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Comparative analysis between Proportional Integral Controller and Wavelet Controller for the fault detection in Induction Motor

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Abstract: Squirrel cage Induction motor is widely used in industries because high efficiency, low cost, and roughest construction. In this paper we proposed the method of comparative analysis between PI and Wavelet Transform for the fault detection in Induction motor. Fault detection in Induction motor is a challenging area of research due to its importance to variety of commercial applications. Fault detection systems are widely implemented in automatic fault detection of machine at industries. The overall problems are subdivided into two key modules, (a) Operation and control, & (b) Fault diagnosis. In this research used the vector control method for speed control. In Induction motor different types of fault are presence and basically divided in to two categories (a) Electrical faults (B) Mechanical faults. In this research we consider only two faults short winding faults, and second is broken rotor bar faults. In this research current is analyze by using PI & Wavelet Transform to detect the faults. Early detection and diagnosis of these faults for condition assessment, maintenance schedule, and improved operation efficiency of an Induction motor. Such a model would to allow the efficient representation of the Induction machine with internal faults. The Discrete Wavelet Transform was used to extract the different harmonics component of stator currents. The key advantage of DWT is local representation (in both Time and frequency domain) of the current signal for normal and faulty modes, and PI controller is provide the variable data by changing the value of Kp and Ki.

Keywords: Wavelet transform, PI Controller, and Fault Diagnosis, Operation and Control.

1. INTRODUCTION

Induction motor is widely used in industries because roughest construction, high efficiency, low maintenance cost, easy controlling, and user friendly as compare to the other motors. Fault detection is the challenging area of research due to its importance of verity of commercial and industrial applications. Automatic fault detection is required now a day for provide the continue service without any interruption. The studies of Induction motor behavior during operation is very complicated case that's why in this research paper we proposed the model of fault detection in Induction motor by using PI controller and Wavelet Transform and compare the results then find out which method is convenient and best for fault detection in IM. A new and advance analysis tool was invented in the start of 1980 called Wavelet, which become very popular among the scientists especially mathematician because of its enhanced technology (1). The requirements of high technology electric devices have now become a basic necessity for the industries for getting the commands processed extremely fast with cent percent accuracy. For such requirements to get the maximum needs, Induction motors are generally used as they are compatible in size, efficiency and cost. (2) Now days in industries are using high power and expensive system, their maintenance should also be provided properly so as to avoid breakdowns and disasters. Induction motors are generally utilized by the industries for the enhanced signal processing which has now become more advanced by using PI Controller and Wavelet technology then compare between them and find out which one is suitable for fault detection in IM. Wavelet has enhanced the stator current which can detect the broken rotor bar by any fault in the temporary state (3). The IM control system is a sensor less system, if its rotor is broken wavelet methodologies are presented by (4) to remove the faults which is known as (EMD) empirical model decomposition through which damaged through rotor bar of nonlinear system can be detected by using the wavelet advanced technique called DWT. In IM different types of fault are create broken rotor bar fault, open winding fault, short stator winding fault and bearing faults etc. In this analysis we consider the current source of variant energy source are used to maintain the loop of current to direct the motor current in the direction of reference source of current. An often used technique for high-performance and drive of IM is vector control technique.

The torque and control of flux will help to maintain the torque control of IM in most of the DC motors. DC and vector control are similar as the vector control help to maintain decoupling, orthogonal and trans-vector control (6). There are two methods for the protection of the IM. (a) Automatic gain control circuit (AGC) for voltage of IM to maintain a satisfactory operation. (b) The other is stopping running when intensity of error is found high. Next method is the fault detection in Induction motor by using PI controller. In this method generate initial value of Kp and Ki after that run the induction motor speed control model for each set of parameter then calculate the parameter of (Kp and Ki) PI controller after that update the value of u(t) then compare to the reference parameter and last stage is if I is equal to Ist$\pm$10% so motor is running continually without any interruption, but I is not equal to the Ist that case motor will be stop.

2. WAVELET AND ITS APPLICATION FOR FAULT DETECTION IN IM

Wavelet analysis allow the representing function in both time and frequency domain. In wavelet analysis, the signals are processes at different scales or resolutions. It is also an emerging field of error finding. It is capable of extracting information in reference to time and class of the occurring faults. Thus, if we look at the signal with a wide window, we will identify general characteristics, whereas if a small window is used then we obtain detailed information about it [5]. Another important feature that makes wavelets interesting is that they allow the analysis of choppy and non-stationary signals. There are various kinds of wavelet transform. In this paper important kind will be discussed.

