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Artificial Neural Networks Based Three Phase Induction Motor Current Analysis

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ABSTRACT

This paper proposes an insurance conspire dependent on Wavelet Multi Resolution Analysis and Artificial Neural Networks which distinguishes and orders different deficiencies like Single staging, Under voltage, Unbalanced stockpile, Stator Turn issue, Stator Line to Ground shortcoming, Stator Line to Line issue, Broken bars and Locked rotor of a three -stage enlistment rotating motor . The three stage Induction Motor is addressed by a general model which is legitimate for a wide scope of frequencies. The equivalent has been reenacted utilizing MATLAB/Simulink programming and tried for different kinds of rotating motor flaws. The wavelet disintegration of three -stage stator flows is done with Bi-O rthogonal 5.5 (Bior5.5). The most extreme worth of the outright pinnacle worth of the greatest level (d1) coefficients of three-stage flows is characterized as shortcoming list which is contrasted with a predefined edge with recognize the issue. The standardized fourth level surmised (a4) coefficients of these flows are taken care of to a Feedforward neural organization to characterize different shortcomings. The standardized pinnacle d1 coefficients of three -stage flows are taken care of to another Feedforward neural organization to recognize the broken period of stator inward blames. The calculation has been tried for different frequency points and ended up being straightforward, dependable and successful in distinguishing and characterizing the different issues and furthermore in recognizing the flawed period of stator.

Keywords- Fake Neural Network, Broken bars, Locked rotor, Multi Resolution Analysis, Single staging, Stator Turn shortcomings, Three-stage enlistment rotating motor , Unbalanced inventory and Under voltage.

1.INTRODUCTION

Electric rotating motor are basic parts of numerous modern cycles and are often incorporated with financially accessible hardware and modern cycles. Squirrel confine acceptance rotating motor are more common being used than different rotating motor because of their minimal e xpense, toughness, low upkeep and activity with an effectively accessible power supply. rotating motor go through different burdens during their activity and these anxieties may prompt a few disappointments. Subsequently condition observing becomes fundamental for enlistment rotating motorto keep away from heartbreaking disappointments [1]. It is assessed that around 38% of the enlistment rotating motor disappointments are brought about by stator winding issues (e.g., turn-turn, line to ground and line to line issues) and around 10% of disappointments are because of rotor blames alongside outside rotating motor issues [2]. These deficiencies include: a) issues in beginning stock, which remember interferences for stages or blowing of circuit/single staging; b) unusual stockpile conditions like loss of supply voltage, lopsided inventory voltage and under voltage; c) mechanical over-burdens, which characterize delayed beginning or locked rotor and slowing down; d) Rotor broken bar faults.The rotating motor works inside its rating when the voltages are adjusted. At the point when the voltages become lopsided, exorbitant warming happens, and the rotating motor must be de- appraised [3]-[4]. The stator inside shortcomings start as undetected go to-turn winding flaws that at last develop and come full circle in significant issues [5]. rotating motor current mark examination (MCSA) is perceived as a norm for checking the rotating motor blames because of its effortlessness. The principle benefit of MCSA is to break down the stator ebb and flow looking for current music straightforwardly identified with new pivoting motion parts, which are brought about by issues in the rotating motor transition distribution.There are various methods used to distinguish bury turn shortcomings utilizing recurrence range of line flows [6]-[7]. The Fourier change is, nonetheless, not proper to examine a sign that has a short lived trademark like floats, sudden changes, and recurrence patterns. Identification of shortcomings utilizing dq0 parts of stator flows with wavelet change is ideal [8]. This plan anyway includes computational weight. The wavelet methods can be utilized for a confined investigation in the time-recurrence or time-scale area. It is accordingly a useful asset for condition observing and issue determination. Examination of stator line flows by Discrete Wavelet Transform can be utilized to identify broke bars in acceptance rotating motor [9]. Flaws like single staging, L-G, and L-L in a 3-stage enlistment rotating motor can be arranged dependent on the modulus maxima of DWT coefficients of the 3-stage line flows [10]. Late improvements in finding frameworks lead to the thought of various methodologies by utilizing Artificial Neural Networks. The learning ability of neural organization assists with ordering the flaws like: lopsided stock voltage, under voltage, single staging, locked rotor and so on [11].

