IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

Improvement on Power Transformer Protection using MATLAB Simulink and Fuzzy Logic

Lakhvinder Singh[1], Preeti Khurana[2]
Department of Electrical Engineering, GZSC College of Engg. & Tech., MRS Punjab Technical University, Bathinda, Punjab, India
[4]Department of Electrical & Electronics Engineering, Lovely Professional University, Jalandhar, Punjab, India
[1]preetbrar721@gmail.com, [2]preeti.khurana@lpu.co.in

Abstract **–Harmonics are a topic of growing interest due to the many and varied effects they cause in electrical distribution networks especially in power transformer. Harmonics also cause imbalance between power generation and load to be served, interference with measurement, protection, control and which further generate magnetising transient current (sometime known as inrush current) in power transfer equipment like power transformer. Since there are many protection methods used for the transformer against inrush current now a days. But In this paper, a brand new algorithmic rule supported fuzzy set is proposed. This algorithmic rule consists of considering the magnitude relation and therefore the distinction phase angle of the second harmonic to the basic element of differential currents beneath varied conditions. These 2 protection functions are computed and therefore the protecting system operates in less than one cycle subjected to the prevalence of disturbance. A brand new relaying algorithmic rule is employed to reinforce the fault detection sensitivities of typical techniques by employing a formal logic approach.**

Keywords **–electrical power systems; fuzzy logic; harmonics; inrush currents.**

I. INTRODUCTION

The electrical device is one amongst the foremost vital equipments inside the structure of the electric power Systems being conferred in numerous varieties, sizes and configurations. A power transformer acts as associate degree interconnection node for 2 points of various voltage levels and so the continual operation of the transformer is of significant importance within the dependability of the electrical system. Since any unexpected repair work, particularly the replacement of a defective transformer becomes very important due to its high costly and time consuming process. Thus, the protection of the costlier equipment i.e power transformer is extremely important for the stable and reliable operation of EPSs and the unnecessary performance of protection relays (especially the differential relay) should be avoided [1]. Because of the magnetization of the iron core, at the moment when the unloaded transformer is energized, a transient current known as an "inrush current" appears in the primary winding which is presented as transient peaks whose amplitude may rise up to high range by placing the life of the transformer is at danger. The transformers used in EPS require, in steady state, excitation currents of the order of 0.5-0.2% of the rated current, while during the energizing process the transient inrush current may have the following characteristics [1-3]:

- High initial peak value (10-20 times the peak value of the transformer nominal current),
- Duration of several cycles,
- Wide spectrum of harmonic components, pre-dominating the 2^{nd} harmonic.

The operation of the protection relay may affect due to large differential current produces by flowing of inrush current in any windings of the transformer. However, these cases are not failure conditions and protection relays must correctly discriminate the energizing phenomenon from an internal fault event [1], [2], [4]. Differential protection is used in transformers with powers greater than 10 MVA, however, over-current protection is used as the main protection in transformer banks with lower capacities [5].

In this current work, this paper the essential theoretical study of the inrush current in transformers and their influence on the protection systems. The objective of the study is to present the main causes and possible solutions that can be used today to mitigate this transient phenomenon.

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

II. Harmonic Analysis

A. Classification

A general classification of the harmonics according to the type of non-linear load and the devices used is [6]: power electronics, ferromagnetic devices and arc devices. The harmonics can also be classified into internal and external to the electrical network [7]. In general form, sources of internal harmonic are:

- Deformation or ripple in the voltage waveform of the electric machines due to pulsations and oscillations of magnetic flux caused by the movement of the poles in front of the teeth of the armature.
- Variation of the reluctance of the air gap due to the inclination of the poles of the synchronous motor, which causes variations in the magnetic flux that affects the waveform and results in generation of harmonics.
- Distortion of the magnetic flux of synchronous motors due to load effects. Large load changes cause sudden velocity changes with no change in magnetic flux, which causes signal distortion.
- Generation of non-sinusoidal fem's due to the non-sinusoidal distribution of the magnetic flux in the air gap of the synchronous motors.
- Non-sinusoidal currents.

External harmonic sources are mainly produced by solid state devices. Some of them are listed below:

- Control of efficiency and load of motors using semiconductors and computers, which produce waveforms of voltage and irregular current.
- Speed control devices, such as those used in traction.
- Direct current transmission in high voltage, because the conversion of DC and AC produces harmonic currents and the possibility of propagation due to interconnection. This source however is limited due to the use of filters on all CD terminals.
- Interconnection with solar and wind energy converters and that, due to the connection with the electric network, inject harmonics that propagate in the network.

