International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 503-512 www.ijaem.net ISSN: 2395-5252

A Fault Detection and Protection Scheme for A 150 MVA Transformer Using Fuzzy

Babagana Ali Dapshima
School of Sciences
Department of Physics
Umar Ibn Ibrahim El-kanemi College of Education
Science and Technology, P.M.B 16, Bama, Borno State.

Submitted: 15-11-2022 Accepted: 25-11-2022

ABSTRACT
Power transformers are one of the most expensive and most important elements in the powersystem. Malfunctions in power transformers result in significant power cuts and, consequently, materialdamage. This important problem needs to be solved. Power transformers must be protected from variousfault conditions and faults in the power system. In this study, Fuzzy logic is used in fault detection and protection scheme for a 150MVA. Fuzzy logic (FL) tool box in MATLAB/ SIMULINK software was utilized in the simulation system thatdiagnosed transformer faults and also monitors its operating conditions. Current and rate of change of currentwith time have been identified as the input variables, duly represented in the programme as "Error" and "Error-Dot". The results from the research show that whenever the output response is zero the current in transformer isnormal. This is obtained when input values of [0] and [0] are injected into the system to produce a response of "$6e^{-017}$" which is approximately zero. Whereas if the output response is greater than zero it implies that thetransformer current is rising beyond normal and protection scheme should be alerted. This condition isachieved when input values of [-1.5] and [5] are used on the system to give a response of "+5". However, if theresponse is less than zero then the transformer current is below normal, hence the protection scheme should bealerted. The study concluded that the electrical faults and mechanical failuresthat occurred in a power transformers are easily identified using Fuzzy logic in a shorter time. Thus, damage to power transformers is prevented bycontrolling relays more effectively and faster. This has led to a significant reduction in maintenance andrepair costs. It is understood that the study is successful.

Keywords: Fault, detection, protection, fuzzy logic, current, transformer.

I. INTRODUCTION

A simple transformer is a static electrical device which transforms the electrical energy from one electrical circuit to another without any change of frequency through the process of electromagnetic induction. It is interesting to note that the transfer of energy from one circuit to another takes place with the help of mutual induction that is flux induced in the primary winding gets linked with the secondary winding which we shall explain in a while. Transformer Failure can also occur if appropriate care is not taken for its operation (Sanda, 2012).

As one of the key elements of the economy and social development, electrical energy hasbecome one of the today's indispensable energy sources. This energy source has becomepreferable because it is easy to use electric energy, easily transformed to other energy sourceswith high efficiency and does not harm the environment while consuming. However, thecontinuous, inexpensive and reliable energy is constantly increasing the demand for thisresource. Parallel to economic and social development, electricity consumption is increasing.

Considering the plant and operation costs for the generation, transmission and distribution ofelectrical energy, the protection of energy systems is given more importance every day in linewith the principle of providing reliable and continuous energy (Behjat, 2011). It is very important forthe consumers to have a very short downtime when the electrical energy is never cut or out. Itis important to consider the services that cannot be produced due to the power outage, the lossof the workforce and the costs for the repair of the system. It is intended to be able to estimatethe faults before they occur. Both the repair costs of the hardware can be reduced and thedisruption of the operation can be minimized due to the disabled equipment. Considering allthis together, the necessity of good fault detection and protection of energy systems is clearly seen. An idealprotection system must have the characteristics of reliability, selectivity, speed, simplicity andeconomy (X. Lei et.al 2014).

Power transformers are one of the most expensive and most important elements in the power system. Malfunctions in power transformers result in significant power cuts and, consequently, material damage. This important problem needs to be solved. Power transformers must be protected from various fault conditions and faults in the power system.High voltage transformers are unavoidably subject to various faults and relayslike differential, Bulchholz and directional relays with sensors are usually adopted todetect and transmit (relay) the decision to a circuit breaker which trips or opens the powersystem. These modern detection schemes do not tolerate uncertainties or impressionunder changing operating conditions.Hence,the use of fuzzy logic in fault detection and protection in transformer became of paramount important.

A fuzzy logic as an alternative method of fault detection and protection on power transformer has been adopted for this paper research. Soft computing has been proposed as a method to solve real-world problems, which defy conventional approaches. In fact, even when expert knowledge is available, it is often more easily stated in descriptive form that is, as statement like "IF a sign of certain type appears THEN one or more faults must be present" (Mohammed et. al).

Fuzzy logic incorporates a simple rule-base if "X AND Y THEN Z" approach to solving problems rather than attempting to model a system used which rely on the operator and experience rather than technical understanding of the system. Design of a fuzzy logic sensor needs qualitative knowledge about the system under consideration.