In the proposed work a sum of 8 blames ordinarily experienced in enlistment engine viz., Single staging, Under voltage, Unbalanced stock, Turn issue, LG issue, LL shortcoming, Broken bar issue, and Locked rotor issue are thought of. The recognition of the shortcoming is performed with the assistance of the outright pinnacle d1 coefficient of stator flows. The standardized a4 coefficients of 3-stage line flows are taken care of to an Artificial Neural Network (ANN) for ordering the different engine flaws. The proposed calculation is tried for variety in shortcoming frequency points.
This paper is coordinated as follows. Segment II presents general
presentation of wavelet changes. Area III arrangements with the recognition of issues dependent on wavelet MRA. Area IV outlines the characterization of different shortcomings utilizing ANN and ends are introduced in segment V.

I. WAVELET ANALYSIS

Wavelet change (WT) was presented toward the start of the year 1980 and has drawn in much interest in the fields of discourse and picture handling from that point forward. Its expected applications to drive industry have been examined in the new writing. A short prologue to the WT and Multi Resolution Analysis (MRA) is given here. Wavelet computations depend on two principal conditions: the scaling capacity (t) and the wavelet work (t)

$$\varphi(t) = \sqrt{2} \sum h(n)\, \varphi(2t-n) \qquad (1)$$

$$\psi(t) = \sqrt{2} \sum g(n)\, \varphi(2t-n) \qquad (2)$$

where $g(n)=(-1)^n\, h(1-n)$

These capacities are two-scale contrast conditions dependent on a picked scaling capacity (mother wavelet), with properties that fulfill the accompanying conditions.

$$\sum_{n=1}^{N} h(n) = \sqrt{2} \qquad (3)$$

$$\sum_{n=1}^{N} h(n)h(n+2l) \begin{cases} = 1 & if\ i = 0 \\ = 0 & if\ i \neq 0 \end{cases} \qquad (4)$$

The discrete arrangements h(n) and g(n) address discrete channels that settle every condition, where g(n)=(- 1)nh(N- n+1). The scaling and wavelet capacities are the model of a class of orthonormal premise elements of the structure

$$\varphi_{m,n}(t) = 2^{\frac{m}{2}}\varphi(2^m t - n); \quad m,n \in z \qquad (5)$$

$$\psi_{m,n}(t) = 2^{\frac{m}{2}}\psi(2^m t - n); \quad m,n \in z \qquad (6)$$

Where, the boundary m controls the expansion or pressure of the capacity in time scale and abundancy. The boundary n controls the interpretation of the capacity on schedule. Z is thearrangement of numbers.

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$$\psi(t) = \sqrt{2} \sum g(n)\, \varphi(2t-n) \qquad (2)$$

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$$\psi_{m,n}(t) = 2^{\frac{m}{2}}\psi(2^m t - n); \quad m,n \in z \qquad (6)$$

Where, the boundary m controls the expansion or pressure of the capacity in time scale and abundancy. The boundary n controls the interpretation of the capacity on schedule. Z is the arrangement of numbers. When a wavelet framework is made, it tends to be utilized to grow a capacity f(t) as far as the premise capacities

$$f(t) = \sum_{l \in z} c(l)\varphi_l(t) \sum_{m=0}^{N-1} \sum_{n \in z}^{\infty} d(m,n)\psi_{m,n}(t) \qquad (7)$$

Where the coefficients c(l) and d(m,n) are determined by inward item as

$$c(l) = \langle \varphi_l | f \rangle = \int f(t)\varphi_l(t)dt \qquad (8)$$

$$d(m,n) = \langle \psi_{m,n} | f \rangle = \int f(t)\psi_{m,n}(t)dt \qquad (9)$$

The articulation coefficients c( ) address the guess of the first sign f(t) with a goal of one point for each every 2N places of the first sign. The development coefficients d(m,n) address subtleties of unique sign at various degrees of goal. c( ) and d(m,n) terms can be determined by direct convolution of f(t) tests with the coefficients h(n) and g(n), which are novel to the particular mother wavelet picked.

The WT can be carried out with an extraordinarily planned pair of FIR channels called a quadrature reflect channels (QMFs) pair. QMFs are unmistakable on the grounds that the recurrence reactions of the two FIR channels separate the high and low recurrence part of the info signal. The separating point is normally somewhere between 0Hz and a large portion of the information testing rate.