Continuous wavelet transform

Unlike Fourier transform, the technique based on wavelets allows to perform, through a multi-resolution analysis (MRA), several overlapped projections of the signal. For a signal f (t) the generating function of the MRA can be expressed as [18]

$$\varphi_j^k \text{ (t)} = 2{-}j/2\phi(2{-}j\ t - k) \qquad 1$$

Where ϕ is the so called mother wavelet, j indicates the decomposition level and k is the time shift factor. The wavelet coefficients obtained by applying an orthogonal wavelet are [18]

$$d_k^j = \int_{-\infty}^{\infty} f(t)\varphi_k^j\,(t)dt \qquad 2$$

$$\omega(\mathrm{m,n}) = \int_{-\infty}^{\infty} \mathrm{f(t)}\,\Psi_{\mathrm{m,n}}(\mathrm{t})\mathrm{dt} \qquad 3$$

Where φ_k^j is the wavelet analyzing function obtain form Haar. Morlet etc could be used.

The discrete wavelet transforms:

Multi-resolution analysis (MRA) Let s(n) be a discrete-time signal to be decomposed into its approximate and detailed versions using the MRA. The first level decomposition coefficients are a1(n) and d1(n), where a1(n) is the approximate version of the original signal s(n) and d1(n) is the detailed representation of the original signal s(n) which are defined as [5],

$$\text{DWT (m, k)}=\frac{1}{\sqrt{m_0^m}}\sum x(n)g\left(\frac{k-nb_0a_0^m}{a_0^m}\right) \qquad 4$$

$$a_l n = \sum_k^n h(k-2n)s(k) \qquad 5$$

$$d_1 n = \sum_k^n g(k-2n)s(k) \qquad 6$$

Where h(n) and g(n) are the decomposition filter of s(n) in $a_l n$ and d_ln respectively. The next (second) decomposition level is based on $a_l n$

$$a_2(n) = \sum_k^n h(k-2n)a_1(k) \qquad 7$$

$$d_2(n) = \sum_k^n g(k-2n)a_l(k) \qquad 8$$

Upper level decomposition can be obtain in a similar fashion. The coefficient a_2 and $d2$ are computed using the tree decomposition level algorithm allowing storing low frequency information of the signal as well as discontinuities.

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There are two characteristics of wavelet:

1. A finite energy signal can be reconstructed when the admissibility condition is satisfied by the Type equation here. Wavelet without any need of decomposition values. As a result, the equation of admissibility equation is presented as follows:

$$\int \frac{|\Psi(\omega)|^2}{|\omega|} d\omega < +\infty \qquad 9$$

The Fourier transform is denoted by $(\boldsymbol{\omega})$ while the wavelet function is denoted by (t). The fourier transform is used to analyses the wavelet signals as well as reconstruct them without any information loss. The Fourier transform will be zero according to the admissibility condition which is given by the equation:

$$|\Psi(\omega)|^2 = 0 \qquad 10$$

The second important characteristic of the wavelet is:

$$\int \Psi(\omega) = 0 \qquad 11$$

2. A limited number of regularity conditions are been imposed in order to resolve the squared relationship that exists between wavelet transform's time bandwidth and the input signal which will then ensure a concentrated and smooth wavelet function in the domains of frequency and time. Down-sampling and filtering can be used to implement decomposition which can be iterated with success as presented in :
   The total levels of decomposition denoted by (L) will be calculated based on the following equation:

$$L \geq \frac{\log\left(\frac{Fs}{f}\right)}{\log(2)} + 1 \qquad 12$$

$$D_{required} = \frac{f_s}{R}$$

A filter design and analysis tool or (FDA) is present in the signal processing toolbox of software called Matlab which can allow to designing of the low and high pass filter as well as export the coefficients of filter to the implemented matching filter as depicted in fig. 1, simulink model of fault detection in IM using DWT in Fig. (2) and result shown in fig (6), & (7)