B. Prevention of Harmonics

Harmonics are a topic of growing interest that must be considered in the design and construction stages of new industrial plants, as well as during their operation. When compensation equipment is applied to limit harmonic levels, the following practical measures can be applied:

- Distribute the controlled rectifiers in transformers with phase shift at the voltages of $\pi/6$.
- Application of high pulse number rectifiers.
- Limit the direct current curl of the rectifiers to the necessary instead of the possible.
- Move the network connection point to a position with the highest short-circuit power.
- Avoid the operation of components that generate harmonics in periods of low load.
- De-energize the transformers in a vacuum.
- Avoid stationary voltage elevations in the transformers.
- Limit the design power of components that generate harmonics.
- Avoid application of angle-of-fire control for high-powered appliances.
- Application of compensation equipment.

III. Characteristics of the Inrush Current

As described above, inrush current is a transient event that can generate the undue operation of the protection systems associated with the transformer (fuses and over-current relay), damaging the quality and reliability of the energy delivered to the consumer, generating effects such as [4], [8]:

- High heating in the windings causing insulation damage,
- Excessive production of mechanical stress due to induced magnetic forces,
- Temporary stresses in the SEP,
- Radio-interference with nearby communication lines,
- Surges due to harmonic resonance phenomena in systems with electric filters.

Fig. 1 schematically illustrates the relationship between the rated current (I_n) of the transformer and the inrush current (I_r) during energizing thereof.

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

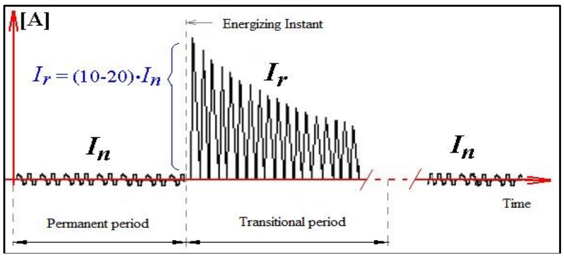

Fig. 1: Relationship between rated current (I_n) and inrush current (I_r)

The current peaks shown in Fig. 1 can reach values close to the short-circuit current of the transformer [2]. On the other hand, the intensity and duration of the inrush current depend on the following factors [3]:

- Instantaneous value of the voltage applied to the transformer at the energizing instant.
- Magnitude and direction of residual flux in the magnetic core.
- Series equivalent resistance and inductance of the feeder circuit.
- Resistance and dispersion inductance of the transformer primary winding.
- Magnetic and geometric characteristics of the core.
- Value of the pre-insertion resistance of the circuit breaker.
- Load impedance connected to the secondary.
- Closing speed of the circuit breaker contacts.
- Existence of tertiary winding connected in delta, in three-phase transformers.

IV. Energy Quality Problems Derived From Inrush Current

Keeping the point of energy quality in mind, the inrush current generally considered as a distorted wave that ends up in 2 main disturbances: imbalances and harmonics [9].

A. *Imbalances*

Current imbalances arising from asymmetric loads are generally not considered a failure or disturbance. Inrush current produce unbalanced currents during the energization of the transformer and this condition may be combined with 2nd harmonic value to find out what's happening throughout linking of the transformer to the electrical network [9].

B. *Harmonics*

The inrush currents contain all the harmonic components. But, 2nd and 3rd harmonics are only relevant to it. In addition to this, DC elements may be right smart throughout the first cycles depending on the residual flow. Some of the most significant harmonics are [9]:

- ***DC component/ Off-set:*** An DC current can always be found within the inrush current, with complete different values for every phase. The off-set value is a function of the residual flow.
- ***2ndharmonic:*** It is present in all phases of the inrush current. The value of 2nd harmonic is a function of degree of saturation of the transformer being the minimum value of this component about 20% of the value of the inrush current in most transformers.
- ***3rdharmonic:*** It can be found with the same magnitude of the 2nd harmonic and are produced by the saturation of the core.

V. Methodologies for Identifying Inrush Currents in Transformers

Inrush current in transformers are traditionally evaluated through Fourier analysis. Such approach offers relays protection immunity to inrush currents. However, in recent years, other methodologies have been proposed and some of them are presented below.

Most conventional transformer protection methods use 2nd harmonic retention. In this sense, different techniques like Discrete Fourier Transform, Artificial Neural Networks, Least Squares Method, Rectangular Transform, Walsh Functions and Haar Functions are currently preferred to identify and evaluate 2nd harmonic content present in the differential current [10-13]. But existence of 2nd harmonics components due to signals generated by internal faults in transformer winding is the main disadvantage of the above said approach. In addition to this, the new transformer cores, built with amorphous materials, generate small 2nd harmonic components when run inrush currents [1].