The yields of the QMF pair are crushed by an element of two. The low recurrence channel yield is taken care of into another indistinguishable QMF pair. This activity can be rehashed recursively as a tree or pyramid calculation, yielding a gathering of signs that partition the range of the first sign into octave groups with progressively coarser estimations on schedule as the width of each phantom band limits and diminishes in recurrence. The tree or pyramid calculation can be applied to the WT by utilizing the wavelet coefficients as the channel coefficients of the QMF sets. Similar wavelet coefficients are utilized in both low-pass and high-pass channels. The LP channel coefficients are related with the h(n) of the scaling capacity (t), and the HP channel is related with the g(n) of the wavelet work (t). The determination of mother wavelet depends on the kind of utilization. In the proposed calculation, bior5.5 wavelet has been utilized as the wavelet premise work for issue discovery.

INDUCTION MOTOR FAULT DIAGNOSIS

A three-stage, 5HP, 415V, 4pole Induction Motor with 36slots, 6coils per stage and 54 turns for each loop is considered for the current review. Fig.1 shows the numerical model of the three- stage acceptance **rotating motor** .

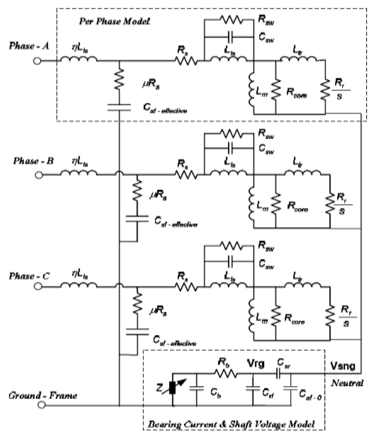

Figure 1. 3-Phase Induction Motor Universal Model

Each curl of the stator winding is addressed by a circulated model as displayed in Fig.2 [12].

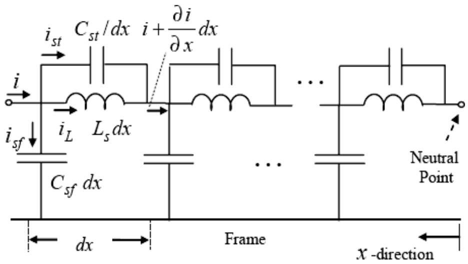

Figure 2. Distributed high frequency model for stator winding

In this paper determination of different flaws like Single staging, Under voltage, Unbalanced stock, Stator Turn shortcoming, Stator Line to Ground issue, Stator Line to Line issue, Broken bar and Locked rotor issue are talked about. Different sorts of wavelets have been tried for MRA of three- stage flows. Bior5.5 is viewed as the most appropriate mother wavelet for the proposed plot. The three-stage flows of the **rotating motor** are inspected at 6KHz and decayed with Bior5.5 to getitemized level coefficients over a moving window of a picked test length.

A. Single Phasing

The term single staging implies the activity of a three- stage enlistment rotating motor when one of its inventory lines gets separated from the a.c. supply. The most widely recognized reason for the single staging of an rotating motor is the consuming of breaker wire in any one stage. Henceforth single gradually easing brings about the most extreme state of voltage unbalance, since the voltage of the one of the three stages isn't recently decreased, yet becomes zero. This condition is reflected by an expansion in current on the two solid stages. Fig.3. addresses the homeless people related with three-stage flows of enlistment engine under single working shortcoming in stage A.

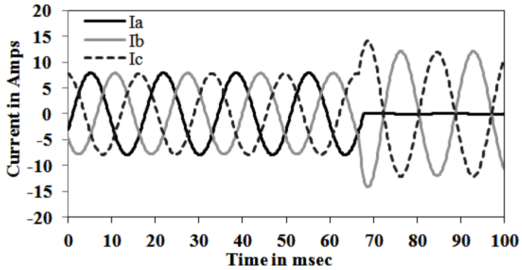

Figure 3. Current signals for a single phasing in phase A

The detail coefficients of these signs are delineated in Fig.4.