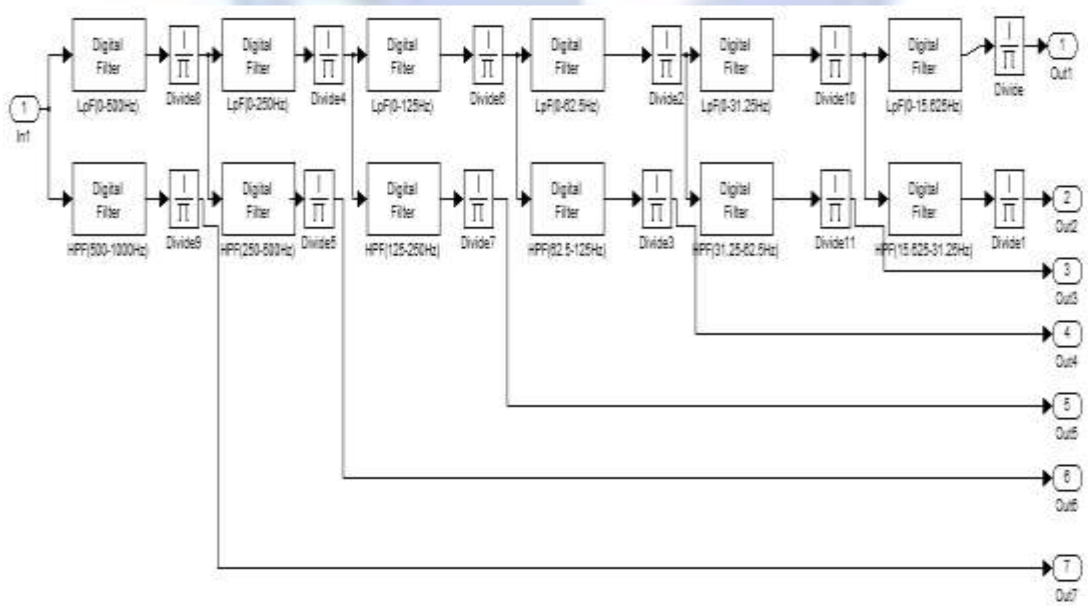

Fig. 1: Wavelet decomposition levels using FDA toolbox

Simulink model of fault detection in IM Show

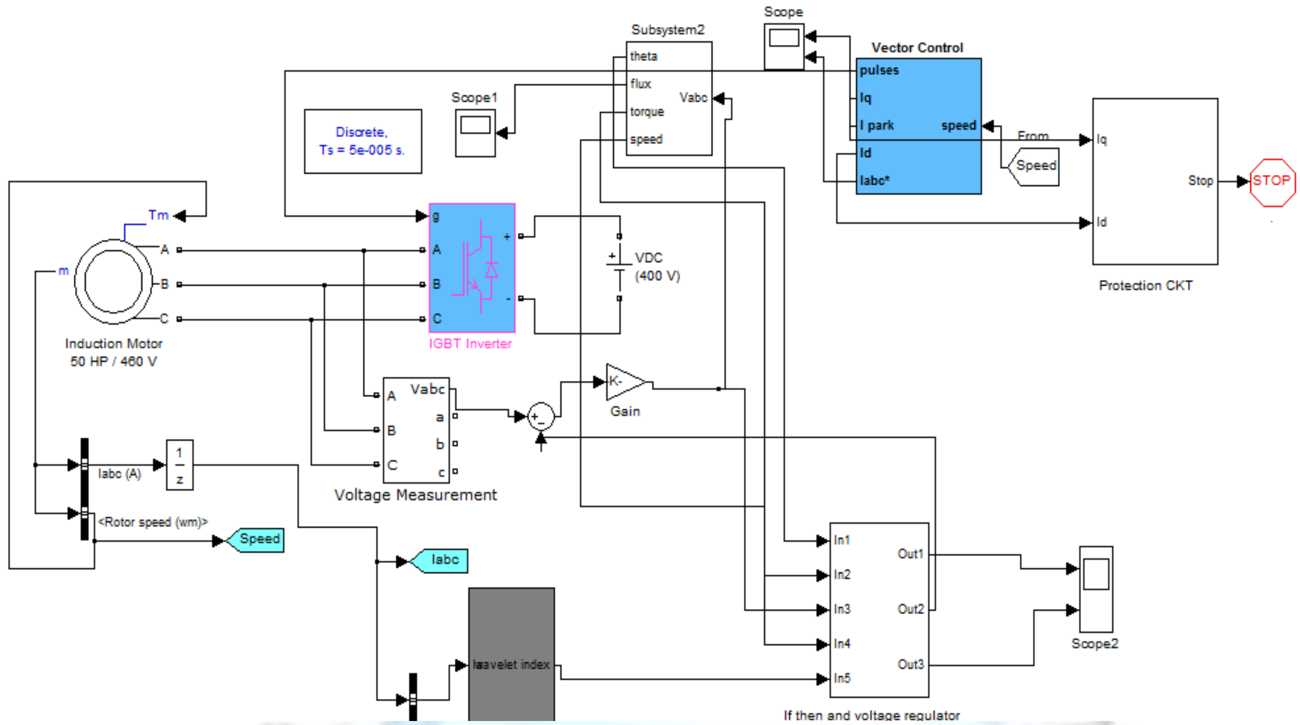

Fig. 2: Simulink model of IM fault diagnosis with DWT

3. PI CONTROLLER AND ITS APPLICATION FOR FAULT DETECTION IM

For integral control action the actuating single consists of proportional error signal added with integral of the error single. Therefore, the actuating signal for integral control action is give by,
the following equation.

$$u = K_I \int e \, d\tau \quad 13$$

In the PI controller we have a combination of P and I control i.e.

$$u = K_p e + K_I \int e \, d\tau \quad 14$$

$$u = K_p e + \frac{1}{\tau_I} \int e \, d\tau \quad 15$$

$$u = K_p \left(e + \frac{1}{\tau_N} \int e \, d\tau \right) \quad 16$$

Where τ_I = "Integration time" [s]
τ_N = "Reset time" [s]

3.1 Integral Gain Factor:

Ensures that under study state condition the motor speed (almost) exactly match the set point speed. A low gain can make the controller slow to push the speed to the set point but excessive gain can cause hunting around the set point. In lass extreme case it can cause overshoot whereby the speed passes through the set point and then approaches the required speed from the opposite direction. Unfortunately sufficient gain to quickly achieve the set point speed can cause overshoot and even oscillation but the other term can be used to damp this out.

3.2 Proportional Gain Factor:

Given fast response to sudden load change and can reduce instability caused by high integral gain. This gain is typically many times higher than the integral gain so that relatively small aviation in speed is corrected while the integral gain slowly moves the speed to the set point. Like integral gain set to high, proportional gain can cause a hard oscillation of a few hertz in motor speed.

3.3 Designing the PI Controller routine:

The PI control problem has to be converted form a theoretical continuous process into a real "discrete" system running on a microcontroller. What this mean in practice is that the measuring of the set point and motor speed and the calculation of the output is only performed a regular interval. In the context of a microcontroller, this is might correspond to some code run from a timer interrupt. The PI controller can thus be expressed as: Output = Proportional Gain*(error_speed) + Integral Gain*S (previous_error_speed_) and **Final output** = [{(Output) or Proportional Gain*(error_speed) + Integral Gain*S (previous_error_speed_)} – (last_error_speed)]

3.4 PI Error calculation:

The PI controller compares the set point (SP) to the process variable (PV) or mean variable (MV) to obtain the error e, as follows:

$$e = SP - PV \qquad 17$$

Then the PI controller calculated the control action, u (t), as follows. In this equation, Kp is the process gain.

$$u = K_p e + \frac{1}{\tau_I} \int e \, d\tau \qquad 18$$

Where τ_I = "Integration time"

The above following formula represents the proportional gain.

$$Up\,(t) = Kp\,(e) \qquad 19$$

3.5 Implementing the PI algorithm with the pi functions:

This section describes how the PI control toolbox function implements the PI algorithm. The PI algorithm used in the PI control toolbox

Error Calculation

The following formula represents the current error used in calculating proportional, integral, where PV is the filtered process variable.\

$$e\,(k) = SP - PV \qquad 20$$

3.6 Proportional Action

Proportional action is the controller gains times the error, as show the following formula:

$$Up\,(k) = Kp * e\,(k) \qquad 21$$

3.7 Trapezoidal Integration

Trapezoidal Integration is used to avoid sharp changes in integral action when there is a sudden change in the PV or SV. Use nonlinear adjustment of the integral action to counteract overshoot The following formula represents the trapezoidal integration action.

