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TRANSFORMERS FAULT DETECTION USING WAVELET TRANSFORM

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Abstract- In order to analyze a signal, wavelet transform can be applied as well as Fourier transform. Fourier transform and its inverse can transform a signal between the time and frequency domains. Therefore, it is possible to view the signal characteristics either in time or frequency domain, but not the combination of both domains. Differently from the case of Fourier transform, the Wavelet Analysis (WT) provides a varying time-frequency resolution in the time frequency plane. In this paper, a new method for protecting power transformers based on the energy of differential-current signals is introduced. The simulation results show that it is possible to detect different kinds of internal faults using this method. Furthermore, it is possible to distinguish such faults from magnetizing inrush current.

Keywords: Transformer, Fault Detection, Wavelet Transform, Fault Monitoring.

I. INTRODUCTION

A broad spectrum of electric machines is widely used in electromechanical systems. A protective algorithm is comprised of a number of mathematical equations which are set on a microprocessor in order to provide frequency, phasors of voltage and current and other related quantities to them. Over the last 30 years, different protective algorithms for digital protection of power systems have been tendered and as a general classification, algorithms based on sinusoidal waveforms, Fourier transform and Walsh transform, least square errors, differential equations solution and algorithms based on traveling waves could be mentioned [1].

The first digital relay for protecting against errors introduced in 1970 [2]. Then Mann and Morrison introduced a computer-based protective model that was able to transmit information [3, 4]. In 1980, digitalized relays superseded the traditional electromechanical and semiconductor relays. Some algorithms such as Walsh functions, Discrete Fourier Transform (DFT), least square method, Harr functions, Kalman filter and etc were applied to such relays [5]. Morrison, Sykes used two recurrent filters in order to extract the first and second harmonics from sampled differential current [6]. This method was applicable to single-phase transformers but could not be applied to three-phase transformers. This method has been tested off-line. Malik used a developed algorithm, crossover correlation, which is very similar to discrete Fourier transform to detect error and inrush current. In this algorithm even and odd functions of all existing harmonics in differential current are calculated.

To reduce the response time of such relays, even and odd pulse functions were applied instead of sinusoid functions. This method reduces the response time meanwhile it reduces the accuracy of the algorithm. Sheweitzer used Finite Impulse Response variables (FIR) to extract the first and second harmonics of sampled differential current [8]. This algorithm was tested off-line over magnetizing inrush current and transformers error current. The number of samples was eight per cycle.
Larson implemented the FIR algorithm for protection of a 500VA power transformer using 14C6800 microprocessor. The relay discriminated the error between 1.25 to 1.5 cycles [9]. Degens used least square curve fitting in order to determine the ratio of the second harmonic to the first one in differential current for detecting inrush current. In this method, it is assumed that there are only five harmonics in inrush current.

The threshold of 12.5% over the ratio of the second harmonic to the first one was determined for detection of error and inrush currents. Then Degenes designed a digital relay using the same algorithm and microprocessors [11]. Rahman used weighted least square technique for protection of power transformers. This algorithm requires that many cases about error and inrush currents in order to obtain the optimum weighted-coefficients be studied [12]. In the research, Fourier analysis, rectangular transform, Walsh function, Finite Impulse Response, Harr functions and least square curve fitting were studied and then compared. They confirm that DFT is the best and most efficient method for computerized differential protection of power transformers [15].

Using harmonic deterrents for prevention of unwanted trip command in the case of inrush and over stimulated currents to protect power transformers differentially are excessively being used. However applying loss less materials in the core of power transformers causes the second harmonic of inrush currents to be reduced [16].

Hence, using modern technology in relays has become prevalent. Gangopadyoy modeled inrush current using computer software. The simulated data approached real amounts very much [17].

Rahman and Zaman suggested a method based on two-layer artificial neural networks and assembled it on DS-1102 digital signal process chip. ANN algorithm was examined on an experimental transformer. The response time in this method was between 1.2 and 3.4 cycles [18]. But another technique that has been recently noted very much is wavelet analysis. A number of papers about differential protection using wavelet transform have been reported [23]. Youssef proposed a wavelet transform with a quadrature accuracy or resolution for discriminating fault and inrush currents. The results show that the response time of relay and its accuracy are high. All of these techniques were examined off-line [25]. In [28] a simple wavelet-based scheme is developed to identify inrush current and to distinguish it from internal faults. The novelty of proposed algorithm is that it does not require any threshold value of differential current; hence it is independent of transformer rating.

The proposed method in [28] is processes the samples corresponding to only one cycle thereby reducing the computational time. A custom-built single-phase transformer was used in the laboratory to collect the data from controlled experiments. In these controlled experiments, a great variety of different fault scenarios on both primary and secondary windings of transformer were intentionally introduced. A schematic algorithm is developed for achieving the objective. The objective of [29] is to design new software to simulate an improvement approach of digital differential relay operation. This software will improve and enhance the sensitivity of operation of the digital differential relays that protects power transformers by the discrimination between inrush current and fault current without blocking the relay during energization of power transformers, as well as avoiding tripping during operation of tap changer.

In this paper a new pattern is presented for protection of power transformers based on the energy of differential current signal. The results show that using this approach can help detect all internal faults. Likewise, it is possible to discriminate such faults from magnetic inrush current. In this paper, wavelet transform has been applied to find faults of a transformer. First, the factors creating fault in a transformer are introduced and modeled and then wavelet transform is explained briefly. Afterwards a real power system is modeled and finally the proposed method is applied to the expected system and the results are evaluated.