Unlike most conventional and modern detection schemes, fuzzy logic sensors are capable of tolerating uncertainties and imprecision to a greater extent. Hence they produce better results under changing operating conditions and uncertainties or imprecision in system parameters

II. FAULTS IN TRANSFORMER

The power transformer is the major and very important component of the power system. Also, the possibility of fault in a transformer is rare compared to a generator, but it must be disconnected as quickly as possible if the fault occurs. It requires highly reliable protective devices. Generally, series fuses are employed for the protection of small distribution transformers. Whereas in the case of power transformers, automatic protective relaying equipment is needed for protection against possible faults.

2.1 TYPES OF TRANSFORMER FAULTS

The faults in transformers are mainly classified as,

a. Faults in the auxiliary equipment which is a part of the transformer,

b. Transformer winding and connection faults, and

c. Overload and External short circuits.

a. Faults in Auxiliary Equipment:

The faults in the auxiliary equipment of the transformer can cause the failure of the transformer windings. Therefore, it is of great importance to detect these kinds of faults. The following are considered the faults in auxiliary equipment.

i. Core and Winding Insulation:

Minor faults, which develop in core and winding insulation may further develop into major faults if proper care is not taken at the initial stages. The failure in the insulation can be due to the poor quality of material used for laminations, core bolts, and joints or connections. These faults do not cause any interruption to the supply but must be cleared as soon as possible.

ii. Gas Cushion:

Oil and insulation of the transformer get affected by the presence of oxygen and moisture in the gas space. The normal operating pressure within the tank varies widely hence, the pressure inside the tank must be monitored which can be done by a pressure vacuum gauge.

A second oil tank known as a conservator tank is mounted above the main oil tank to overcome the change in volume of the oil. It is partially filled with oil and takes the expansion and contractions of the oil in the main tank. During this process, the air moves in and out of the conservator tank and is made to pass through a silica gel before entering the tank to prevent moisture and so only dry air enters.

iii. Transformer Oil:

In order to protect the parts of the transformer from excessive heat, the whole assembly of the transformer is immersed in oil usually known as transformer oil i.e., transformer oil acts as a cooling medium. If the oil level drops below the specified level or if it losses its cooling property, then the parts of the transformer will get exposed to heat and may cause severe damage to the equipment and surroundings. Hence, oil level

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 503-512 www.ijaem.net ISSN: 2395-5252

indicators with alarm circuits are provided to ensure the oil level is maintained at a specified level and the oil is regularly checked for its cooling property.

b. Winding Faults and Connection Faults:

These faults occur due to unbalanced current or voltage and are serious in nature that causes immediate damage. Phase to phase faults such as faults between adjacent turns or coils short-circuits between turns on the HV and LV windings. Phase-to-earth faults on the HV and LV external terminals or on the windings.

The short circuits between the turns are mainly due to mechanical forces or insulation damage due to overload on a loose connection. A short circuit between the phases results in the flow of huge amount fault currents as well as the emission of a large amount of gas due to the decomposition of oil. These types of faults are easy to detect but they need fast clearance to avoid severe damage.

c. Overload and External Short Circuits:

The insulation of the windings is greatly affected by the loads. It will get deteriorated during overload conditions. Overloads and external short circuits raise the temperature of the windings and cooling system. To monitor winding and oil temperature, an alarm system is placed so as to permit the temperature limits at specified values. External short circuits are prevented by the transformer reactance.

2.2 Constructional feature to reduce faults and increase efficiency.

There are various transformer parameters and constructional features that couldreduce faults and increase transformer efficiency. These include;

i. Core

The core is constructed from cold-rolled grain oriented material. The core platesare insulated on the sides. The 0.3mm thick laminations are also stress relieved. The sizesof the laminations are stepped to produce limbs and yokes of almost circular orrectangular cross section. The core is the steel system, which forms the magnetic circuit. It is around thecore that the windings are wrapped. A transformer is described as core type if thewindings envelope the core, and shell type if the windings are partially enveloped by thecore.

ii. Windings

The windings are either rolled or rectangular copper or aluminium conductors. Round conductor windings consists of individually wound coil sections connector in serial to produce the phase winding. Windings with rectangular conductors are of the continuous disc type or the layer type. Axial and radial ducts are channels in the windings that allow cooling and insulating liquid to quickly and uniformly dissipate heat due to losses. The low voltage windings are thicker because it carries more current and it is wound to rest round the core. The high voltage windings are thinner and are wound on the high voltage side of the transformer. The tertiary windings where it exists, is placed between the low voltage windings and the core. (Arshad, 2004)

iii. Insulation

The major insulation comprises the insulation between the low voltage winding and the core and between the high voltage winding and low voltage windings as well as between adjacent limbs and insulation between the coils and core yokes. The minor insulation consists of the insulation on individual turns and between layers.