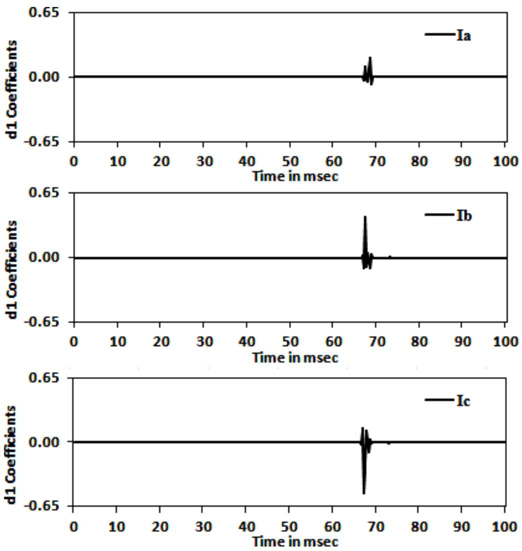

Figure 4.Variation in d1 coefficients for a single phasing in phase A

B. Under Voltage

Under voltage is a normal line to line voltage that is lower than the base satisfactory working voltage. The decrease in supply voltage for steady force load brings down the **rotating motor** speed since it is straightforwardly relative to the square of the voltage drop. Accordingly the working s lip would increment and rotor power variable would be diminished. Consequently the current inventory to the **rotating motor** is expanded definitely. This recommends that low voltage is sufficiently significant to warrant assurance in specific cases. The impact of 30% under voltage on stator flows is shown in Fig.5. Fig.6. shows the variety of d1 coefficients for an under voltage.

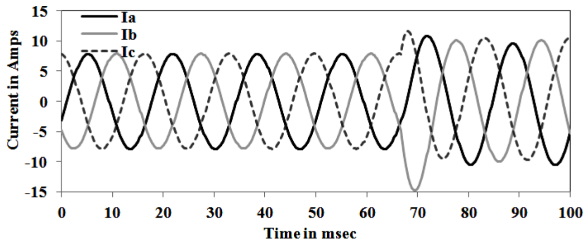

Figure 5. Current signals for an under voltage

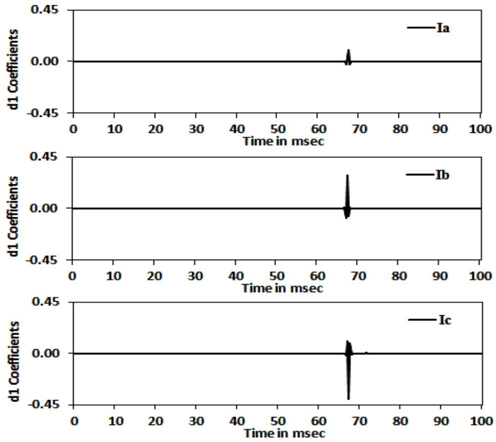

Figure 6. Variation in d1 coeffi cients for an under voltage

C. Unbalanced Supply

Ordinarily the inventory to an enlistment **rotating motor** is unequal because of the presence of uneven burdens on the framework or because of some line aggravations. A modest quantity of voltage unbalance might expand the current definitely and brings about inordinate warming of the acceptance **rotating motor** . Subsequently a defensive framework might be needed to separate the engine from the stock mains on the off chance that the level of voltage unbalance is in excess of a preset passable worth. Fig. 7 addresses the current drifters because of the impact of 10% uneven stockpile. The d1 coefficients of these signs are delineated in Fig.8.

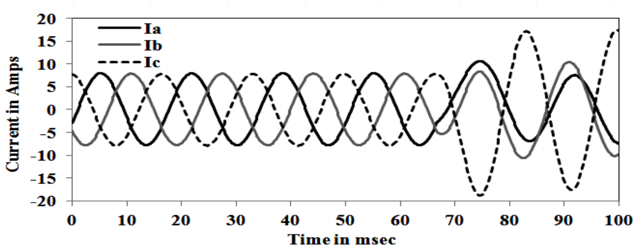

Figure 7. Current signals for an unbalanced supply

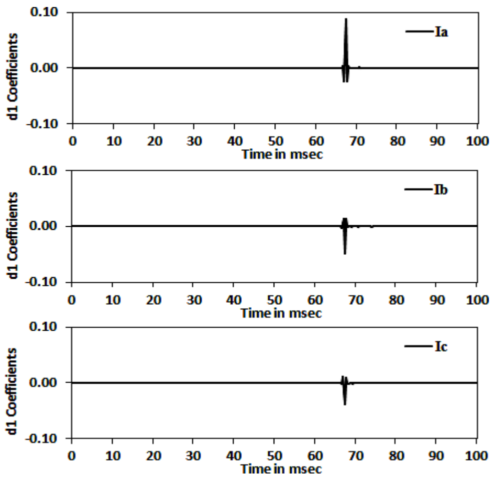

Figure 8. Variation in d1 coefficients for an unbalanced supply

D. Stator Faults

Stator shortcomings are essentially the breakdown of the winding protection. This might be brought about by overabundance warm or voltage stress, mechanical vibrations, or a scraped area between the stator and the rotor. The shortcoming of the winding protection can additionally bring about the turn-turn impede, in the long run winding-ground and line to line hamper. The current homeless people due the stator issues are outlined in Fig.9, Fig.10 and Fig.11 for Turn shortcoming, Line to Ground issue and Line to Line issue individually. Fig.12, Fig.13 and Fig.14 outline the detail coefficients under the above flaws.