II. MAGNETIZING INRUSH CURRENT

After disconnecting a transformer from its source, some magnetizing flux is remained in the core while re-electrifying the transformer and connecting to the network, an initial surge of current is created in the primary winding. This current resumes until DC component of magnetizing flux is completely removed. Such a condition is given in Figure 1.

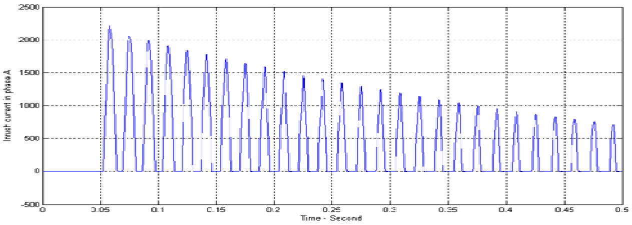

Figure 1. Inrush current while a transformer is loaded

After cutting out the transformer from the source, some magnetizing flux still remains in the core. After electrifying the transformer and connecting the network, the initial surge of current that occurs when voltage is first applied to the primary winding of transformer with no load connected, is called magnetizing inrush current. Due to the existence of a small resistor and big distance of transformer windings, a transient current appears in the primary winding which can be multifold of transformer rated current so that it can be equal to the current of transformer windings in short circuit status [27].

A. The Effects of Inrush Current

Totally the effects of inrush current on transformer are as the following:

1- Emerging hyper electromechanical forces between windings and their dependent components.

2- Unequal distribution of voltage between different parts of windings and their loops.

3- Appearance of over current in windings.

B. Study of Saturation and Hysteresis in Transformers

When an outer electromagnetic field is applied to a ferromagnetic material, the walls of those domains having moments aligned with the applied field move in such a way as to make volumes of those domains grow at the expense of other domains as a result, magnetic flux density is increased. But when an applied field becomes stronger, domain-wall movements are no longer reversible, and domain rotation toward the direction of the applied field also occurs.

This phenomenon of magnetization lagging behind the field producing it is called hysteresis. As the applied field becomes even much stronger in Figure 2, domain-wall motion and domain rotation will cause essentially a total alignment of the microscopic magnetic moments with the applied field, at which point the material is said to have reached saturation [22].

Core modeling [23]: To initiate studying transients, first the magnetic core of a transformer must be modeled. A lot of models for modeling the non-linear function relating core flux to excitation current have been presented. One of these methods relates the flux $\varphi(t)$ and magnetizing current $i(t)$ by inverse target.

$$\varphi = a\tan^{-1}(\frac{i}{c}) + abi \tag{1}$$

C. Efficient Factors in Magnetizing Inrush Current [16-19]

To simulate magnetizing inrush current a 500kv/230kv three-phase transformer is used as Figure 3. The primary and secondary windings are shown as Y_g / Y_g. As mentioned before, inrush current appears in primary winding. The simulated power grid is shown in Figure 4. The inrush currents of phase A, B and C are shown in Figure 5. These currents in three phases are not equal and their amount is determined by fluxes.

The amount of distortion is dependent on the density of magnetic flux in transformer. Also the magnitude of inrush current in transformer is affiliated by switching conditions, the structure of transformer and its place in power system. Since the electrical resistance of a transformer is very small, power transformers have a big constant which increases damping time. As the size of a transformer becomes larger, the inductance becomes larger compared to the electrical resistance of the primary circuit and hence time constant grows.

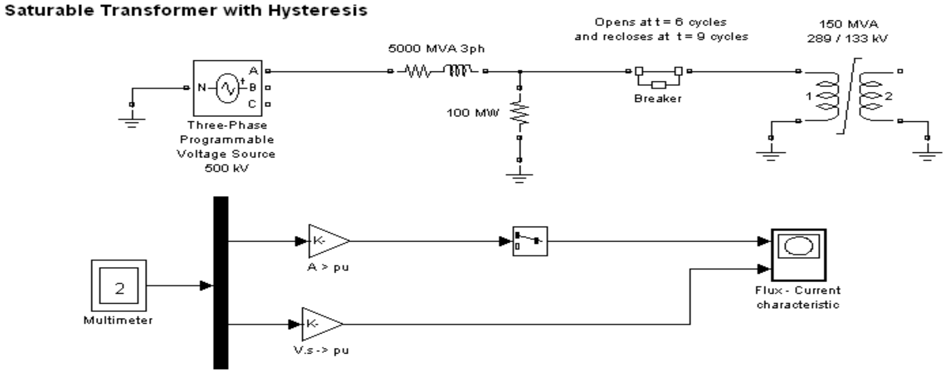

Figure 2. Simulated circuit for displaying hysteresis current

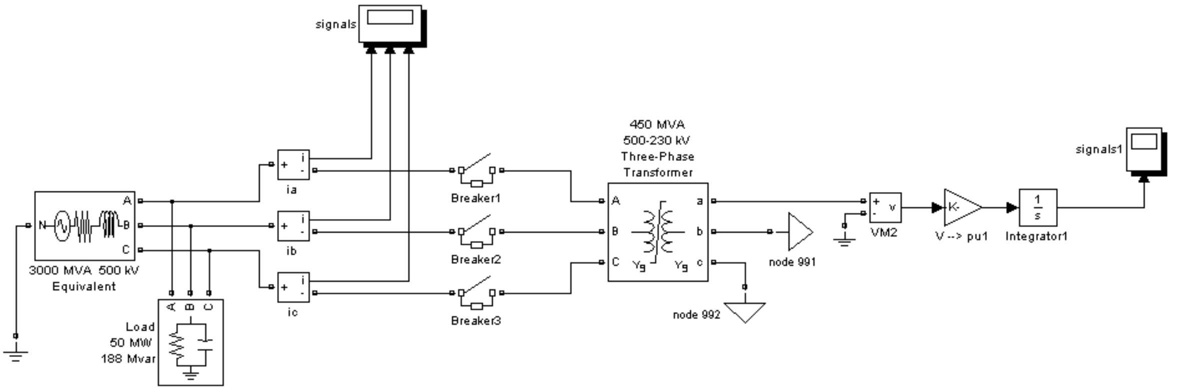

Figure 3. Simulation circuit for creating magnetizing inrush current in transformer