Only high quality insulating material such as cable paper and pressboard are used, all moisture is removed from the insulating materials by careful drying. The insulationstructure is designed from impulse voltage distribution to give adequate dielectricstrength both for continuous steady-state loading and incoming surge voltages.

iv. Dehydrating Breather:

This is the part through which transformer communicates with outside air. When the insulating liquid heats up It expands and the levels arises forcing air out of the tank through the breather. When the operating temperature of the transformer drops, the volume of the insulating liquid decreases and a corresponding quality of air is simultaneously sucked in from the atmosphere leaving behind particles dust and water into the lower part through the breathing openings.(Arshad, 2004)

v. Desiccant

Attached to the breather is the desiccant glass. The desiccant is either pure aluminium silicate gel impregnated with cobalt chloride. Desiccants have sizes of about 3mm and a very good absorption power. In the active condition, their appearance is crystalline blue. On taking up moisture, the colour changes to pink. In the dehydrating breather, moisture is almost completely retrieved from the air flowing into the conservator by this desiccant when transformer cools down. The lowering of the dielectric strength of the insulants due to moisture ambient air and the formation of condensation. So the hydrating breather with the desiccant increase the operational reliability of transformers. (Arshad, 2004).

III. METHODOLOGY

This paper investigates the feasibility of using fuzzy logic method to predict and detect faults at early stage in distribution transformer. The fuzzy logic based detector has been developed to monitor and predict faults at an early stage on transformer. The diagram shown in figure 1 clearly show an improved fault detection and protection for a transformer using fuzzy logic fault detector.

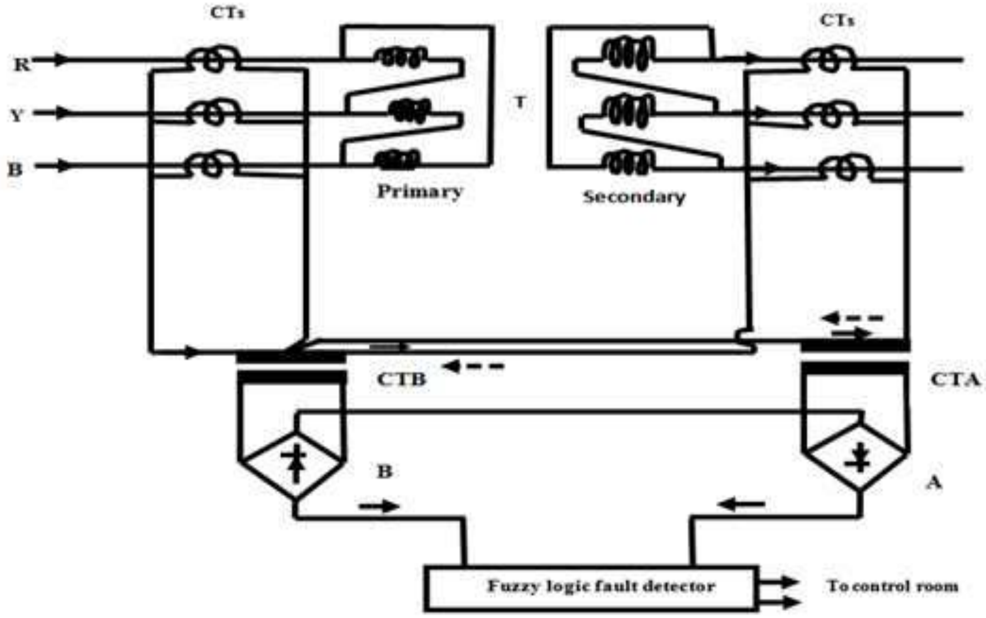

Figure 1: Circuit diagram of fuzzy logic fault detector

Considering the High Voltage (HV) side of transformer,

Current $I_1 = \frac{MVA}{\sqrt{3}\,MV}$

or $I_1 = \frac{KVA}{\sqrt{3}\,MV}$ ……………………………………………………………1

$\frac{I_1}{I_2} = \frac{N_2}{N_1}$ ……………………………………………………………………2

$I_2 = I_1 \times \frac{N_2}{N_1} =$ Input of current (error) …………………3

From the circuit above,

CTA = Auxiliary current transformer at operating side.

CTB = Auxiliary current transformer at restraining side.

IA = Operating current.

IB = Restraining current

R, Y and B represent the voltage lines from both side of the power transformer.

CTs is the currenttransformer on both sides of the power transformer.

T = Transformer Protected.

During differential, at time t, our second input I_3 now becomes

$\frac{dI_2}{dt}$ =error – dot…………………………………………4

Note that; I_2 which is the output current from the transformer becomes the input current "Error" to the fuzzydetector, while $\frac{dI_2}{dt}$ which is the output current at time t, becomes the second input current error-dot to the fuzzy detector.