Recently, several differential protection algorithms were introduced using the Wavelet Transform for the treatment of non-stationary signals due to their capability to collect information from transient signals in both time and frequency domain [14 - 16]. In this way, there have works that propose the

IJDACR
ISSN: 2319-4863
International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

use of the S transform as a tool to discriminate the inrush currents [17].

Different from the traditional methods, in [8] a method based on the use of asymmetric windings is proposed. In this methodology the inrush currents were reduced based on the increase of the equivalent inductance, altering the quantitative relation between inner and outer layer of the winding. To calculate the winding distribution index the formula for the corresponding inductance and concatenated inductance are determined from structural parameters of the transformer.

VI. Proposed Methodology

A. Residual flow

The Residual Flow (ϕ_R) is very important during the energization of transformers. The value adopted by this parameter when the transformer is de-energized will determine the magnitude to be reached by the inrush current at the next energization. All ferromagnetic material, after being subjected to a magnetization, does not return to its original state after leaving the influence of the external magnetic field.

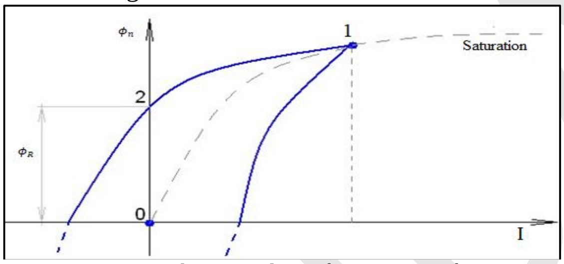

Fig. 2: Generic hysteresis loop of a power transformer

Fig. 2 shows the hysteresis loop of a generic core of a power transformer. The graph indicates that when transformer core is in saturation (increasing magnetizing current I until the flux reaches hysteresis loop point 1) the magnetic flux of the core (ϕ_n) will travel through path 1-2 when the external field is removed. The ordinate to the origin of point 2 (0-2) is called "residual magnetic flux" and its value has an important influence on the generation of the inrush current when the energization of the transformer occurs [2].

Considering a single-phase transformer and neglecting both the magnetic flux dispersed in the air and the resistance of the coils, we see that the flux ϕ_n is related to the voltage in the coil u_b through the law of electromagnetic induction (Faraday-Lenz law) defined by the following expression:

$$u_b(t) = N_b \frac{d\phi_n(t)}{dt} \qquad (1)$$

Where N_b is the number of turns of the coil.

When the transformer is de-energized and removed from the permanent state without load (steady state), the current in the primary winding is interrupted at a time called t_0 and the residual current ϕ_R is calculated as:

$$\phi_R = \frac{1}{N_b}\int^{t_0} u_b(t)\,.\,dt \qquad (2)$$

Where,

$$u_b(t) = U_0.\sin(\omega_0 t) \qquad (3)$$

Assuming now a permanent state, (2) is expressed as:

$$\phi_R = -\phi_0\cos(\omega_0 t_0) \qquad (4)$$

By neglecting the damping effects given by the losses in the core and by the resistance of the windings, and using (1) and (3), the magnetic flux in the first energizing period can be calculated analytically through the following equation:

$$\phi_n(t) = \frac{1}{N_b}\int_{t_f}^{t} u_b(t)\,.\,dt + \phi_R$$

$$\phi_n(t) = \underbrace{-\phi_0\cos(\omega_0 t)}_{\phi_P} + \underbrace{\phi_0\cos(\omega_0 t_e) + \phi_R}_{\phi_P} \qquad (5)$$

If a transformer is energized at a random time (t_e) it may occur that transient inrush currents appear or not. This occurs because, according to sample (5), the inrush currents do not only depend on the energizing instant t_e, but also on the residual flow ϕ_R set at the previous de-energization instant of the energization t_e, but also of the residual flow ϕ_R set in the instant of de-energization of damping present in the transformer, that flux decays to zero after a few seconds, and the permanent state magnetization current ϕ_P begins to flow [2].

B. Generation of the Inrush Current

As expressed in (5) the magnetic flux in the transformer core (ϕ_n) at time energization is composed of a permanent flow (ϕ_P) and transient flow (ϕ_T).

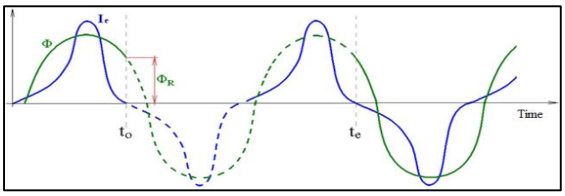

Fig. 3: Magnetizing current I_e when the energization occurs in a time where the voltage wave corresponds to the residual flux in the core

Fig. 3 illustrates the instant of de-energization and energization together with the behaviour of the flows within a transformer. In this figure, it is

IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

observed that if the transformer were energized at time t_e, in which the voltage waveform corresponds to the residual magnetic density inside the core(ϕ_R), there would be a uniform continuation in the current waveform of energization I_e from the de-energization in t_0, without occurrence of electromagnetic transients [2].