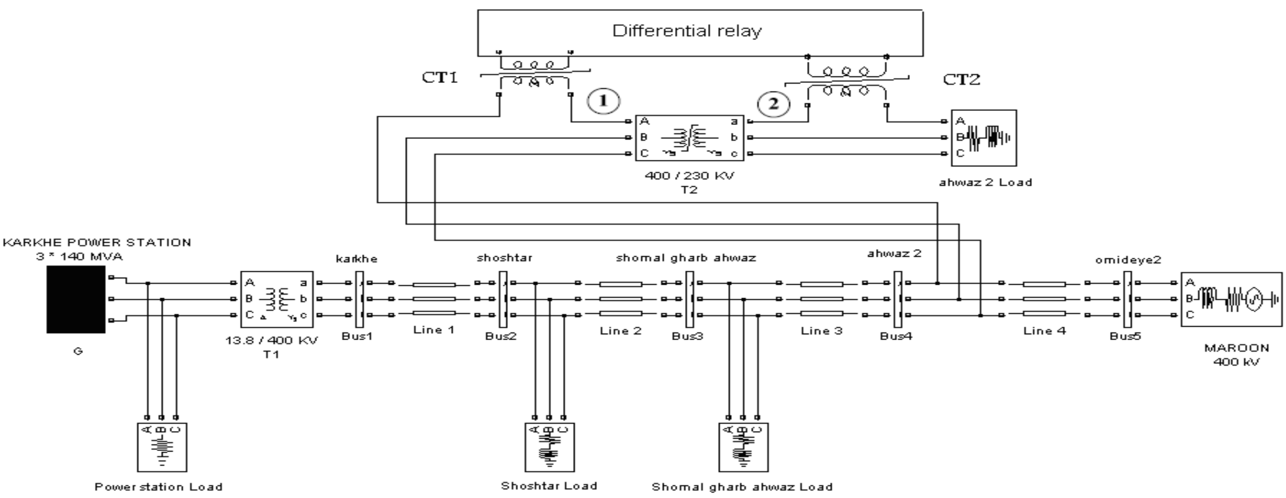

Figure 4. Simulated power grid

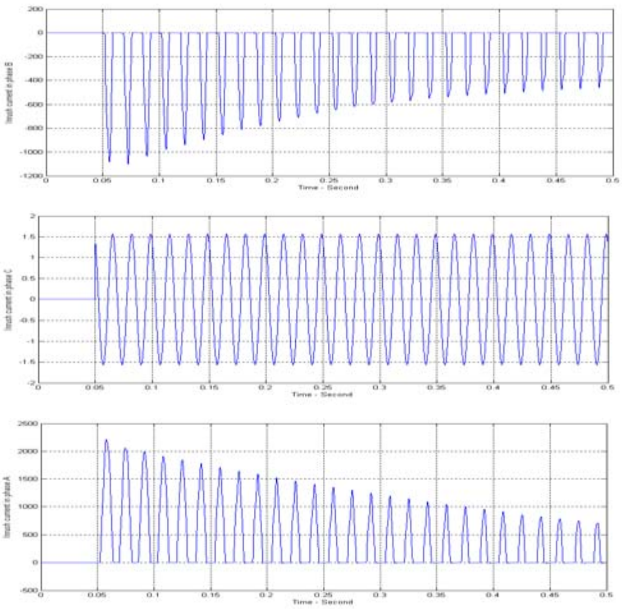

Figure 5. Inrush currents of phase A, B and C

D. Comparison between Inrush and False Currents [20]

Almost all harmonics exist in inrush current and the amount of these harmonics is dependent upon many factors such as magnetic flux, core residual and switching time in transformer. Generally harmonics are generated in transformers due to magnetizing inrush current, over excitation of transformers or saturation of current transformers.

As long as current waveform is symmetric with respect to horizontal axis, there will be only odd harmonics. Thus, there will be odd harmonics in both fault and inrush currents and the currents encompass the 3rd, 5th, 7th and etc harmonics. Because of the existence of dc component in magnetizing inrush current, they cannot be symmetrical anymore and they contain even harmonics as well as odd ones.

E. Statistical Study of Fault Diagnosis in Distribution Transformers

A transformer is the main part of a transmission grid, therefore for providing reliability of a network, high cost of transformer and existential importance of it, recognizing influential factors in damaged transformers and giving some solutions to protect transformers seem mandatory [21].

1- Studying damaged transformers according to causes of failure from the point of operation, the causes of failure in transformers can be summarized as the flowchart in Figure 6.

2- Faults in transformers

The faults that threaten transformers can be categorized into six main groups [22-27]. Fault in winding, fault in tap changers, fault in bushing, fault in transformer terminals, fault in core and other faults. Also the percentage of the occurrence of abovementioned faults is given in Table 1.