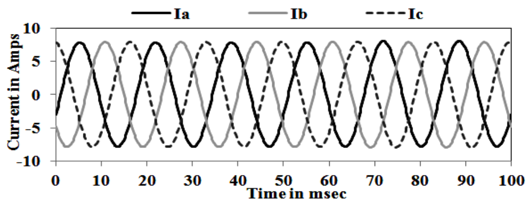

Figure 9. Current signals for a turn fault in phase A

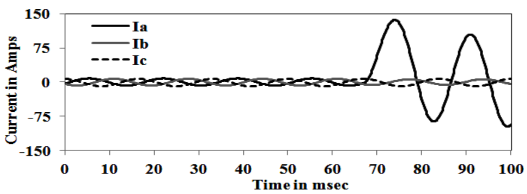

Figure 10. Current signals for a Line to Ground fault in phase A

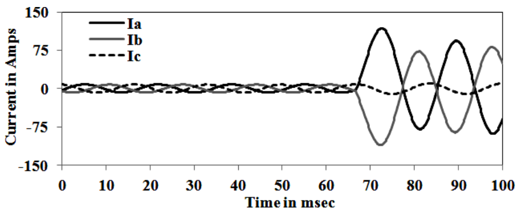

Figure 11. Current signals for a Line to Line fault between phase A & B

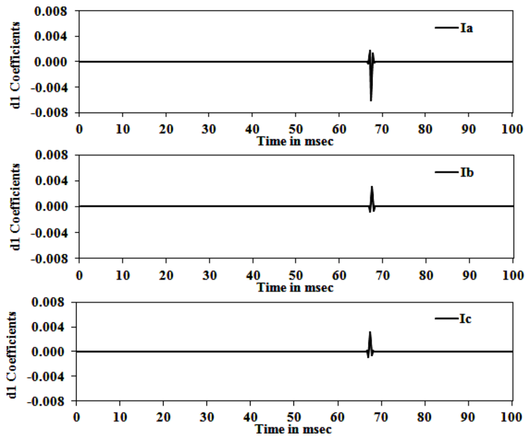

Figure 12. Variation in d1 coeffi cients for a turn fault in phase A

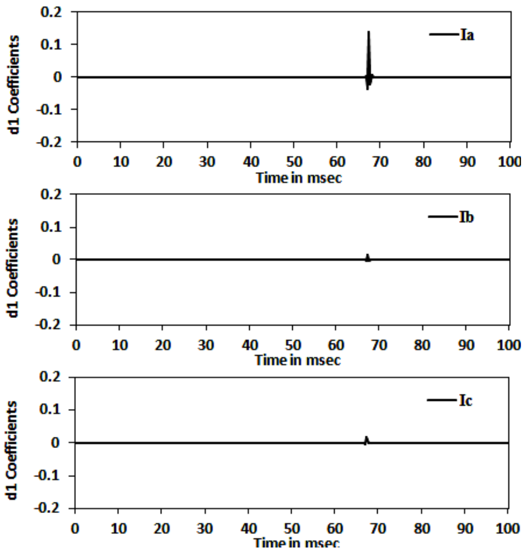

Figure 13. Variation in d1 coefficients fo r a Line to Ground fault in phase A

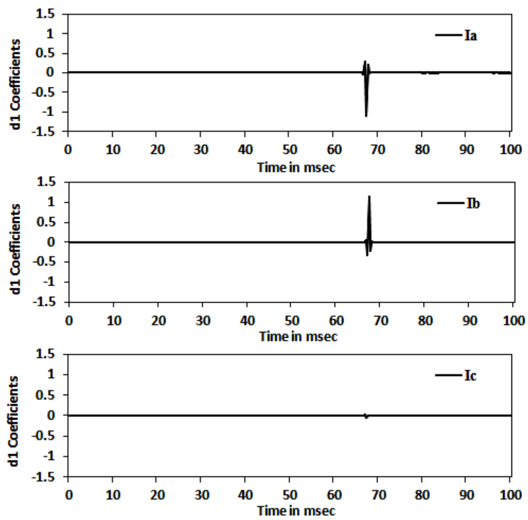

Figure 14. Variation in d1 coeffi cients for a Line to Line fault betweenPhase A & B

E. Broken Bar Fault

At the point when a rotor issue happens the flows in the nearby bars are expanded, making them break. This can be presented in the lattice model through an extra obstruction with a worth of a few significant degrees more prominent than the bar opposition [13].The extra opposition is gotten by

$$\Delta R = \frac{3R_2 n}{N} \quad (10)$$

where R2 is rotor obstruction, n is no. of broken bars and N is complete no. of rotor bars.