The circuit of Figure 1 shows the circulating-current scheme for the protection of a 3-phase delta/deltapower transformer against current. Note that the CTs on the two sides of the transformer are connected in star.

These compensate for the phase difference between the power transformer primary and secondary. The fuzzylogic fault detector is connected to the current transformer on the power transformer to be protected. Differentialrelay is equally connected. The currents at both sides of the transformer are compared by the differential circuit.

An auxiliary CTA and CTB are connected in the operating and restraining current circuits respectively. Thesecondary of these auxiliary CTs are connected to the rectifier bridge comparator. The output of the operatingauxiliaries CTA and CTB is given to Rectifier Bridge A and B respectively, whose output values give forwardcurrents to the fuzzy logic detector as input1 and input 2. These input values undergo the process of fuzzification according to the rule structure one after theother. The initial results from each input values are feedback into the system and back to the controller throughthe rectifier as seen in Figure 1. Similarly, depending on the number of possible fuzzy rules as, these inputvalues are fuzzified logically to produce output response values, which are combined to produce a crisp outputvia the controller (fuzzy logic fault detector). The fuzzy logic fault detector will detector the fault and tries torectify the fault within a pre-set time, but if the fault persists an alarm as well as signal will be send to the controlroom before the system trips off.

This paper investigates the feasibility of using fuzzy logic method to predict and detect faults at earlystage in distribution transformer. The fuzzy logic based detector has been developed to monitor and predictfaults at an early stage on particular section of the transformer. The detector for this early warning faultsdetection device only requires external measurement taken from the input and output nodes of the transformer asshown in Figure 1.

The measurement taken from the transformer will be processed by the fuzzy logic controller available inMATLAB Tool Box.

Generally, fault detection and protection of high voltage transformer using fuzzy logic consist of the followingsteps.

(i) Identification of input and output variable
(ii) Construction of control rules
(iii) Fuzzification and fuzzy membership functions
(iv) Selection of composition rule of inference
(v) Defuzzification method

The simulation software used in this research is Simulink MATLAB. This can be achieved by buildingthe system using the graphical user interface (GUI) tools provided by fuzzy logic tool box.

The five primary graphical user interface GUI tools for building, editing and observing fuzzy inference systemsin fuzzy logic tool box in is shown in Figure 2

The fuzzy Inference System Editor (FIS Editor): Handles the high level issues for the system: How manyinput and output variables? What are their names?

Membership Function Editor: Used to define the shapes of the membership functions associated with eachvariable.

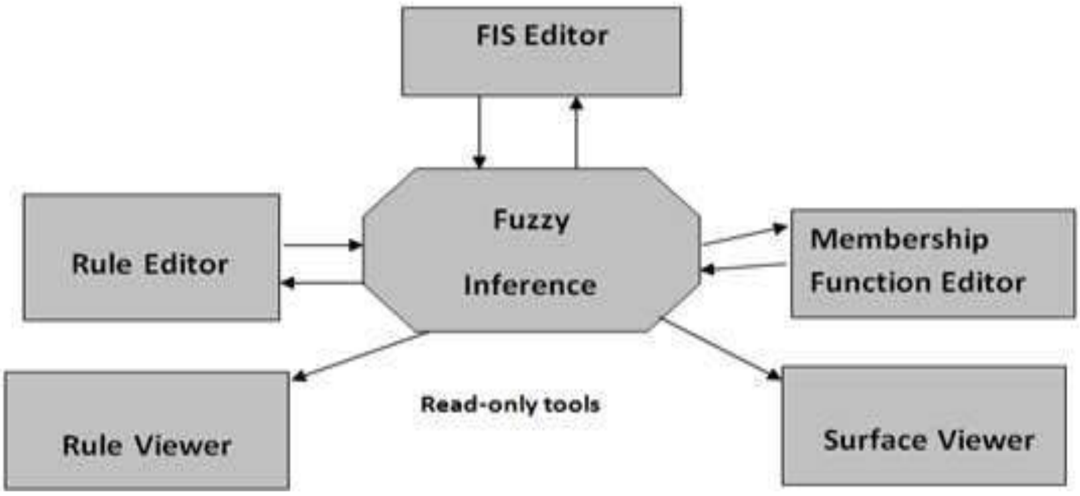

Figure 2: Building Systems with Fuzzy Logic Toolbox

Rule Editor: For editing the list of rules that defines the behaviour of the system.