Table 1. Construction cost of 230 kV

Fault type	1955-1965	1975-1981
fault in winding	51%	51%
fault in tap changers	19%	19%
fault in bushing	15%	9%
fault in transformer terminals	7%	5%
fault in core	3%	2%
other faults	5%	13%

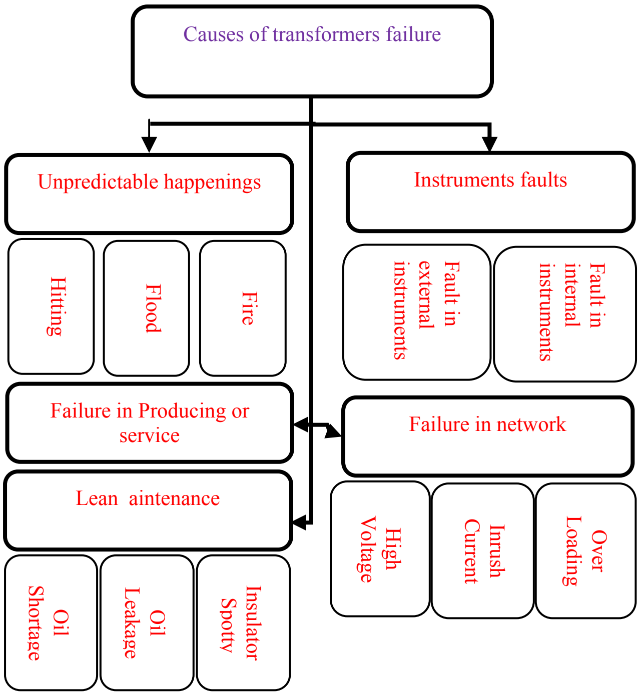

Figure 6. Flowchart of failure in transformers

III. POWER SYSTEM SIMULATION AND DATA EXTRACTION

For simulating a power system from generation up to transformer Matlab software is used. The features of production grid, transmission grid and related tables to them are fully explained. As the proposed pattern is trained based on input-output data, the relay can be placed on each phase and there is no need for a particular design to extend the algorithm to three-phase transformers. Also this algorithm can be applied to any three-phase transformers and any connection.

A. Simulation of a Power Network

The data for simulation has been extracted from one line diagrams of the network available in Iran Grid Management Company. The features of transmission and generation are depicted in Tables 2 to 6. In this simulation, different states of residual flux can be selected for any types of transformers. In order to study inrush currents precisely and completely, it is necessary to consider different angles of input voltage source waveform.

B. Simulation of a Power Network

The simulation of a model power grid is given in Figure 4. The data for simulation has been extracted from one line diagrams of the network available in Iran Grid

Management Company. The features of transmission and generation are depicted in Tables 2 to 6. In this simulation, different states of residual flux can be selected for any types of transformers. In order to study inrush currents precisely and completely, it is necessary to consider different angles of input voltage source waveform.

Table 2. The features Karkhe dam generators

G1-3 (ELIN)
Type: SSV 870/40-218
Rated Voltage: 13.8 KV
Rated Speed: 150 rpm
Rated Power
140 MVA (Max: 160 MVA)
133 MW (*pf* = 0.95)
125 MVAR at 80
P = 40

Table 3. Transmission line features

	Line 1	Line 2	Line 3	Line 4
$R^{+}(\Omega/\text{km})$	0.0313	0.240	0.0256	0.0256
$R^{0}(\Omega/\text{km})$	0.3513	0.3560	0.3520	0.3520
L^{+} (H/km)	0.952e-3	0.001	0.998e-3	0.998e-3
C^{+} (F/km)	3.311e-3	0.003	0.0029	0.0029
C^{0} (F/km)	11.893e-9	11.43e-9	11.35e-9	11.35e-9
distance (km)	92	81	25	25

Table 4. Transmission line features

Transformer	Primary Voltage (KV)	Secondary Voltage (KV)	Primary Winding	Secondary Winding	Nominal Power (MVA)	Z pu (%)
T1	13.8	400	Δ	star	160	14
T2	400	230	Y	star	200	5.4

Table 5. Load features

Load	Active power (MW)	Reactive power (MVAR)
Power Station Load	20	-
Shoushtar Load	240	100
North West Ahwaz Load	180	100
Ahwaz-2 Load	240	100

Table 6. Current transformer features

Converting ratio	1-2000-1500-1000-500	1-1200-600-300-150
Class	5P20	0.5FS5
Voltage	400 KVA	230 KVA
Max Burden	50 VA	30 VA
Current Trans	CT1	CT2

C. Preprocessing of Training Pattern

Some preprocessing is accomplished over the obtained data from simulations before applying them to Fuzzy-Neural network for training, this preprocessing includes passing the difference of the currents of CTS from anti-aliasing filter and sampling with the sampling frequency of 12.8 kHz (256 samples per cycle) is done and the cut-off frequency of this low pass filter is 6 kHz. Fourier analysis (STFT) is used for extracting harmonics.

D. Low Pass Filter

Low pass filters are used whenever it is important to limit the high frequency context of a signal. Low pass filters eliminate unwanted frequencies before sampling. According to sampling theorem, the frequencies higher than Nyquist frequency (half the sampling frequency) must be attenuated otherwise they cause error and fault. In order to prevent equi-potential effect, after conversion of primary and secondary current to per unit forms, a low pass filter named anti-aliasing filter is applied. Sampling frequency is 12.8 kHz (256 samples per cycle) and anti-aliasing filter is quadratic in cut-off frequency of 6 kHz.