In practice, however, it is difficult to control the instant of energization (t_e), a fact which makes the occurrence of an electromagnetic transient unavoidable.

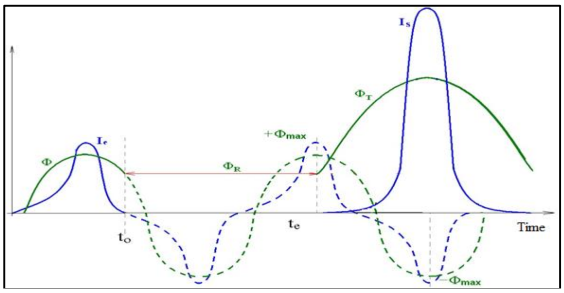

Fig. 4: Magnetizing current I_e when energization occurs at a time where the flux is at its maximum value

Fig. 4 shows the energization of a transformer at the instant the flow is at its maximum negative value ($-\phi_{max}$) and the residual flow has a positive value. In this situation, the magnetic flux will start at the value of the residual flow, following the curveϕ_t. The magnitude reached by the energizing current of the transformer, now called saturation current I_s [2], can be observed.

If we consider a linear saturation characteristic in the transformer, the curve ϕ_T will be a displaced sinusoidal function in which the value of ϕ_{max} is$\pm|\phi_{max}| + 2|\phi_{max}|$. This excess magnetic flux produces a very large magnetizing current value, as shown in Fig. 4.

The magnetic flux in each of the three phases of a three-phase transformer has a phase shift of 120°, that is, one phase will have a positive flow ϕ_R and the other a negative flow, or vice versa. As a consequence, the residual flux may be added to or subtracted from the total flux by increasing or reducing the magnetizing current [2].

The time in which the inrush current wave is present in the transformer depends on the time constant of the system, given by the following expression:

$$\tau = \frac{L}{R} \tag{6}$$

where R is the resistance and L is the equivalent inductance. In practice, the time constant does not represent characteristics of a constant since the parameter L changes with the saturation of the transformer core. During the first few seconds the saturation is high and L is low. Due to the losses in the core the saturation decays and L increases. In these cases the parameter R remains constant and represents the damping of the circuit. Faced with this, transformers near a generator will have a long-lasting magnetizing current due to the low resistance value due to the short distance between the transformer and the generator. In the same way, high-capacity transformers have a tendency to have long-term magnetization currents due to their high reluctance value in relation to system resistance [2].

C. Unsaturated Behaviour

The RL circuit, shown in Fig. 5, is used for the study of transient currents during the energization of the single-phase transformer through a nominal voltage source. The indicated nonlinear inductor has magnetization characteristics $i = f(\lambda)$ where λ is the bond flux in the primary. Initially the losses in the magnetic core are neglected [3].

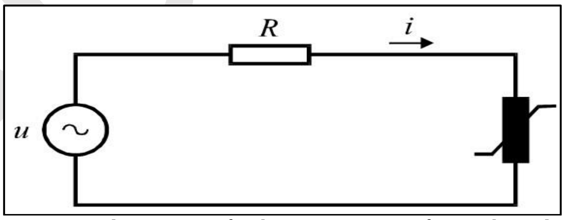

Fig. 5: Non-linear circuit for the representation of an uncharged transformer

After closing the power switch, we have:

$$\frac{d\lambda}{dt} + R.i = U_m.\sin \omega t \tag{7}$$

Since the relation $i = f(\lambda)$ is not linear, (7) can only be solved numerically. If we assume that the core does not reach saturation we can make $i = f(\lambda) = \lambda/L_m$, where L_m is the magnetization inductance of the transformer, which corresponds to the slope of the line of the saturation characteristic $\lambda - i$. In this way, (7) can be rewritten as [3]:

$$\frac{d\lambda}{dt} + \frac{R}{L_m}.\lambda = U_m.\sin \omega t \tag{8}$$

For simplicity, it is assumed that $\lambda(0) = 0$ so that (8) has as solution:

$$\lambda(t) = \frac{\omega L_m^2 U_m}{R^2 + (\omega L_m)^2} e^{-(R/L_m)t} + \frac{\omega L_m^2 U_m}{R^2 + (\omega L_m)^2}\left[\frac{R}{\omega L_m}\sin \omega t - \cos \omega t\right] \tag{9}$$

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

Considering $R << \omega L_m$ and making $\lambda_m = U_m/\omega$, it results:

$$\lambda(t) = \lambda_m\left[e^{-(R/L_m)t} - \cos\omega t\right] \quad (10)$$

We see that that equation (10) is composed of a term with exponential decay (related to the transient behaviour of λ after the application of voltage) and a cosine term related to the permanent regime.