Broken rotor bars infuse sounds to the stator current and the stator current range should be utilized for determination of the shortcoming. This impact can be shown in Fig.15. The comparing variety of d1 coefficients are addressed in Fig.16.

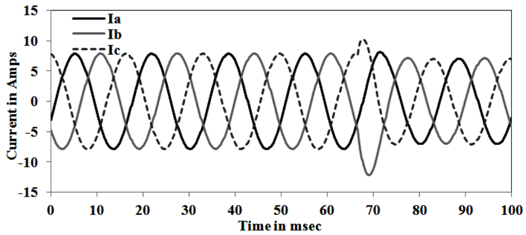

Figure 15. Current signals for a Broken bar fault

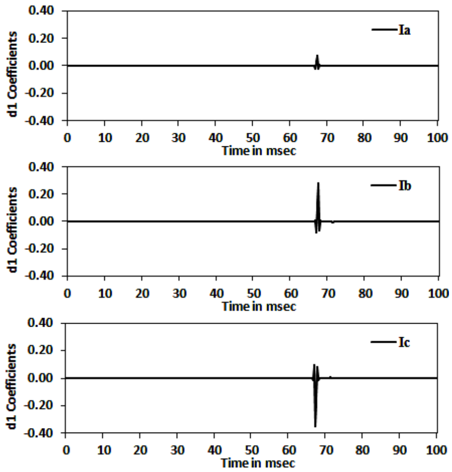

Figure16. Variation in d1 coefficients for a Broken bar fault

F. Locked Rotor Fault

Locked rotor implies that the rotating motor rotor becomes impeded and kept from revolution because of some mechanical reasons. The rotating motor current changes from its ordinary run worth to the slow down or startup esteem, which implies that the rotating motor attracts 5 to multiple times of the evaluated esteem. Since the rotating motor isn't intended to convey such a size of current persistently, insurance is needed for the rotating motor . Locked rotor shortcoming would be produced by recreating the model with slip equivalents to 1. The current homeless people relating to Locked rotor shortcoming are delineated in Fig.17. Fig.18 shows the variety of d1 coefficients.

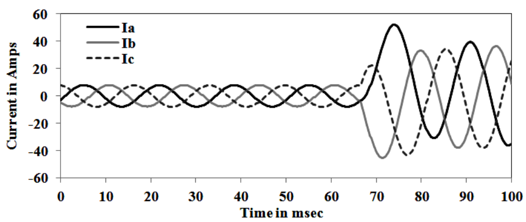

Figure 17. Current signals for a Locked rotor fault

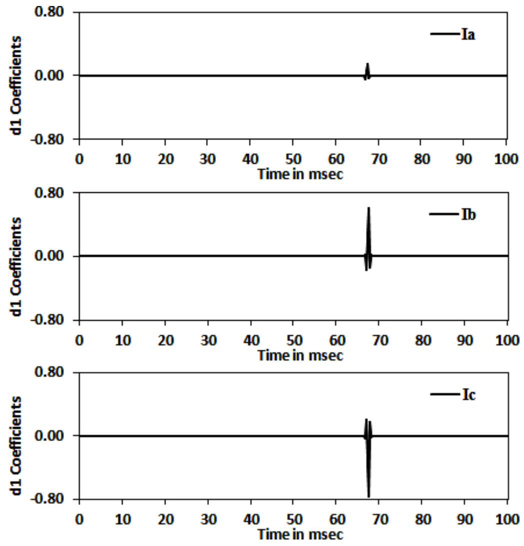

Figure18. Variation in d1 coeffi cients for a Locked rotor fault

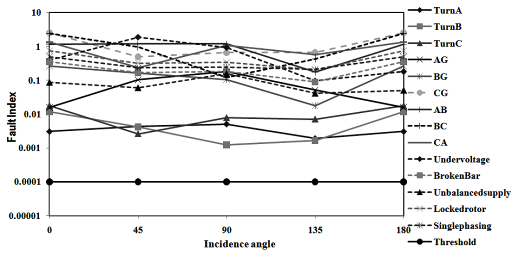

Figure19. Variation of fault index with respect to incidence angle

The outright worth of pinnacle d1 coefficients are gotten for all the stage flows. The maximium worth of these outright pinnacle esteems is characterized as issue record (If) and this is contrasted and limit esteem (Th) to identify the issue. This issue list relies upon shortcoming occurrence points. Fig.19 shows the variety of issue list with frequency plots for different issues in the 3-stage acceptance **rotating motor** . From Fig.19 it is apparent that the shortcoming file for an issue at any ratepoint is well over the limit esteem.