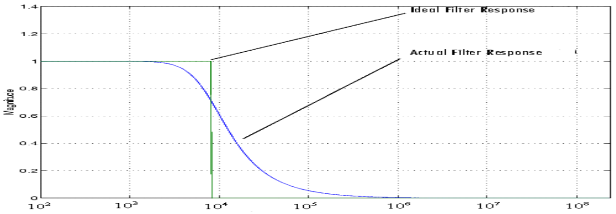

Figure 7. Frequency response of anti-aliasing filter

E. Harmonic Extraction

In recent studies, Fourier analysis has been used to demonstrate inrush current of transformers from one period to another. The signal is converted to a window in each period and is analyzed for the fundamental frequency component and then the peak values are depicted as a function of the number of cycles (or it is plotted in relation to time). In the Fourier transformer it is supposed that the signal *f*(*x*) is periodic while the inrush current is non-periodic. Currently, there are two methods to protect transformers. The first method is General Electric and the second one is Westinghouse. In General Electric method, all harmonics are used as deterrents of relay operations whereas in Westinghouse method only the second harmonic is applied. In both methods an electrical circuit is used which filters the harmonics. In General Electric method the sum of all harmonics is used and in Westinghouse method the second after amplification is used to excite a relay that blocks the main relay [31].

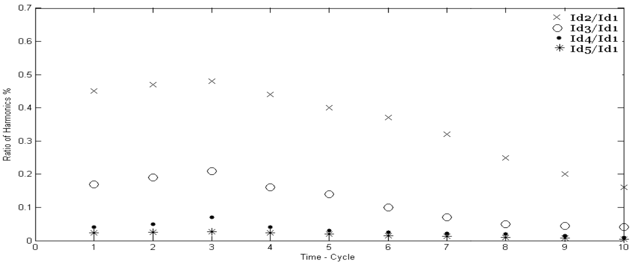

Figure 8. The ratio of the amplitude of harmonics to the main amplitude of inrush current in a transformer in 10 cycles

An example of Fourier analysis of inrush current from one period to another is shown in Figure 8. Therefore if a local transient exists in a small period of signal, its related frequency will exist in Fourier transform but the position of such a transient cannot be shown by Fourier transform. To overcome such a dilemma, for obtaining harmonics, short time Fourier transformation is used.

Short Time Fourier Transform (STFT): In Fourier transform there is not any problem related to resolution because the existing frequencies are exactly known; similarly because the value of signal is specified any time, there is not any problem concerning time resolution. Adversely, the STFT time and frequency resolutions cannot be optimal at the same time and a trade-off should be found between them, so temporal resolution in FT and frequency resolution in time domain are equal to zero, because there is no useful data pertaining to them. The window function of STFT has a limited narrow length, now if we consider the length of the window to be infinite, time information is lost and indeed STFT is replaced by FT. Moreover, the window must be considered too small to be constant in this range. The narrower the window is the better temporal resolution is obtained. In this research, the length of the window is considered only in one cycle.

IV. THE PROPOSED ALGORITHM

The common way to recognize inrush current from fault current is using the second harmonic. Nevertheless, in power transformers with a high capacitance, internal fault of transformers can include even harmonics. Furthermore, in modern and huge transformers, the amount of the second harmonic in magnetizing inrush current of one or two phases can be relatively small [29].

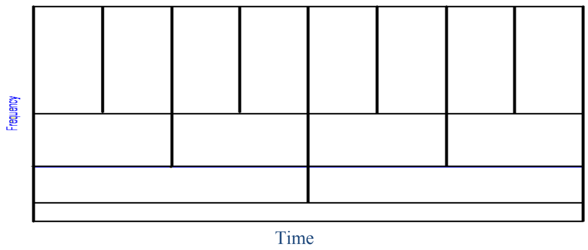

Figure 9. The relation between time-frequency in wavelet transform

For analyzing a signal, wavelet function can be used as well as Fourier transform. The Fourier transform of transformer currents shows frequency characteristics without expressing their location in time domain, whereas wavelet analysis shows both frequency and time characteristics. Therefore wavelet function method is ideal for studying transient signals.

A. Signal Energy

Like Fourier transform, using Parsval’s theorem, signal energy can be defined for wavelet transform as the following formula:

$$f(x) = a_0 + \sum_m \sum_n a_{2^m+n} \psi(2^m x - n) \qquad (2)$$

The function above represents signal energy in time-frequency domains. In time-frequency mapping, each level is divided into 2l quadrilateral. The total energy of a signal is the surrounded area of these levels (Figure 9). The time-frequency mapping is divided to rectangular which has a particular weight. Zero level (DC level) and level one are rectangular that are shown with the weights a_0^2 and a_1^2, respectively. Level 2 is divided into two segments and one of them weighs $0.5a_2^2$ and the other one $0.5a_3^2$. Thus each level is divided into $2'$. Total energy is the surrounded area in this level.