A factor of fundamental importance in the degree of asymmetry of the flow wave is the voltage value of source at the moment of energization. From above analysis, we have $u = U_m \sin\omega t$ so that $u(0) = 0$. However, the most common energizing case occurs when $u(0) \neq 0$. In this sense, we can consider $u = U_m \sin(\omega t + \theta)$ which implies having $u(0) = U_m \sin(\theta)$ where θ is known as the "angle-of-fire" and determines the initial value of the voltage [3].

The flow wave in the core has a maximum value when $\omega t = k\pi (k = 1,3,5,\dots)$ and $\theta = 0$, cases where the voltage of the source is zero at the energizing instant. Thus, the maximum value of λ will be $\lambda + 2\lambda m$. On the other hand, there is no asymmetry in the waveform of λ for $\lambda_R = 0$ and $\theta = \pi/2$, where the voltage assumes the peak value U_m at $t = 0$. This is the most favorable condition since over-flows are avoided which can lead to the transformer saturation [3].

D. Saturated Behaviour

During the first energizing instants of a transformer, the high flux values reach the saturation region of the core hysteresis loop. Thus, for small variations of λ, very high variations of, shown in Fig. 6, may occur.

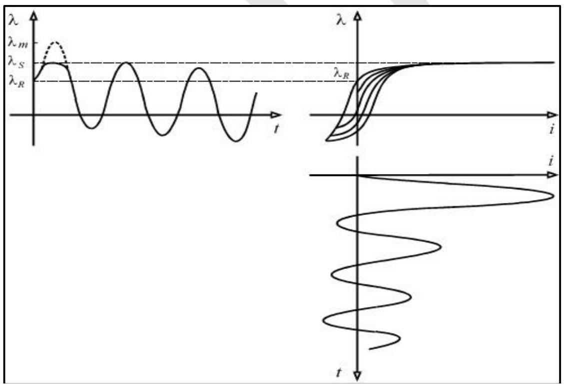

Fig. 6: Link flow and inrush current [3]

Since the excitation is asymmetrical, the path described in the plane $\lambda - i$ has smaller asymmetric loops. Since λ is limited by the saturation level (λ_s) the value λ_m is not reached. It is observed that, if the residual flux in the core presents the same signal of the flow imposed by the source, the saturation region can be reached more quickly resulting in a greater asymmetry of the flow wave and in higher values of current peaks Inrush. On the other hand, if the said flows have opposite signals, the inrush current will be attenuated. These currents can cause the quick operation protection relays to malfunction during the energization of the transformer. To prevent this from occurring, the differential relays use a criterion capable of distinguishing an inrush current from a short-circuit current. A typical inrush current has a harmonic composition where the second order harmonic predominates, which can represent more than 60% of the value of the fundamental component. Thus, when the transformer is energized under normal conditions, these harmonics are filtered, exerting a blocking action that avoids the operation of the relay. On the other hand, typical short-circuit currents are normally composed of a fundamental component summed from a continuous component with exponential decrement, with the harmonic content being negligible compared to those observed in the inrush current. In this way, the blocking action is not verified in the sense of preventing the operation of the relay [3].

VII. Fuzzy Logic

Fuzzy logic includes zero and one as extreme cases of truth (or "the state of matters" or "fact"). However, conjointly includes the assorted states of truth in between so, as an example, the results of a comparison between 2 things can be not "tall" or "short" but ".38 of tallness." Fuzzy logic appears nearer to the method our brains work. We have a tendency to aggregate knowledge and type variety of partial truths that we tend to aggregate additional into higher truths that successively, once certain thresholds are exceeded, causes certain additional results like motor reaction. An identical quite method is employed in artificial computer neural network and professional systems. In recent years, the quantity and sort of applications of fuzzy logic have multiplied considerably. The applications vary from client product like cameras, camcorders, washing machines, and microwave ovens to process management, medical instrumentation to decision-support systems. Fuzzy logic has totally 2 different meanings. In an exceedingly slim sense, fuzzy logic is an extension of multivalued logic. However, in an exceedingly wider sense fuzzy logic (FL) is a sort of synonymous with the idea of fuzzy sets, a theory that relates to categories of objects with un-sharp boundaries within which

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

membership may be a matter of degree. During this perspective, fuzzy logic in its slim sense may be a branch of itself. Even in its additional slim definition, fuzzy logic differs each in conception and substance from ancient multivalued logical systems.

