essentially determined by their respective energy band structures. It has different values in different materials and varies with the electron concentration, with the magnitude of the reciprocal quantizing magnetic field under magnetic quantization, with the quantizing electric field as in inversion layers, with the nano-thickness as in quantum wells, wires and dots and also with superlattice period as in the quantum confined superlattices of small gap compounds with graded interfaces having various carrier energy spectra.

This method can predict the confined energy levels of nanostructures by solving Schrodinger equation assuming the barriers have an infinite confining potential. The “effective mass” solutions of the Schrödinger equation for electrons confined in a quantum dot or NCs, quantum wire and quantum well are,

Quantum dot or Nanocrystals:

$$E_{n,m,l} = \frac{\pi^2 \hbar^2}{2m^*} \left(\frac{n^2}{L_z^2} + \frac{m^2}{L_y^2} + \frac{l^2}{L_x^2} \right), \psi = \phi(z)\phi(y)\phi(x)$$

Quantum wire:

$$E_{n,m}(k_x) = \frac{\pi^2 \hbar^2}{2m^*} \left(\frac{n^2}{L_z^2} + \frac{m^2}{L_y^2} \right) + \frac{\hbar^2 k_x^2}{2m^*}, \psi = \phi(z)\phi(y)\exp(ik_x x)$$

Quantum well:

$$E_n(k_x, k_y) = \frac{\pi^2 \hbar^2 n^2}{2m^* L_z^2} + \frac{\hbar^2}{2m^*} (k_x^2 + k_y^2), \psi = \phi(z)\exp(ik_x x + ik_y y)$$

where $n, m, l = 1, 2, \dots$ the quantum confinement numbers, L_x, L_y and L_z are the confining dimensions, $(\exp ik_x x + ik_y y)$ is the wave function describing the electronic motion in x and y direction, similar to free electron wave functions

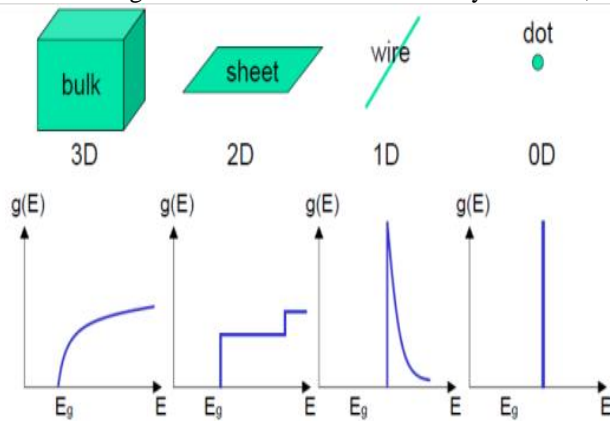


Fig. 3.2 Density of electron states of a semiconductor as a function of dimension.

The optical absorption spectrum is roughly proportional to the density of states.

The in-plane effective electron mass (m_i) in narrow Ga_{0.47}In_{0.53}As/InP quantum wells is strongly dependent on the quantization energy.

III-V materials are being increasingly used in integrated optoelectronics, passive filter devices, distributed feedback lasers and Bragg reflectors.

In recent years, with the advent of MBE, MOCVD and other experimental techniques, the influence of quantization of band states on the different physical properties of nanostructure materials such as quantum wells, quantum well wires, quantum dots, inversion layers, magnetic quantization, and different field added dimensionally reduced systems. The influence of band structures on the physical properties of quantized structures is becoming increasingly important.

REFERENCES:

- 1- Bhattacharya P. (2008), "Semiconductor optoelectronic devices", Pearson education, pp 1-155
- 2- Buczko R(1992) "Valance band quantization in a spherical quantum dot"Acta Physica Polonica A, Vol. 82(5), pp 789-792.
- 3- John Sanjeev (1987) "Localization and density of states for an electron in a quantized elastic continuum",Physical Review B, Vol. 35(17),pp 9291-9294.

- 4- Lundstrom M. and Guo J.(2006), “Nanoscale transistors”, Springer, pp 1-80
- 5- Ovsyuk N.N. and Sinyukov M.P. (1980) “Effect of quantization on electrical reflection spectra in the surface region of a semiconductor”, JETP lett, Vol. 32(5),pp. 366-370.
- 6- Paitya N. and Ghatak K. P. (2013) “Quantization and Carrier Mass” Reviews in Theoretical Science Vol. 1(2), pp. 1–141.
- 7- Piper L. F. J.(2008), “Observation of quantized subband states and evidence for surface electron accumulation in CdO from angle-resolved photoemission spectroscopy” Physical Review B, Vol. 78(12),pp 165127-1-165127-5.
- 8- Schmidt K. H.et. al. (1997), “Size quantization effects in InAs self-assembled quantum dots”, Appl. Phys. Lett., Vol. 70 (13), pp 1727-1729.
- 9- Wetzel C. et. al (1996) “Electron effective mass and nonparabolicity in Ga 0.47In 0.53As/InP quantum wells” Physical Review B, Vol. 53(3),pp 1038-1041.
- 10- Zhang Li et. al. (2013), “Weak localization effects as evidence for bulk quantization in Bi₂Se₃ thin films” Physical Review B, Vol. 88(12),pp 121103-1-121103-4.
- 11- https://en.wikipedia.org/wiki/Potential_well

**D & D
I & A**



Publication

International Journal of Engineering Research and general science is an open access peer review publication which is established for publishing the latest trends in engineering and give priority to quality papers which emphasis on basic and important concept through which there would be remarkable contribution to the research arena and also publish the genuine research work in the field of science, engineering and technologies

**International Journal Of Engineering Research and
General Science**

ISSN 2091 - 2730