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A Differential Protection of Indirect Symmetrical Phase Shift Transformer and Internal Faults Classification using Wavelet and ANN

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ABSTRACT

This paper illustrates a differential protection algorithm for indirect symmetrical phase shifting transformer (ISPST) using wavelet transform (WT). Further, a Multi-Layer Feed Forward Neural Network (MLFFNN) based algorithm has been developed for classification of internal fault in ISPST. Detailed coefficient at level four (D4) of phase current is used as input vector for MLFFN network. Principle component analysis (PCA) at input reduces the burden and makes the detection and classification algorithm fast. Genetic Algorithm (GA) is used to obtain the optimal structure of MLFFNN. The discrimination between internal fault and magnetizing inrush is developed based on the time elapsed between the instant of inception of disturbance and the instant of the maximum peak in frequency component D4 of WT. It distinguishes magnetizing inrush and internal fault within quarter cycle after disturbance. An ISPST is simulated using MATLAB platform to obtain the differential current signal.

Keywords—ISPST,MLFNN,GN,MATLAB

I.Introduction

This paper deals with differentiation of magnetizing inrush and internal fault currents of an ISPST using WT and subsequent classification of types of internal faults and location of internal fault using WT and ANN. MATLAB are used to generate differential current signals for the verification of proposed algorithm. Phase shift compensation is also taken in account to resolve the problem of non-standard phase shift. Proposed algorithm is also compared with the conventional HR method. Multi-layer Feed-forward Neural Network (MLFFNN) is used for the classification of types of internal fault. Principle component analysis (PCA) is used to reduce the number of training samples so that training of ANN becomes smooth and fast. Genetic algorithm (GA) is used to optimize the number of neurons in hidden layers [1].

Recently, researchers have been formulating protection algorithms for power transformer differential protection using intelligent techniques like artificial neural networks, wavelet transform fuzzy logic, phase angle difference method, harmonic restraint method etc. These techniques are proving to be

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the most suitable for classifying various operating conditions of transformer, the abnormal condition or the fault classification. Moreover, techniques like Fourier transform, wavelet transform, wavelet packet etc. have been employed by the researchers in their studies for analyzing the transient signals in power system under faulted condition in time domain, frequency domain or both and thereby for feature extraction to discriminate between healthy and unhealthy condition is wavelet transform is very useful tool [3].

II. Need and significance of work

Power transformers are an important and vital component of the power systems networks whose protection needs to be addressed so as to ascertain the stability and reliability of the system network. Tremendous amount of electricity usage in the present scenario of rapid industrialization have triggered the need to install equipment with higher ratings and sizes. Although protection is ensured in the form of minimum usage of circuit breakers, relays and other protective devices but since then the abnormal conditions and faults cannot be avoided. Such a situation requires the digital relays as protection measures which employs software algorithm relying on advanced logics to ensure a higher degree of protection.

Considering the importance of an ISPST, it requires fast and reliable protection. Many protection schemes such as differential, overload protection, over-excitation protection, through backup protection etc. are used for the protection of an ISPST. Conventional differential protection of non- standard phase shift transformers (PSTs) is reported in literature. Conventional differential relaying principle is used for transformer protection results in high current (order of 8-10 of the full-load current) during energization and causes the relay to operate. This mal-operation of relay can be avoided by proper discrimination between magnetizing inrush and the fault current. Differential relays with harmonic restraint (HR) for dual, redundant primary and secondary protection of an ISPST. Now days, the transformer run at high flux density due to modern core material and design that generates low second harmonic components during magnetizing inrush, which affect HR scheme. Protection of PST, which is based on normal operating voltage-current relationship and tracking of the tap- changer position requires additional potential transformer in conjunction with current transformer (CT).Waveform identification-based methods can distinguish inrush from the internal fault currents. Their application in transformer protection has gained momentum with developments in Artificial Neural Network (ANN) and wavelet transforms.