$$Ui\,(k) = Kp/Ti\Sigma\ \{[e\,(i) + e\,(i-1)]/2\}\ \Delta t \qquad 22$$

Where i = 1, 2, 3 …k

3.8 Controlled Output

Controller output is the summations of the Proportional, and integral action, as show in following formula:

$$U\,(k) = Up\,(k) + Ui\,(k) \qquad 23$$

3.9 Output Limit:

The actual controlled output is limited to the range specified for control output as follows:

If U (k) ≥ Umax then U (k) = Umax

And

If U (k) ≤ Umin then U (k) = Umin

The following formula shown the practical model of PI controller

$$U\,(t) = Kp\,[(SP\text{-}PV) + \frac{1}{T_i}\int_0^t (SP - PV)\,dt]$$

The PI function uses an integral sum correction algorithm that facilitates anti-windup & bumpless manual-to-automatic transfers. Windup occures at the upper limit of the controller output, for example, 100% when the error (e) decreases the controlled output is decreases, moving out of the windup area. The integral sum correction algorithm prevents abrupt controller parameters. The default range for the SP, PV and output parameter corresponds to percentage value; adjust the corresponding range accordingly.

3.10 Error calculation:

The current error used in calculating integral action for the precise PI algorithm is shown the following formula:

$$e(k) = (SP\text{-}PV_f)\left(L+(1\text{-}L)*\frac{|SP-PV_f|}{SP_{range}}\right) \qquad 24$$

Where SP range is the range of the SP and L is the linearity factor that produces a nonlinear gain term in which the controller gain increase with the magnitude of the error. If L is 1, the controller is linear. A valve of 0.1 makes the minimum gain of the controller 10% Kp. Use of a nonlinear gain term is referred to as a precise PI algorithm. Simulink block show in fig (3), (4), & (5) Results shown in figure no. (8) & flown chart shown in fig (9)