Rule Viewer and the surface Viewer: Used for looking at, as opposed to editing, the FIS. They are strictlyread-only tools. It can show (for example) which rules are active, or how individual membership functionshapes are influencing the results. The Surface Viewer is used to display the dependency of one of the outputson any one or two of the inputs that is, it generates and plots an output surface map for the system. Though it ispossible to use fuzzy logic tool box by working strictly from the command line, in general it is much easier tobuild a system graphically. There are five primary GUI tools for building, editing, and

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 503-512 www.ijaem.net ISSN: 2395-5252

observing fuzzy inferencesystems in fuzzy logic tool box.
(i) Fuzzify the inputs
(ii) Application of fuzzy operator
(iii) Application of an implication operation
(iv) Aggregate the outputs
(v) Defuzzify the output

Fuzzification
Input variable are assigned degree of membership (u) confidence (CF) or degree of fulfillment variousclasses. The fuzzy output sets are aggregated to form a single fuzzy output set.

Defuzzification
The output fuzzy set is defuzzified to find the crisp output current, output = centroid (control, aggregation). If ordinary analysis is used instead of the simulation procedure, which is used in this research work, the centre –of-max method should be applied. Here each fuzzy output is taken as the strength or weight at y axis position ofthe corresponding output membership function. During de-fuzzifciation, each fuzzy output is multiplied by itscorresponding maxima of the output membership functions. The sum of these products is divided by the sum ofall fuzzy output to obtain the x-axis position (Weedy 1977).

IV. RESULT ANALYSIS

The result and simulations of this analysis are presented as follows:
The fuzzy parameter of Current (error) is modified by the adjectives negative big (nb), negative small (ns), zero(z), positive small (ps) and positive big (pb). This is done by the source code. Error = [-1.5 1.5]. The simulationresult of input error (current) is shown in Figure.3

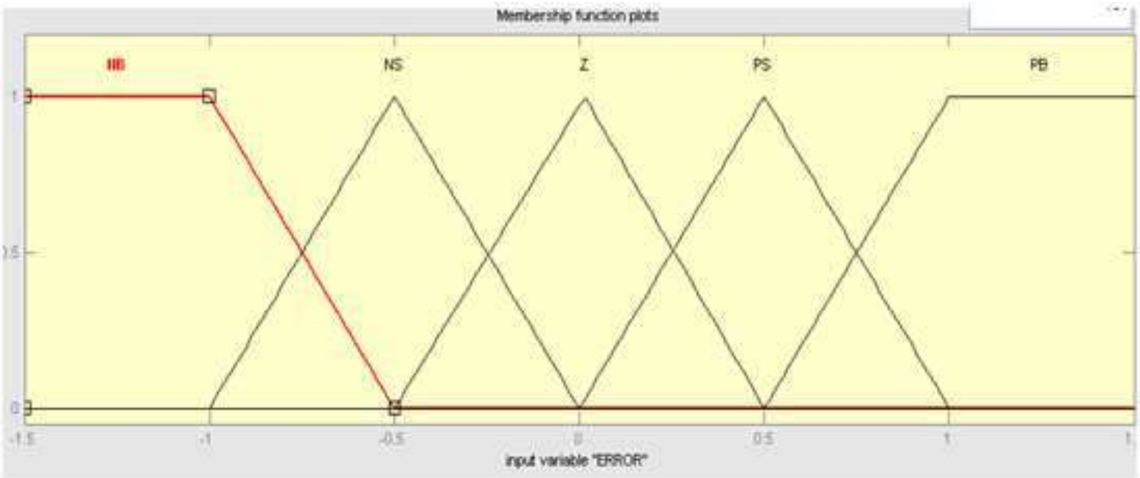

Figure 3: Error Membership Function

The second fuzzy input parameter of the rate of change of error (dele-error) is modified by the linguisticvariables positive (p), zero (ze) and negative (n).
Del- error = [-10, 10]
The simulation result of rate of change of current Error-dot is shown in Figure 4.

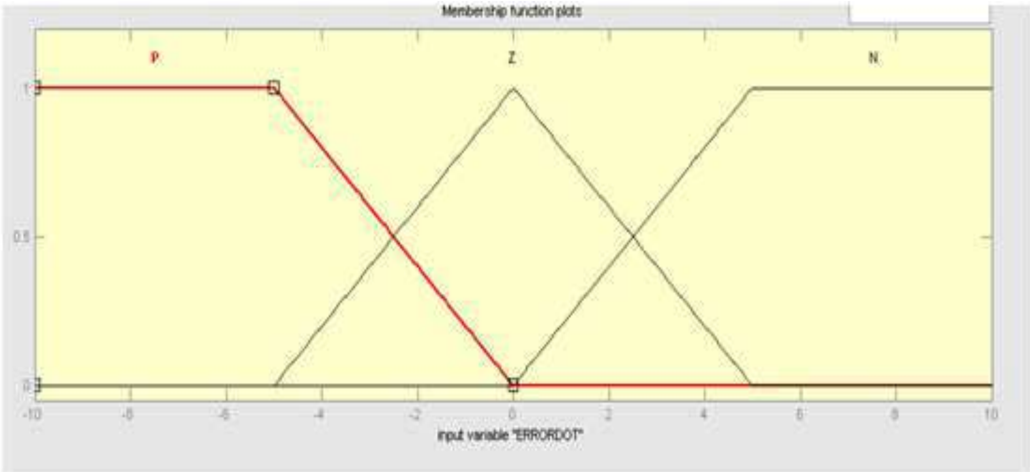

Figure 4: Error-Dot membership functions

The fuzzy Output („control current‟) is modified by the linguistic variables;
"H" = "High" Output response.
"NC" = "No change" to current output.
"L" = "Low" Output response.
The simulation result of the consequent of the degree of membership with which the antecedents Error andError-dot were calculated is shown in Figure 5.