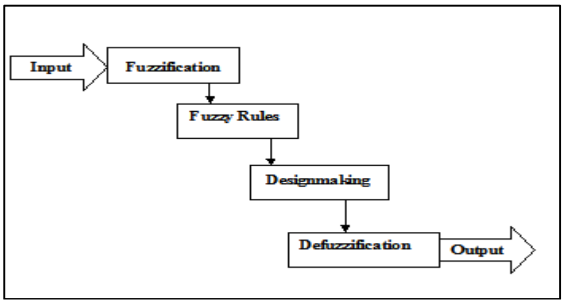

Fig. 7: Fuzzy Logic model flow chart

VIII. SIMULATION RESULTS & DISCUSSIONS

The performance of proposed algorithms has been studied by means of MATLAB simulation.

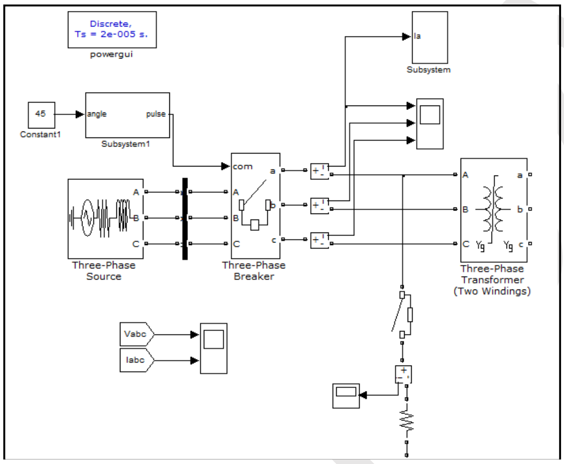

Fig. 8: Simulink model for Power Transformer Protection

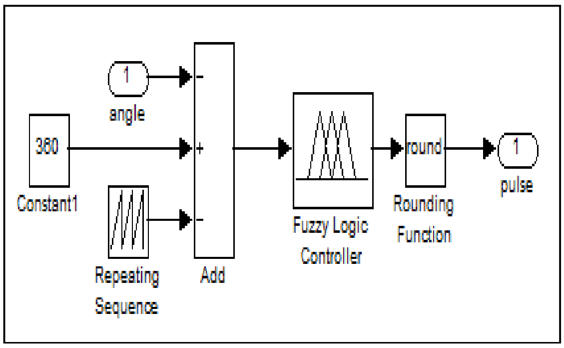

Fig. 9: Fuzzy control Block

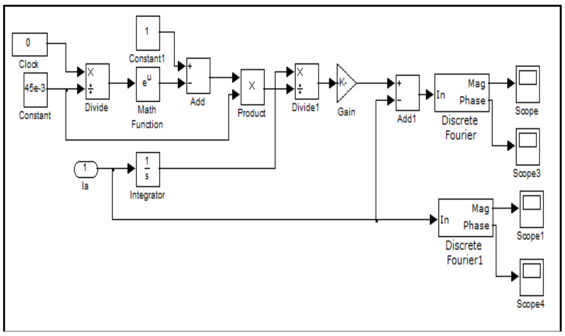

Fig. 10: Filters circuit

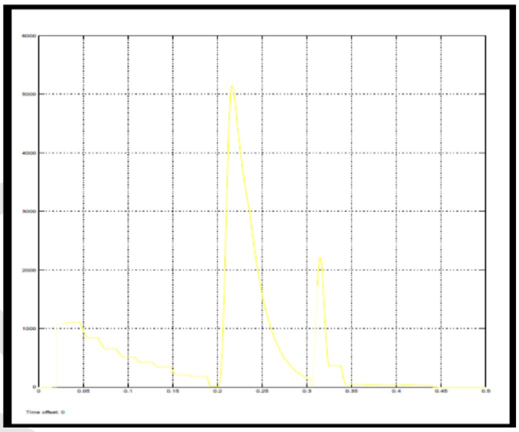

Fig. 11: Magnitude Current with DC elimination as Fuzzy with fault

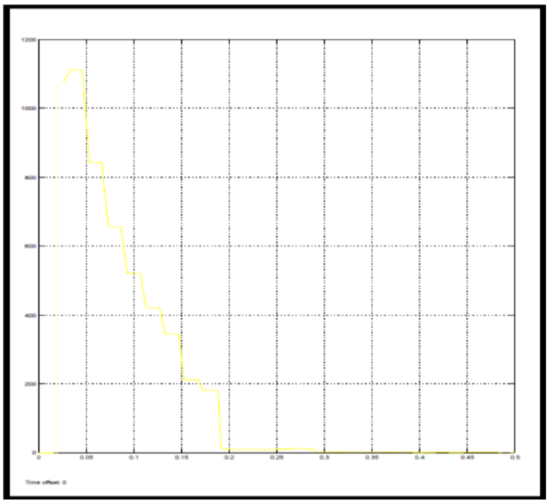

Fig. 12: Magnitude Current with DC elimination with Fuzzy without fault

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

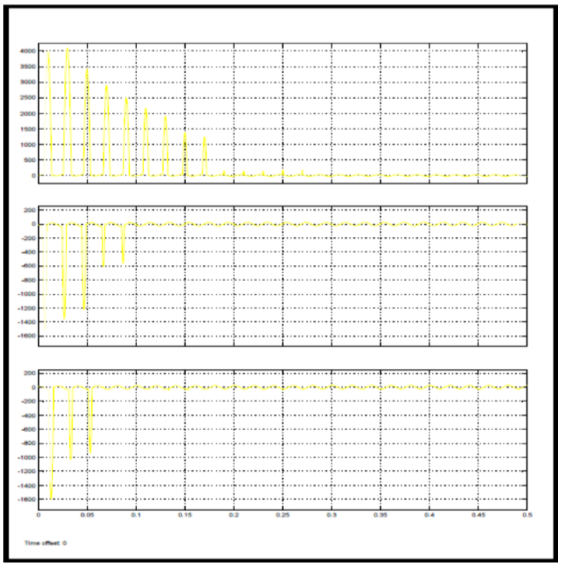

Fig. 13: Three phase current with DC elimination as Fuzzy without fault

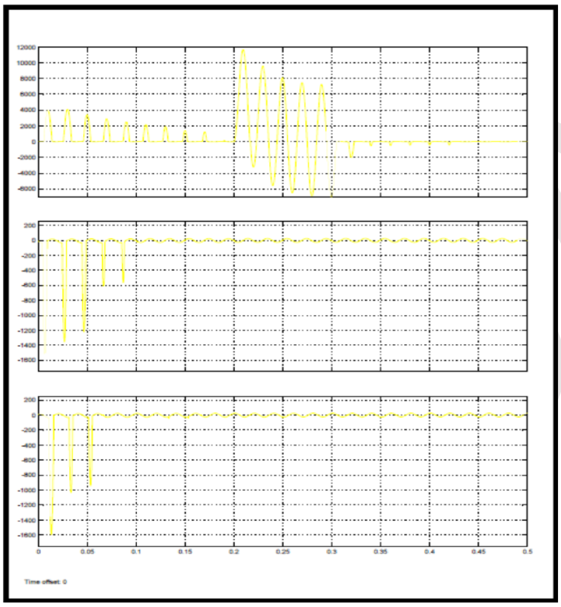

Fig. 14: Three phase current with DC elimination as Fuzzy with fault

Table 1: Results

S. No.	Angle of Energization (in degree)	Magnitude Intensity
1.	30	high
2.	45	high
3.	90	low

IX. CONCLUSION

The protection of power transformer is carried out using the MATLAB SIMULINK and FUZZY LOGIC. The results have been taken with faults and without faults. These results were taken using Fuzzy Logic. The magnitude current and the three phase current amplitude wave forms are taken using Fuzzy Logic with fault and without fault. The DC components that is largely responsible for errors and mal-operation of relay. Because when the inrush current is comes in transformer core then the relay is trip and system is disconnect. This is the false operation that is done by the relay. To improve this, Fuzzy system is used. In which a standard ratio is set if the Inrush current amplitude is cross that limit then the relay will trip otherwise system works continue. So the relay false operation is stopped. Inrush current is observed at various instant angles. In the result waveforms the Inrush current is shown at 30 degree and 45 degree. From these waveforms, clearly see that the inrush current amplitude going lower when the angle increased and the 90 degree the peak value of the inrush current is lower than others.

ACKNOWLEDGMENT

The authors would like to thank I.K.G. Punjab Technical University, Kapurthala and M. R. S. Punjab Technical University, Bathinda for providing their facilities and valuable assistance to complete this research work.

REFERENCE

[1] C. Akuner, and O. Ozgonenel, "A study on magnetizing Inrush current of different core materials," Ondokuz Mayis University, Electrical & Electronic Engineering Faculty, Kurupelit, Samsun, Tukey, Pp.1-4.