Figures 10 and 11 show the signal energy for fault and inrush currents. These figures show that the energy of inrush current is more focused in lower levels i.e. DC components. The reason is pertaining to the existence of DC component and bigness of the second harmonic in inrush current. If the number of samples in each window is $2n$ samples, the ratio of energy in each level can be obtained in Percentage.

$$Energy\ Level\ (k) = \frac{\sum_{j=2^{k-1}}^{2^k-1} a_j^2}{\sum_{i=0}^{2^n-1} a_i^2} \qquad (3)$$

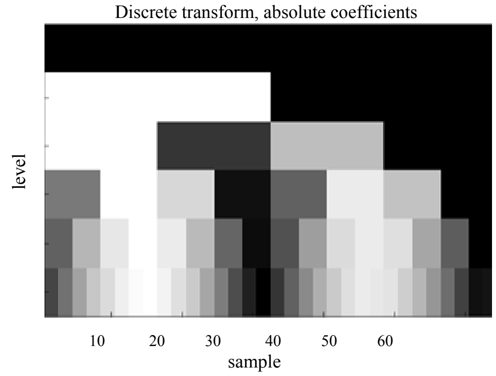

Figure 10. Time-frequency mapping of signal energy of fault current

As it was explained, mother wavelet function is represented by $\psi(x)$ and consists of breaking up a signal into shifted and scaled version of the original wavelet. Mother wavelet is calculated by using scaling function. Therefore signal energy can be obtained by squaring and summing the function in each side.

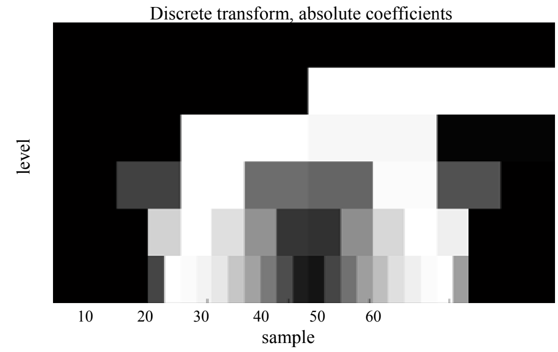

Figure 11. Time -frequency mapping of signal energy of inrush current

B. Designing a Protection Algorithm

The model in Figure 4 is used for simulating the power grid model once more. Some preprocessing contains passing the difference of CT currents from an anti-aliasing filter and then sampling at a frequency of 3.2 kHz (64 samples per cycle) and the cut- off frequency of anti aliasing frequency is 0.6 kHz and its relocation in each turn is half of a cycle. If the sampling frequency is f, then the first level contains the frequencies from $\frac{f}{4}$ to $\frac{f}{2}$ totally, the nt$\frac{f}{2^{n+1}}$h level of wavelet transform encompasses frequencies from $\frac{f}{2^{n+1}}$ up to $\frac{f}{2^{n}}$.

As the sampling frequency is 3200 Hz and the number of samples is 64 (the size of each window is equal to one cycle), each signal can be decomposed to six levels and a DC level. The proposed algorithm diagram of fault detection for protecting power differential transformer is shown in Figure 12.

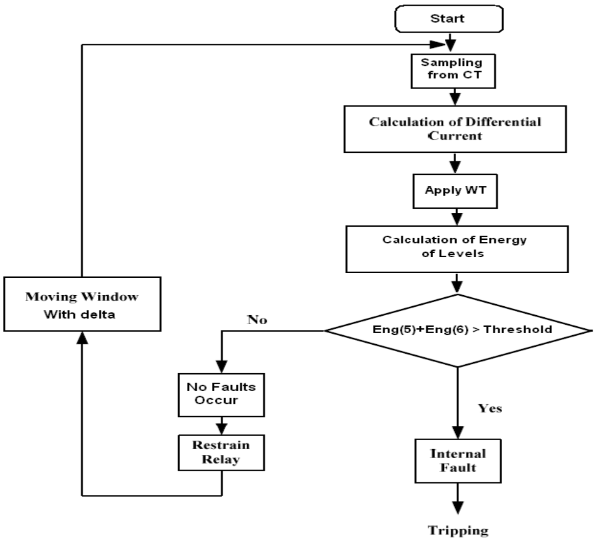

Figure 12. The flow chart of the proposed algorithm

In this algorithm, the threshold is chosen 50% .The information window has 64 samples that is relocated up to 32 samples each time. Regarding the simulations that have been done, the response rate of this method is after the half cycle. The proposed algorithm is applied to each phase goes down, all the circuits get tripped. Meanwhile wavelet function with Haar mother wavelet is used.

C. The Simulation Results

In order to examine the performance of fault detection algorithm similar to ANFIS approach, the cases of on-load inrush currents for the faults of one phase to ground, two-phase, two phases to ground, three-phase and three phases to ground in both ends of a transformer, as well as switching in different angles and different residuals of transformer have been studied.

The Figures 13 and 14 are comprised of three parts, part one is related to differential current which is diagnosed as noise in relays. Part two is the sum of 5th and 6th energy levels and part three is the response of relay according to proposed algorithm. In the figure above, switching occurs at $t = 0.15\sec$ in which the transformer is loaded. In this situation, the response after a cycle is converged to a favorite response.