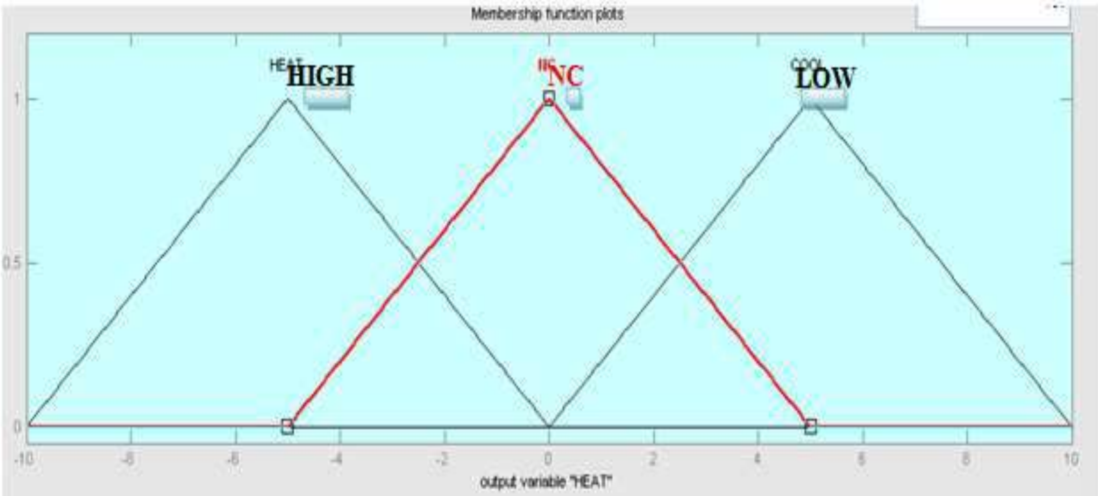

Figure 5: Consequent of Fuzzy rules

The aggregation of fuzzy rule outputs and the crisp output value for current is shown in Figures 6a, 6b and 6c

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 11 Nov. 2022, pp: 503-512 www.ijaem.net ISSN: 2395-5252

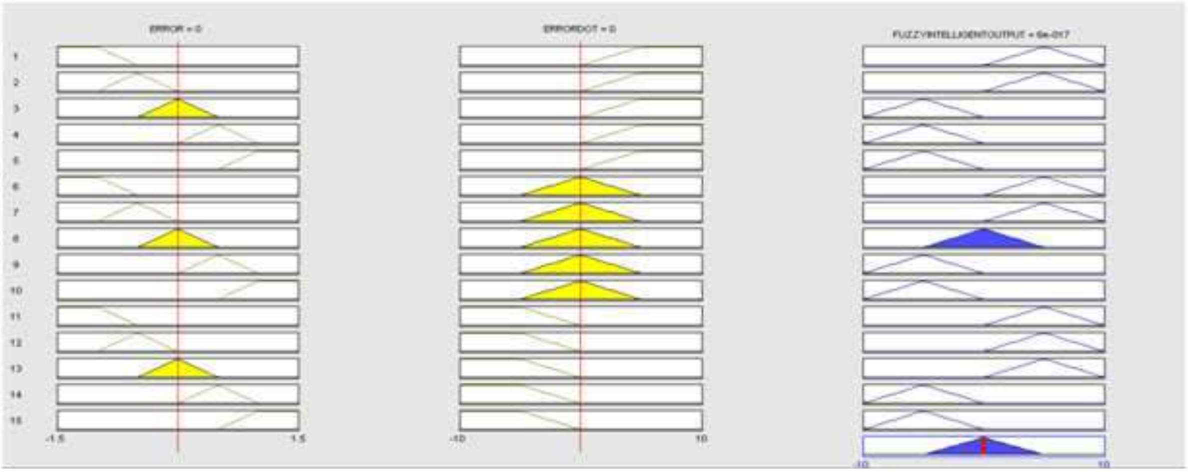

Figure 6a: Aggregate of Fuzzy for "NO CHANGE" Output Response

At input "Error" of [0] and "Error-Dot" of [0], the fuzzy output sets are aggregated to form a singlefuzzy output set. These conditions of error and error-dot occur when the Current of the transformer is within thetolerable limit; hence, the system sees no input data and thereby works with zero as input data. The outputfuzzy set is defuzzified under this condition to find the crisp output value for the transformer Current to be "$6e^{-017}$", which implies that the system is calling for "NO CHANGE" Output response; hence the system is runningat a normal current level.