III. Objectives:

1. Differentiation of magnetizing inrush and internal fault currents of an ISPST using WT and subsequent classification of types of internal faults and location of internal fault using WT and ANN.
2. Two platforms (MATLAB) are used to generate differential current signals for the verification of proposed algorithm.
3. Phase shift compensation is also taken in account to resolve the problem of non-

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standard phase shift. Proposed algorithm is also compared with the conventional HR method.

4. Multi-layer Feed-forward Neural Network (MLFFNN) is used for the classification of types of internal fault.
5. Principle component analysis (PCA) is used to reduce the number of training samples so that training of ANN becomes smooth and fast.
6. Genetic algorithm (GA) is used to optimize the number of neurons in hidden layers.

IV. Working principle of ANN

This paper presents a novel power transformer differential protection algorithm by using combined wavelet transform and Artificial Neural Network (ANN) which provide the means to enhance the classical protection principles and facilitate faster, more secure and dependable protection for power transformers. Wavelet transform is used to extract the feature from transient signal and the neural network is trained by the extracted features of the transient signal to discriminate between the internal fault and magnetizing inrush current. The wavelet transform is firstly applied to decompose the differential current of power transformer in to a series of detailed wavelet components and then the spectral energies of the detailed wavelet components are calculated. The obtained spectral energies are employed to train the Optimal Feed Forward Neural Network (OFFNN). The proposed technique being pattern recognition based will be able to maintain relay stability even during sympathetic inrush and external fault condition

V.SYSTEM DEVELOPMENT

MATLAB is a multi-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, analysis of data, develop algorithms, and create models and applications are done. The language, tools, and built-in math functions enable to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. MATLAB can be used for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology.

The name MATLAB stands for Matrix Laboratory. MATLAB was originally written to provide easy access to matrix software developed by Lin pack and eispack projects. Today, MATLAB engines incorporate the lapack and blas libraries, embedded the state of the art in software for matrix computation.

MATLAB is a very powerful package which allows to manipulate simultaneously:

- Vectors and matrices
- Complex functions of complex variables
- Electrical power systems are combination of electrical circuits, and electromechanical devices, like motors and generator. Engineers working in this discipline are constantly asked to improve the performance of the systems.
- Requirement for drastically increased efficiency have a forced power system

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designer to use power electronics devices and sophisticated control system concepts that tax traditional analysis tools and techniques.

➢ Further complicating the analyst's role is the fact that the system is often so nonlinear, the only way to understand it is through simulation.

➢ Comprehensive Block Libraries

➢ The Sim Power System libraries contain more than 150 blocks distributed in eight sublibraries. The blocks represent simple electrical components, such as resistors, inductors, and capacitors, and complex components, such as transistors and electric drives. The lines joining these components represent ideal conduction lines. Numeric signals can be 24 pass into the circuit model from simulink and extract numeric signals from the circuit model for analysis in tradition simulink blocks.

➢ The library can be used with Simulink to create electrical block diagrams that connect Sim Power Systems elements and control algorithms, enabling to study the way the control system relates the power system.

➢ The Sim Power Systems library includes the following sub libraries:

➢ Electrical sources-AC and DC voltage and current sources.

➢ Electrical circuit elements-resistor, inductor, capacitor; linear and saturable transformers; arrestors and breakers; and transmission line models.

➢ Electrical machinery-models of synchronous, permanent magnet synchronous, and ¬ DC machines; excitation systems; and models of both hydraulic and steam turbinegovernor system.

➢ Power electronics-diodes, simplified and complex thyristors, GTOs, switches, ¬ MOSFETs, IGBT models, and Universal Bridge.