ANN BASED FAULT CLASSIFICATION

An Artificial Neural Network (ANN), with its great example acknowledgment abilities can be successfully utilized for recognizing different kinds of three-gradually ease acceptance **rotating motor** blames that cause unbalance in **rotating motor** execution and disappointment of engine parts. In this work, a Feed forward Artificial Neural Network is utilized to characterize the various motor deficiencies. Liebenberg- Marquand technique is utilized to prepare the counterfeit neural organization. The exchange work utilized for the info and secret layers is tan sigmoid and that of yield layer is log sigmoid. The three-stage flows are disintegrated with Bior5.5 to acquire fourth level surmised coefficients over a moving window of 3/4 cycle length from the shortcoming moment. The standardized a4 coefficients are utilized as contributions to ANN. The ANN comprise of 18 info neurons, 24 secret neurons and 8 yield neurons as displayed in Fig.20.

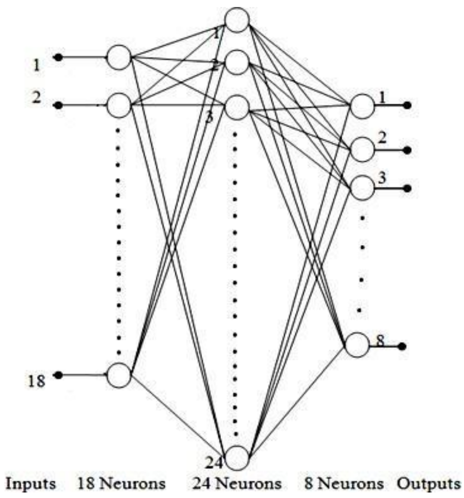

Fig.20. ANN Structure for fault classification

The standardization of the sources of info is finished regarding greatest and least upsides of a4 coefficients of three stage flows. The observing and shortcoming analysis of the three-stage enlistment **rotating motor** is accomplished by utilizing eight yields, each for one issue type. The yield O1 goes high (for example 1) for Single staging issue, O2 goes high for under voltage and so on Table I addresses target information for the neural organization.

TABLE I. TARGET DATA

Output	Type of Fault							
	Single phasing	Under voltage	Unbalanced Supply	Turn Fault	LG Fault	LL Fault	Broken Bar	Locked Rotor
O_1	1	0	0	0	0	0	0	0
O_2	0	1	0	0	0	0	0	0
O_3	0	0	1	0	0	0	0	0
O_4	0	0	0	1	0	0	0	0
O_5	0	0	0	0	1	0	0	0
O_6	0	0	0	0	0	1	0	0
O_7	0	0	0	0	0	0	1	0
O_8	0	0	0	0	0	0	0	1

The shortcoming preparing information is gotten by reenacting the different blames and changing the issue frequency point from 0-1800 in strides of 450. The prepared neural organization is tried with new information created by reproducing different flaws with new rate points going from 150 to 1500 in strides of 450. Table II shows mistakes in order of different issues. It very well may be seen from Table II that the deficiencies can be arranged productively with insignificant mistake.

TABLE II. Blunders IN Fault Classification

Fault Type	Incidence Angles			
	15^0	60^0	105^0	150^0
Single Phasing	**0.00**	**0.00**	**0.00**	**0.00**
Under Voltage	**0.03**	**0.03**	**0.00**	**0.00**
Unbalanced Supply	**0.00**	**0.00**	**0.00**	**0.00**
Turn to Turn	**0.00**	**0.00**	**0.00**	**0.00**
Line to Ground				
Line to Line	**0.00**	**0.00**	**0.00**	**0.00**
Broken Bar	**0.00**	**0.03**	**0.00**	**0.00**
Locked Rotor	**0.00**	**0.00**	**0.00**	**0.00**

One more Feed forward Artificial Neural Network is utilized to recognize the broken stage if the shortcoming is a stator issue. The standardized pinnacle upsides of d1 coefficient of three-stage flows are utilized as contributions to an ANN. The ANN comprises of 3 info neurons, 5 secret neurons and 3yield neurons as displayed in Fig.21.