If there is change between the error membership and error-dot membership, then, there exists change at outputas shown in Figure 6b.

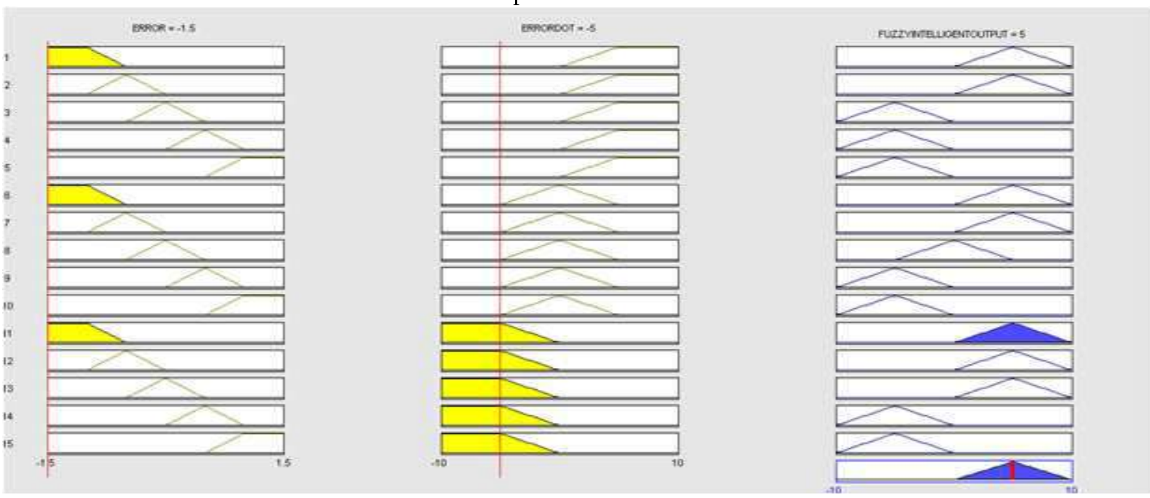

Figure 6b: Aggregate of Fuzzy for "High Current" Output Response

In this result analysis, input "error" = [-1.5] and "error-dot" = [5], after defuzzification, we have a crisp output= "5", which implies that the system is alerting the protection scheme since the Current may be too high.

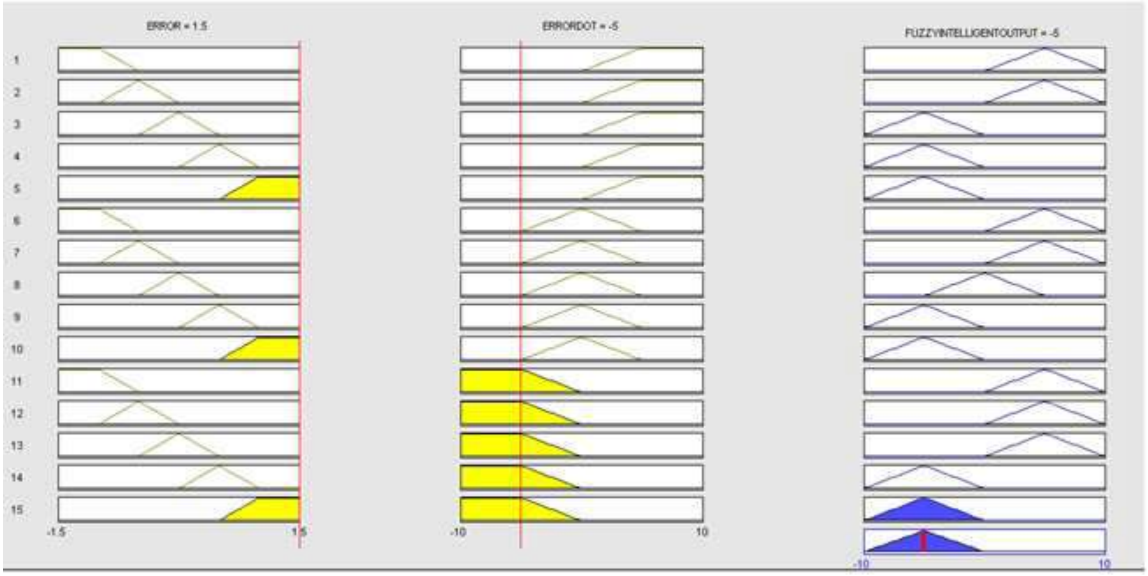

Figure 6c: Aggregate of Fuzzy for "Low Current" Output Response

The simulation result of the input data "1.5" and "-5" from the analysis = "-5", which implies that thetransformer is having low current; hence the detector is just notifying the control engineer that the current in thesystem is low**.**