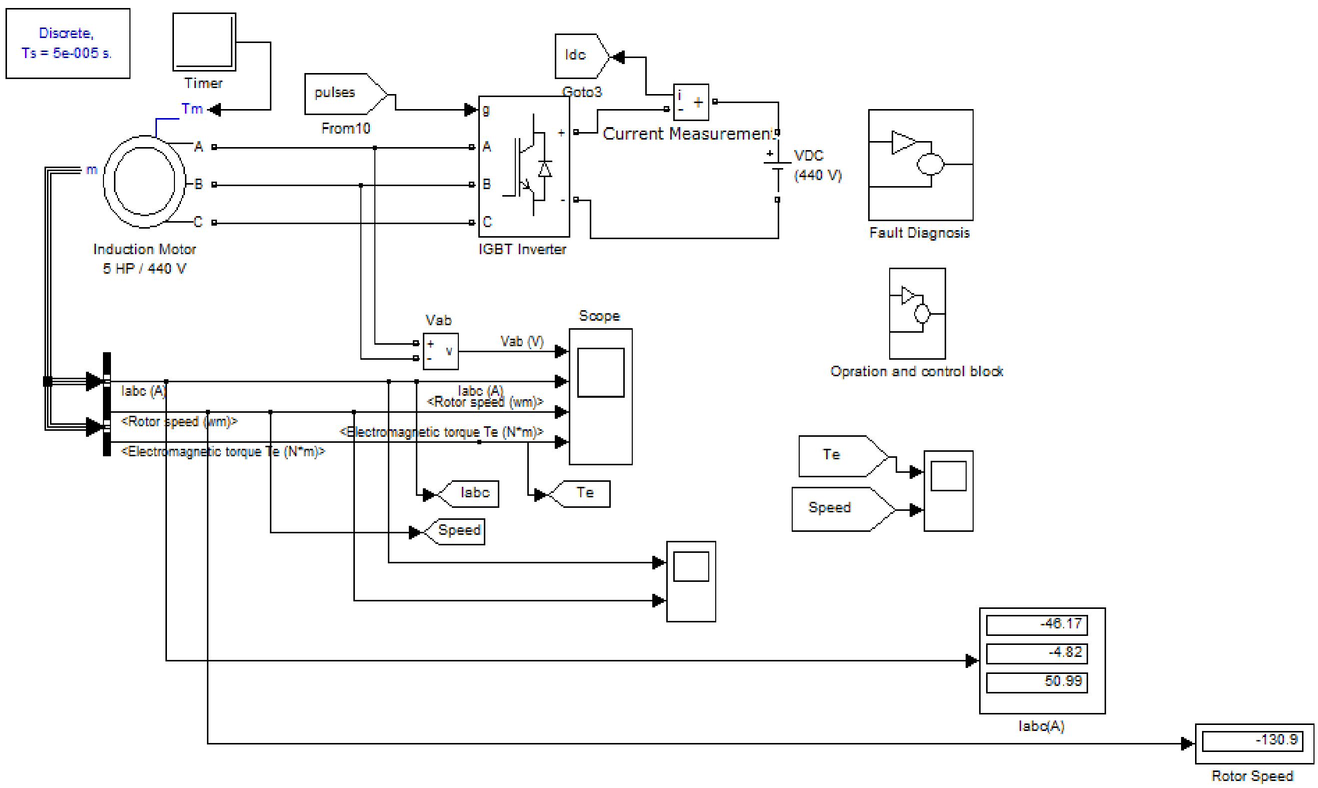

Fig. 3: Simulink model of Fault detection in IM using PI Controller

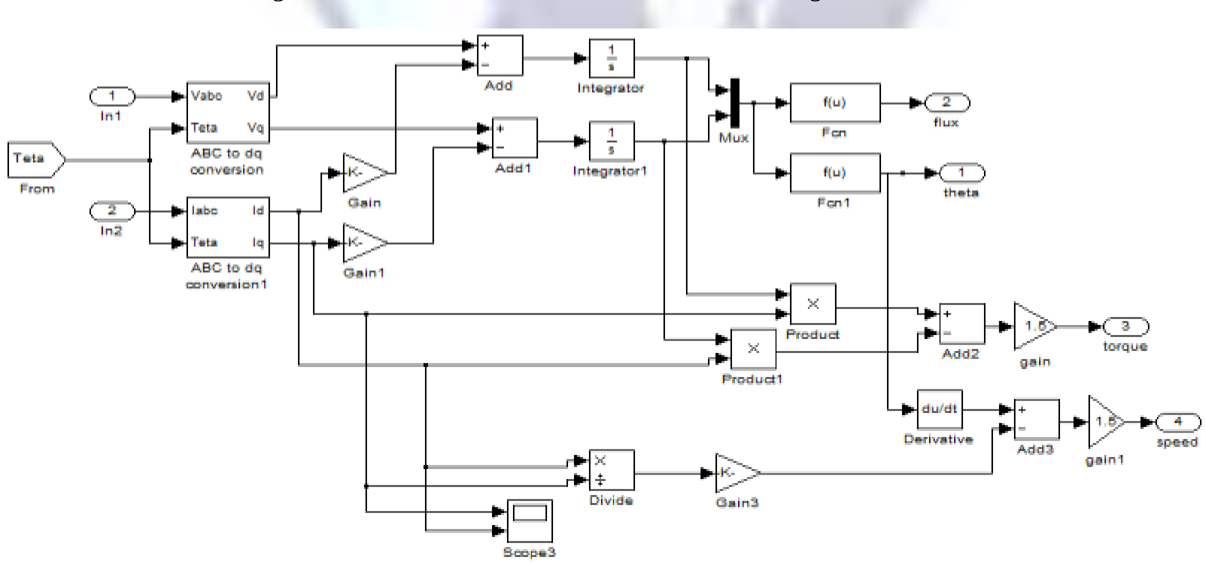

Fig. 4 Operation Block

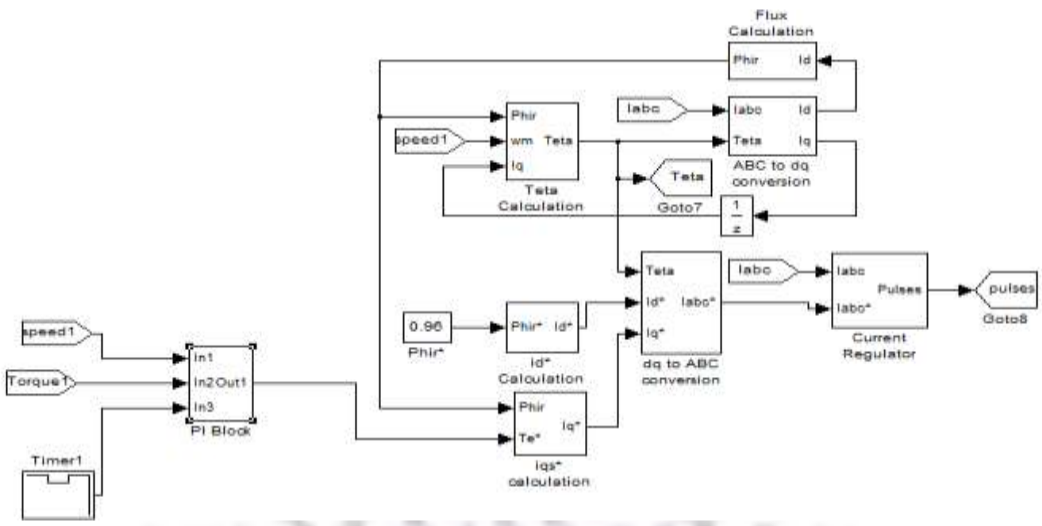

Fig. 5: Fault diagnosis block

4. RESULTS

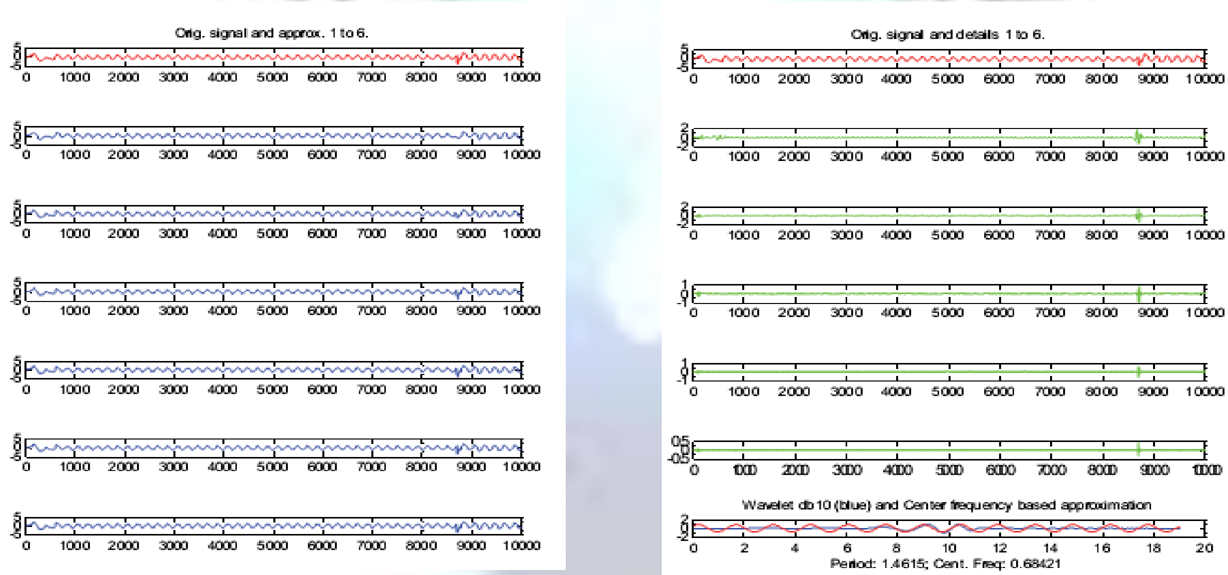

Fig. 6: Broken rotor bar fault case using DWT

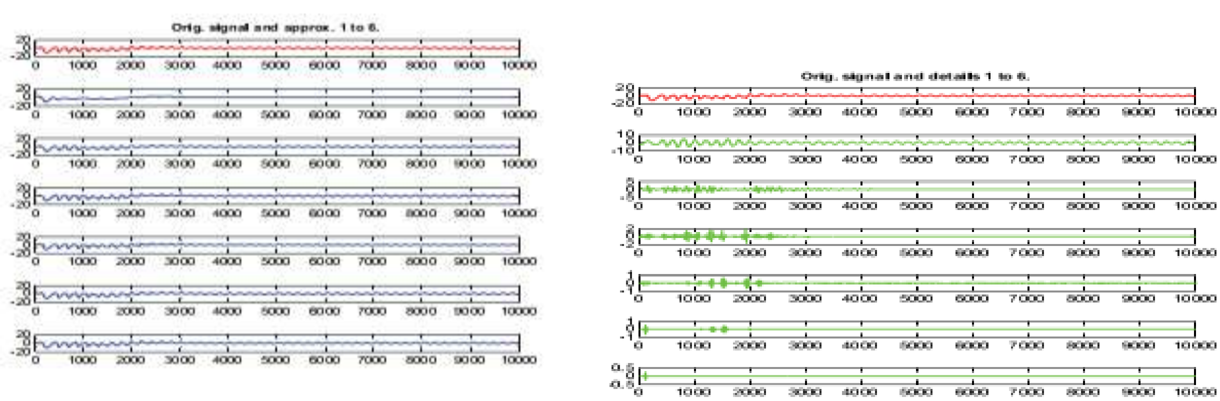

Fig. 7 Short winding fault using DWT

Fig. 8: Fault Detection in IM Using PI

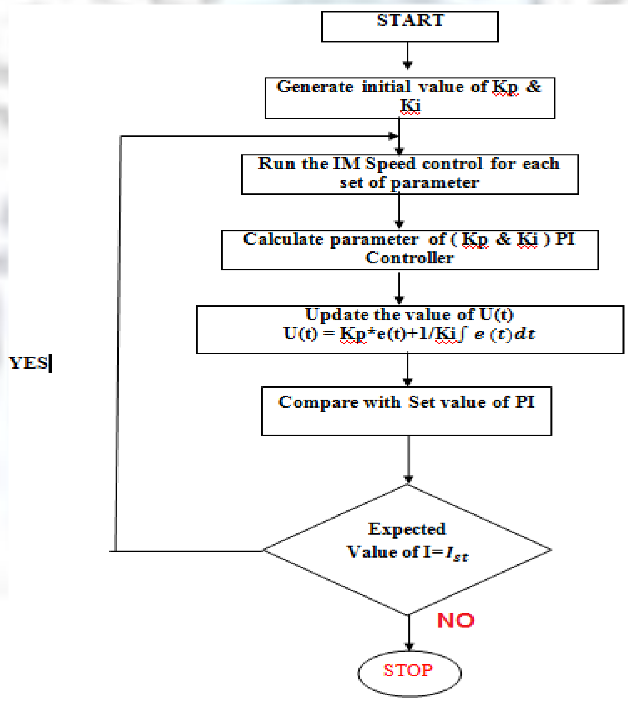

Fig. 9: Flow chart of PI controller for fault detection in IM

5. CONCLUSION

A Squirrel cage Induction motor 5 hp 440 volts 50 Hz input supply fully loaded condition checked out the fault by using wavelet transform & PI controller. When we apply the PI controller (conventional method) & checked