[2] M.O Oliveira, R.H. Salim, and A.S. Bretas, "Differential protection of three-phase transformers using wavelet transforms," in IEEE/PES Transmission and Distribution Conference and Exposition, Latin America, August 2008, pp. 1-6.

[3] C. Carrander, "Magnetizing Currents in Power Transformers: Measurements, Simulations, and Diagnostic Methods," Ph.D. dissertation, Electrical Engineering Department, KTH Royal Institute of Technology, Stockholm, Sweden, 2017.

[4] S.J. Asghar, "Elimination of inrush current of transformers and distribution lines," in Proc. of IEEE int. conf. on Power Electronics, Drives and Energy Systems for Industrial Growth, vol. 2, January 1996, pp. 976-980.

[5] L.C. Wu, C. W. Liu, S. E. Chien and C. S. Chen, "The effect of inrush current on transformer protection," in 38th IEEE North American Power Symposium (NAPS), pp. 449-456, September 2006.

[6] J.G. Webster, "Electrical Measurement, Signal Processing, and Displays," CRC Press, London, New York, Washington, 2003.

[7] J. Arrillaga and N.R. Watson, "Power System Harmonics," 2nd ed., chapter 2nd, John Wiley & Sons, United States, October 2004.

[8] C.K. Cheng, S. D. Chen, J. F. Chen, T. J. Liang and W. H. Yang, "Transformer design for reducing the inrush current by asymmetrical winding," Journal of the Chinese Institute of Engineers, vol. 28, issue 5, pp.811-818, 2005.

[9] M. Mañana, L.I. Eguíluz, A. Ortiz, G. Díez, C. J. Renedo and S. Pérez, "Effects of magnetizing inrush current on power quality and distributed generation, "in 9th Spanish Portuguese Congress on Electrical Engineering (9CHLIE), Marbella, July 2005.

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 7, Issue 02, September 2018)

[10] H. Wang and K. L. Butler, "Finite element analysis of internal winding faults in distribution transformers, "IEEE trans. power del., vol. 16, issue 3, pp.422-428, 2005.

[11] W. Thomas and O. Ozgönenel, "Diagnostic of transformer internal faults through ANN based on radial basis functions and dynamical principal component analysis," IET Generation, Transmission & Distribution, pp.1-11, 2007.

[12] D. Barbosa, U.C. Netto, D.V. Coury and M. Oleskovicz, "Power transformer differential protection based on clarke's transform and fuzzy systems," IEEE trans. power del., vol. 26, issue 2, pp.1212-1220, 2011.

[13] S.K. Nanda, "Application of neural network for transformer protection," M.Tech Thesis, Department of Electrical Engineering, National Institute of Rourkela, Rourkela, Odisha, 2013.

[14] M.O. Oliveira and A.S. Bretas, "Application of discrete wavelet transform for differential protection of power transformers," in IEEE Power Tech Bucharest, pp. 1-8, June 2009.

[15] K. Ramesh and M. Sushama, "Power transformer protection using wavelet packet transform," in IEEE Int. Conf. on Computer Communication and Informatics (ICCCI), pp. 1-7, 2014.

[16] S. Kumar and V. Sreeram, "Elimination of DC component and identification of inrush current using harmonic analysis for power transformer protection," in IEEE TENCON Spring Conference, Sydney, NSW, Australia, pp. 151-155, April 2013.

[17] A.M. Shah, B.R. Bhalja and R.M. Patel, "Power transformer differential protection using S-transform and support vector machine," in IEEE National Conference on Power Systems (NPSC), Bhubaneswar, India, Pp. 1-6, December 2016.

BIOGRAPHY

Er Lakhvinder Singh was born in Bathinda (Punjab), India in 1987. He obtained his Diploma in Electrical Engineering in 2008, B. Tech in Electrical Engineering in 2011 & M. Tech in 2014 respectively. He is presently working in electrical engineering department of Giani Zail Singh Campus College of Engineering & Technology at Bathinda (Affiliated to Maharaja Ranjit Singh Punjab Technical University, Bathinda). His research interests are energy management, transformer protection, Fuzzy logic. He may be contacted at preetbrar721@gmail.com

Er Preeti Khurana was born in Ludhiana (Punjab), India. She obtained her B.Tech and M.Tech in Electrical Engineering from Guru Nanak Dev Engineering College, Ludhiana in 2003 and 2010 respectively. She is presently working as Assistant Professor in Department of Electrical and Electronics Engineering of Lovely Professional University, Jalandhar. Her research interests are Condition monitoring of three phase Induction Motor, Fuzzy logic, Neuro Fuzzy Logic, Transformer protection and Electrical Machines. She may be contacted at preeti.khurana@lpu.co.in