V. CONCLUSION

The main task of power systems is to provide energy to the end user in the most economicalway, at an acceptable level of reliability and quality. The reliability of the system also depends on the reliability of the elements that make up the system. The most basic and importanthardware in power systems are power transformers. It is very important in energy systems toprevent malfunctions and to operate the transformers in good operating conditions. It isimportant to establish assets for the secure system infrastructure by making investments in the energy system. In addition, it is very important to manage these resulting assets effectivelyand efficiently. Power transformers are the most valuable place in these assets. Compared toother assets, both their functions and their economic values constitute the largest price. In anideal protection system, reliability, selectivity, speed, simplicity and economic features shouldbe present. These protection operations are provided by various protection relays.

In this study, protection in the power transformer where the malfunction occurred wasdetermined by determining the place where the malfunction occurred and by separating thispart from the system as soon as possible. In this disconnection, differential protection relaysare used. These protection relays are controlled with fuzzy logic. The fault in the transformer was quickly detected. Thus, it is possible to quickly remove the defective part from thesystem. Relay control software was created in Matlab program with fuzzy logic. These relaysused in the protection of power transformers have been effectively and quickly controlled. This software was tested on the protection relays in 150MVA Transformer. Withthis software, malfunctions in the power transformer were determined in a short time. Thedefective part was provided to leave the system in a short time. Thus, malfunctions in powertransformers are prevented from causing significant damage to the power transformer. Thishas led to a significant reduction in breakdown costs in power transformers.

REFERENCES

[1]. a.Abu-Siada, S. Islam (2012), A novel on line technique to detect power transformer winding faults, IEEE Trans. Power Delivery, 27(2),, 849-857. 70 M. Zile

[2]. A.F. Abbott, (1980) "Ordinary level physics, Heinemann Educational Books London," 3rd Ed.

[3]. a.Koochaki, S. M. Kouhsari, G. Ghanavati(2008), Transformer Internal Faults Simulation, Advances in Electricaland Computer Engineering.

[4]. Bogdan Kasztenny(2004), "Improved Power Transformer protection using numerical relays", Texas, A and M University USA.

[5]. B.M. Weedy (1977), “Electric power systems”, John Welly and sons New York.
[6]. C.C. Lee (1990), “Fuzzy Logic in Control Systems” IEEE Trans. On Systems, Man, and Cybernetics, SMC, Vol. 20; No. 2.
[7]. D. Wang, W. H. Tang, Q. H. Wu(2010), Ontology-Based Fault Diagnosis for Power, 2010 IEEE Powerand Energy Society General Meeting.
[8]. H. C. Sun, Y. C. Huang, C. M. Huang(2012), Fault Diagnosis of Power Transformers Using ComputationalIntelligence: A Review, Energy Procedia.
[9]. H. Z. Ma, Z. Li, P. Ju, J. D. Han, L. M. Zhang(2005), Diagnosis of Power Transformer Faults on Fuzzy Three-RatioMethod, The 7th International Power Engineering Conference.
[10]. M.I.S.M. Arshad (2004), “Power Transformer Critical Diagnostic for reliability and life Extension” CCECE–CCGEI.
[11]. N.A. Muhamad and S.M.A Ali (2006), “Labview with Fuzzy Logic Controller Simulation Panel for Condition Monitoring of Oil and Drytype Transformer”, World Academy of Science, Engineering and technology.
[12]. O.L. Kagho (2002), “Maintenance of Electrical Distribution Transformers”, Nigeria Society of Engineers
[13]. P.O. Ayaegbu(2003), “Fault section diagnosis in power system using fuzzy logic”, M. Eng. Thesis ESUT, Enugu, Nigeria.
[14]. P. P. Buckle, K. L. Butler, N. D. R. Sarma, A. Kopp(1998), Simulation of Incipient Transformer Faults, IEEE g…/ Symposium tYHMidwest on Circuits and Systems.
[15]. S.O. Okolo.(2018), " A Fault Detection and Protection Scheme for A 200 MVA Transformer Using FuzzyLogic." IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE).
[16]. V. Behjat, A. Vahedi (2011), Numerical modelling of transformers interturn faults and characterising the faultytransformer behaviour under various faults and operating conditions, IET Electric Power Applications.
[17]. X. Lei, J. Li, Y. Wang, S. Mi, C. Xiang (2014), Simulative and experimental investigation of transfer function of interturnfaults in transformer windings, Electric Power Systems Research.