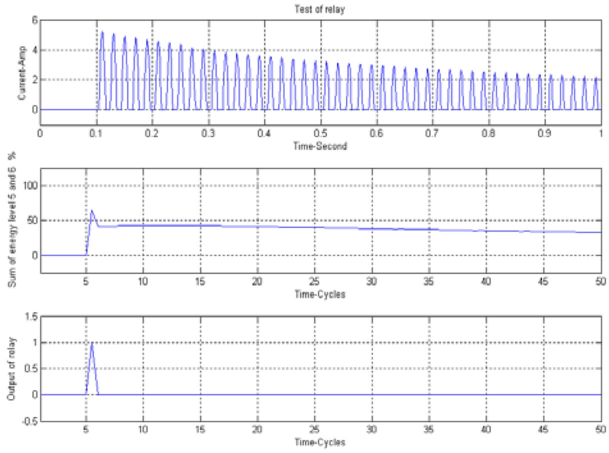

Figure 13. Differential current of phase A and the output of differential relay for inrush and on-load current with fire angle of 0 degree

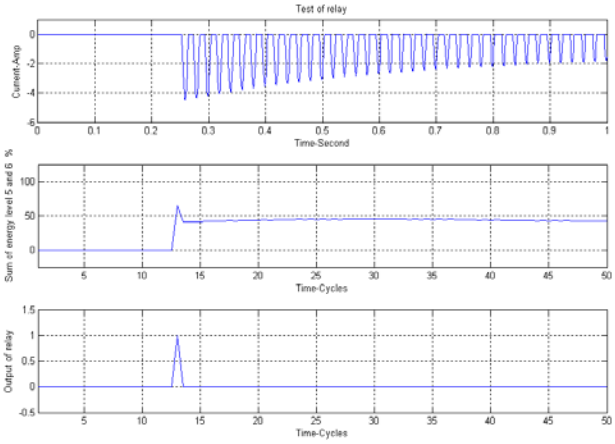

Figure 14. Differential current of phase A and the output of relay for differential and no-load current with fire angle of 30 degree

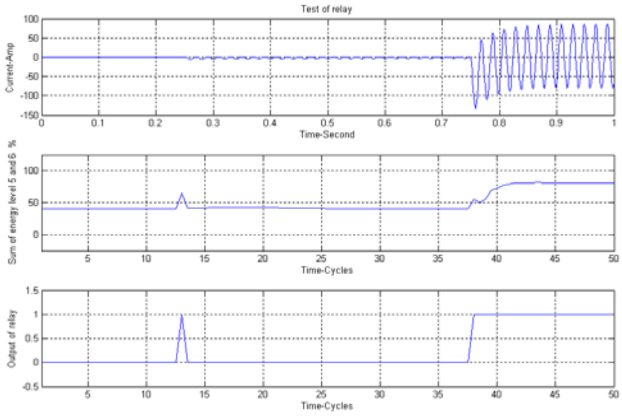

Figure 15. Differential current of phase A and the output of differential relay for the simultaneous accordance of inrush current and AB fault at t=0.75s in primary side with fire angle 0 degree

Figure 15 refers to simultaneous occurrence of inrush current and phase to phase fault. In this case, the response rate is half cycle. Here some other cases of simulations are mentioned. The response rate of this method is very appropriate.

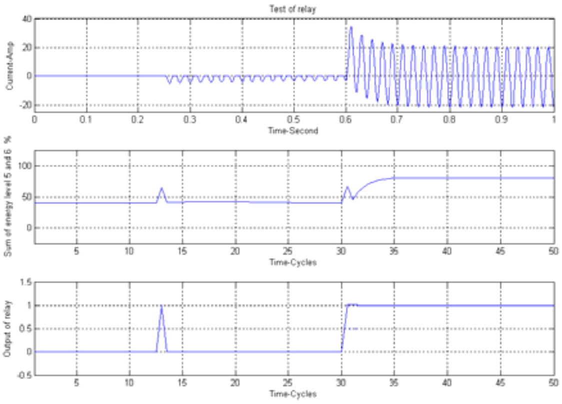

Figure 16. Differential current of phase A and the output of differential relay for the simultaneous occurrence of inrush current and ABC at *t*=0.75sec in secondary side with fire angle of 60 degree

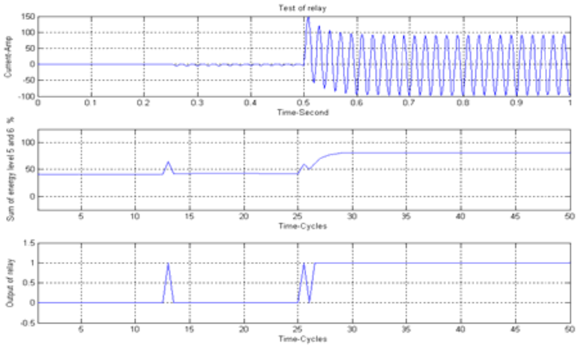

Figure 17. Differential current of phase A and the output of differential relay for the simultaneous occurrence of inrush current and ABG at *t*=5sec in secondary side with fire angle of 60 degree

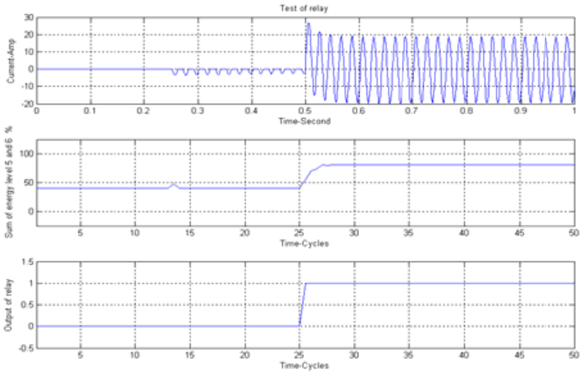

Figure 18. Differential current of phase A and the output of differential relay for the simultaneous occurrence of inrush current and AC at *t*=0.5sec in secondary side with fire angle of 60 degree