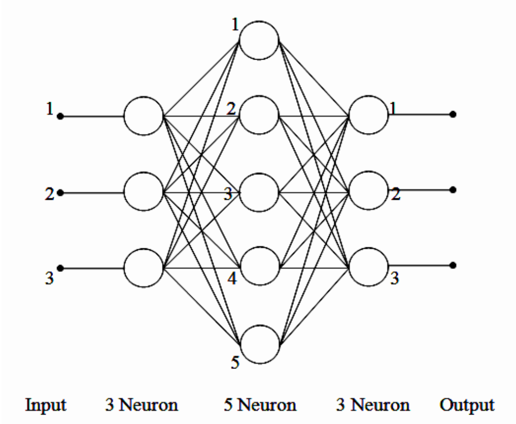

Fig.21. ANN Structure for fault phase identification

The standardization of the sources of info is finished as for the greatest worth of pinnacle d1 coefficients of three stage flows. The yields O1, O2 and O3 are equivalent to 1 if the shortcoming is on stage A, stage B and stage C windings separately. In this way for the bury turn and line to ground blames any of yields O1 to O3 will be 1.For LL blames any two of yields O1 to O3 will be 1. This is portrayed in Table III.

TABLE III. Target Data

Outputs	Turn/Line to Ground Faults			Line to Line Faults		
	Phase A	Phase B	Phase C	AB	BC	CA
O_1	1	0	0	1	0	1
O_2	0	1	0	1	1	0
O_3	0	0	1	0	1	1

The issue preparing information is acquired by mimicking the different stator inward blames and fluctuating the issue frequency point from 0-1800 in strides of 450. The prepared neural organization is tried with the new information produced by reenacting different deficiencies with new frequency points going from 150 to 1500 in strides of 450. Table IV shows blunders in shortcoming stage recognizable proof. It tends to be seen from Table IV that the flawed stage can be recognized proficiently with truly unimportant blunder. The stream outline for the proposed calculation is displayed in Fig. 22.

TABLE IV. ERRORS IN PHASE IDENTIFICATION

Incidence Angle	Turn/Line to Ground Faults			Line to Line Faults		
	Phase A	Phase B	Phase C	AB	BC	CA
15^0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
60^0	0.0000	-0.0003	0.0000	0.0000	0.0000	0.0000
105^0	0.0000	-0.0001	0.0000	0.0000	0.0004	0.0000
150^0	0.0000	-0.0005	0.0000	0.0002	0.0000	0.0000

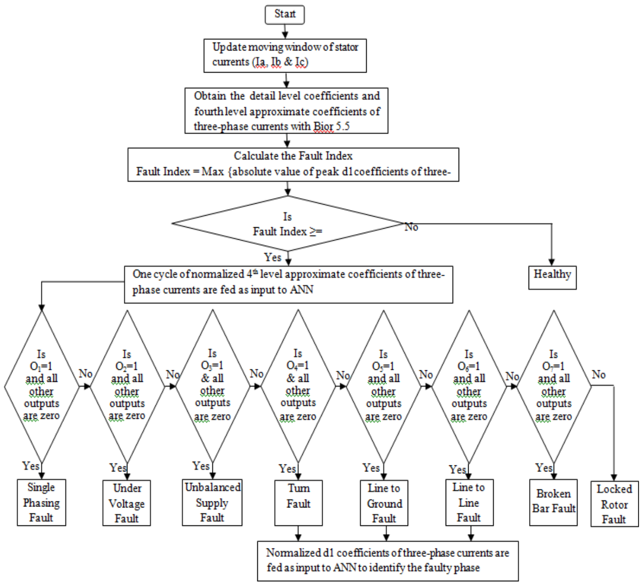

Figure 22. Flow Chart for proposed scheme

CONCLUSIONS

This paper depicts a Wavelet ANN based methodology to screen and examine three-stage enrollment motor inadequacies. Weakness acknowledgment can be performed inside a half cycle using d1 coefficients of three-stage streams. The normalized a4 coefficients are dealt with to a phony neural association to arrange various blemishes of enrollment motor. The normalized d1 coefficients are dealt with to another phony neural association to perceive the messed up time of selection motor. The reenactment results show that the proposed protection scheme is considered speedy, strong and definite for recognizing and describing various imperfections in three-stage enrollment motors and perceiving the faulty time of stator winding.

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