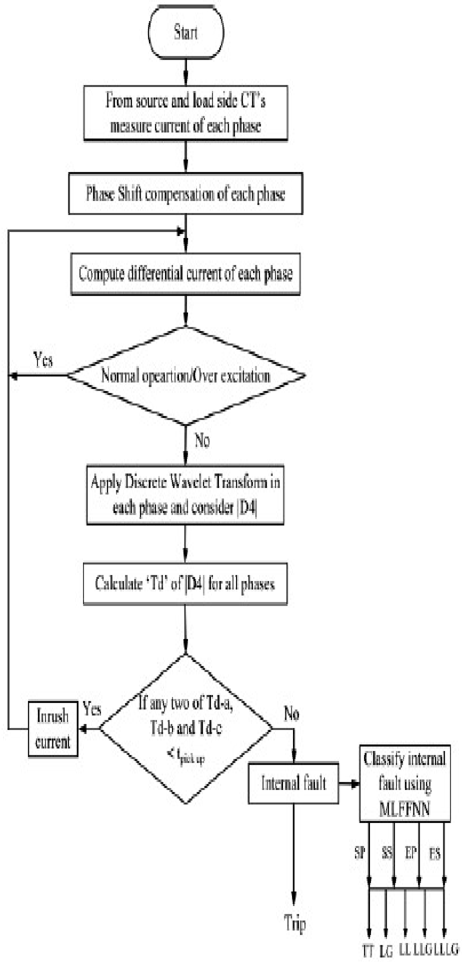

Fig. 1 Complete protection scheme of ISPST

VI.Result Discussion with MATLAB:-

The working of the recommended algorithm is evaluated for different types of internal faults such as turn-to-turn (TT), phase A-to-ground (AG), phase A-to-phase B (AB), phase A-to-phase B-to-ground (ABG), three phase-to-ground (ABCG) in the primary and secondary

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sides of series and exciting transformer of an ISPST and magnetizing inrush currents. Internal faults are simulated with different fault inception angles, on-load and no-load conditions at different percentage of faulted winding. Various cases of magnetizing inrush with different percentage of residual core flux, switching-in angle, on-load and no-load conditions that affects differential current are also simulated. The table II and III shows the time duration (Td) between time of disturbance and the maximum peak of |D4| after disturbance for internal faults in series unit and excitation unit respectively at different conditions which have been discussed earlier. Table IV shows Td for magnetizing inrush condition at different switching-in angle considering different percentage of residual flux. Analysis of various simulations reveals that values of Td for various internal fault conditions are usually less than 1.5 msec. Also for the magnetizing inrush conditions, the values of Td are usually greater than 4.0 msec. Hence in this paper tpick-up is chosen as 1.5 msec. The proposed algorithm is also verified by simulation using RSCAD/RTDS platform in next section.

Fault Inception angle (Deg.)	**Types of fault**	**On-Load**			**No-Load**		
		Phase			**Phase**		
		a	**B**	**c**	**a**	**B**	**C**
0	TT	1.2	1.2	1.2	1.2	1.1	1.1
	AG	1.1	1.0	1.1	2.8	1.1	1.1
	AB	2.8	1.1	1.1	2.8	1.1	1.1
	ABG	2.8	1.1	1.1	2.8	1.1	1.1
	ABCG	1.1	1.1	1.2	1.1	1.1	1.2
90	AG	0.4	0.9	0.9	0.4	0.5	0.5
	AB	0.4	6.0	1.1	0.4	6.0	1.1
	ABG	0.4	6.0	1.1	0.4	6.0	1.1
	ABCG	1.2	4.3	1.2	4.4	4.3	1.2

Table:1 Td (msec.) for internal faults in series unit of an ISPST

Fault Inception angle (Deg.)	**Types of fault**	**On-Load**			**No-Load**		
		Phase			**Phase**		
		A	**B**	**c**	**a**	**B**	**C**
	AG	1.1	1.1	2.8	0.3	1.9	2.8
	AB	1.2	1.1	1.1	1.1	1.1	1.1
	ABG	1.2	1.2	1.1	1.1	1.1	1.1
	ABCG	1.1	1.1	1.1	1.1	1.1	1.2
90	AG	1.1	1.2	1.1	1.1	1.1	1.1
	AB	1.1	7.8	1.1	1.1	7.7	1.1
	ABG	1.1	7.6	1.1	1.1	7.8	1.1
	ABCG	1.1	7.8	1.2	1.1	1.1	1.2