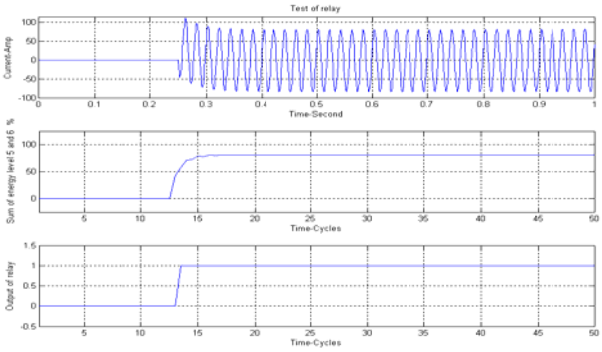

Figure 19. Differential current of phase A and the output of differential relay for the simultaneous occurrence of inrush current and AB at *t*=5sec in secondary side with fire angle of 60 degree

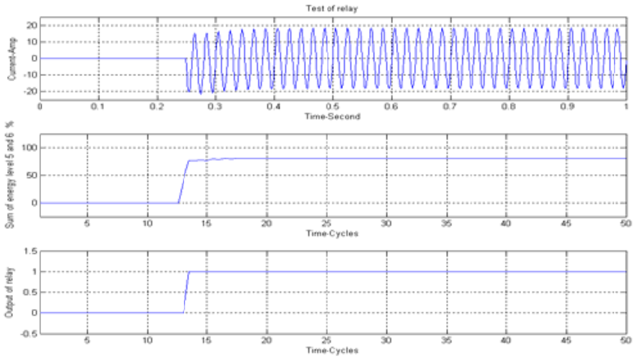

Figure 20. Differential current of phase A and the output of differential relay for the simultaneous occurrence of inrush current and ACG at *t*=5sec in secondary side with fire angle of 60 degree

The Tables 7 to 10 show some of the results of performance of the proposed relay. In the tables the test of differential relay versus inrush current, inner faults and inner faults along with inrush current and outer faults have been depicted.

Table 7. Inrush current and designed relay response

Disturbance	Fire angle	Proposed relay response
Inrush current	0	0
Inrush current	30	0
Inrush current	60	0
Inrush current	120	0
Inrush current	150	0
Inrush current	180	0
Inrush current	270	0

Table 8. Simultaneous occurrence of internal fault, inrush current and designed relay response

Fault	Fire angle	Proposed relay response
AG	0	1
AG	30	1
AG	60	1
Short circuit AB	0	1
Short circuit AB	30	1
Short circuit AB	60	1
ABG	0	1
ABG	30	1
ABG	60	1
Short circuit ABC	0	1
Short circuit ABC	30	1
Short circuit ABC	60	1

As can be seen, relay does not act at the time of the occurrence of different external and inrush current with different fire angles and while different internal faults occur, with inrush currents in different fine angles simultaneously, it works and tripping happens.

In Table 11, it is referred to the sum of energy in the 5th and 6th levels in percent at the time of occurrence of inrush current in the first cycle. The first column shows the amplitude of residual flux in the core of transformer in each phase in per unit. The second column shows the angle of voltage phase A at the time of switching. The third and fourth column show on and off situations of the secondary side of the transformer at the time of switching and occurrence of inrush current.

Also in both situations, the effect of flux density transitions at knee point of magnetic characteristic of the core of transformer has been studied. The flux density of knee point in char≠1 is bigger than it in char≠2. The sum of energy in 5th and 6th level are expressed as a percentage of the total energy and also Figure 16 represents the characteristic of signal in half of a cycle.

Table 9. The occurrence of external fault and designed relay response

Fault	Fire angle	Proposed relay response
AG	75	1
AG	90	1
Short circuit AB	75	1
Short circuit AB	90	1
ABG	75	1
ABG	90	1
Short circuit ABC	75	1
Short circuit ABC	90	1

Table 10. The occurrence of external fault and designed relay response

Fault	Fire angle	Proposed relay response
AG	Out of differential zone	0
ABG	Out of differential zone	0
Short circuit ABC	Out of differential zone	0

Table 11. The sum of energy in the 5th and 6th levels in percent at the time occurrence of inrush current in the first cycle

Br	Θ_A	No Load		On Load	
		Char #1 %	Char #2 %	Char #1 %	Char #2 %
Br_A=0.8pu Br_B=-0.4pu Br_C=0.4pu	0	41.53	38.12	41.54	37.87
	30	40.98	37.57	41.08	37.73
	54	47.34	42	47.80	41.94
	72	44.73	44.41	46.25	45.07
Br_A=0.003pu Br_B=-0.001pu Br_C=-0.001pu	0	34.99	40.09	34.23	41.58
	30	52.24	48.56	49.12	39.69
	54	64.17	60.29	51.22	33.12
	72	35.98	39.53	32.51	41.58

Table 12. The sum of energy in the 5th and 6th levels in percent at the time of occurrence of internal faults in the first half cycle

	Θ_A	0	72
No Load	AG	67.4	50.3
	AB	61.7	52
	ABC	66.9	55.6
	ABG	65.88	49.25
On Load	AG	67.0	55.1
	AB	61.8	48.0
	ABC	66.5	57.1
	ABG	65.53	59.23

V. CONCLUSIONS

In this study, a new approach was presented in order to recognize and distinguish fault signal from inrush current. Wavelet transform splits off the signal energy in time- frequency domain whereas Fourier transformer does not have this capability. With this kind of analysis, these two currents can be separated simply since the distribution of energy in time and frequency domain for inrush and fault currents is very different. Because of the existence of DC component and even harmonics in inrush current and regarding the sampling frequency (64 samples per cycle) the energy of zero, third and fourth levels can be a proper criteria for recognition and applying some intelligent networks such as ANFIS can help classify signal in all different conditions.

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