Table: 2 Td (msec.) for faults on the excitation of an ISPST

%	**Switching**	**ON-Load**	**No Load**

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Residual flux	in angle (Deg.)	Phase			Phase		
		A	b	c	a	B	(
0%	0	5.9	4.3	7.5	5.8	6.7	4.
	90	1.1	7.5	8.1	6.0	6.0	8.
50%	0	2.7	5.7	7.6	2.7	7.8	7.
	90	4.3	7.6	2.7	4.3	7.6	2.
80%	0	4.3	7.6	2.7	4.3	7.6	2.
	90	4.4	4.2	5.9	6.0	7.5	7.

Table: 3 Td (ms) for each phase differential current for inrush

VII. Performance evaluation

A total of 1234 data cases have been simulated using the MATLAB software for different operating conditions of power transformer. Out of 1234 patterns, 794 patterns are simulated for magnetizing inrush and/or sympathetic inrush conditions, and 440 patterns are generated for internal fault cases including phase-to-ground, phase-to-phase, and turn-to-turn faults respectively. Out of these 1234 patterns, 1086 patterns have been used to construct the OFFBNN. The rest 148 cases have been used to test the generalization ability of the neural network. These 148 test patterns are other than those been used to train the OFFBNN. Figshows the performance plot of training, validation and test errors and reasonability can be observed since:

•The final mean squared error is very small.

•Test and validation set errors have similar characteristics.

• No significant over fitting has occurred

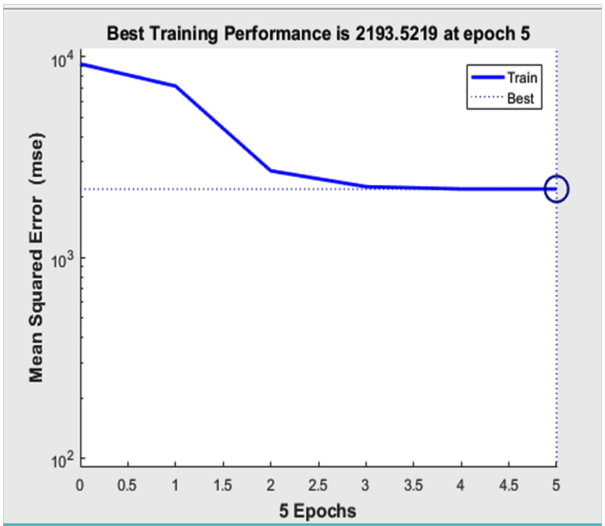

Fig.: Typical performance of the OFFBNN

VIII.CONCLUSION

This report presents a novel power transformer differential protection scheme by using combined Wavelet Transform and Artificial Neural Network which is faster, stable and accurate. Wavelet transform is used for the feature extraction from the differential relaying signal. Dead angle detection in wavelet energy of signal has an advantage that that it will always lie in the first quadrant, as the wavelet energy is always a positive value, thereby making algorithm simpler. The proposed scheme does not require any threshold index to discriminate between the internal fault and inrush condition.

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The proposed digital differential protection scheme is an intelligent technique based scheme and can be used as effective approach for modern power transformer protection.

This project presents an effective algorithm to distinguish magnetizing inrush and internal fault condition using WT for an ISPST. The aforesaid criterion used the time interval between time of disturbance and maximum peak in frequency component D4 of WT to differentiate magnetizing inrush and internal fault currents which arise from their characteristic profiles. The fault detection is fast, reliable and accurate. Proposed algorithm distinguishes internal fault and magnetizing inrush with in quarter cycle which is verified for the signal.

The proposed algorithm works fine in case of magnetization inrush without the use of restraining or blocking unit whereas conventional differential protection with harmonic restraint fails to operate. The proposed algorithm provides good sensitivity against low turn-to-turn faults where the conventional method fails.

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