out the results so scope is shown large distortion in current. Due to faults change the nature of current and as well as speed. An Induction motor apply the PI controller easily find out the fault point but we cannot decide which fault is create. When we apply the modern signal processing technique (Wavelet) and find out faults. In these methods we can easily decide which fault is created. An Induction motor applies the discrete wavelet transform and finds out two faults separately (1) Broken rotor bar faults, (2) Short stator winding fault. The wavelet is considered as powerful tools in the fault detection and diagnosis of induction motors as compare to PI controller. Many wavelet classes can be generated by different kinds of mother wavelets and can be constructed by filters banks. The improvement of fault detection and diagnosis can be exploiting the wavelet properties to get high detection and diagnostics effectiveness.

REFERENCES

[1]. Khalaf Salloum Gaeid, Hew Wooi ping (2010), “Diagnosis and Fault Tolerant Control of the Induction Motors Techniques: A review”, Australian Journal of Basic and Applied Sciences, Vol.4 No.2, pp. 227-246.

[2]. Yang, C., Cui, G., Wei, Y., & Wang, Y. (2007), “Fault Diagnosis for Induction Motors Using the Wavelet Ridge”, Second International Conference on Bio-Inspired Computing: Theories and Applications, BIC-TA, pp. 231 – 235.

[3]. Khan, M., & Rahman, M. (2006), “Discrete Wavelet Transform Based Detection of Disturbances in Induction Motors”, Electrical and Computer Engineering, ICECE, pp. 462 –465.

[4]. Kia, S., Henao, H., & Capolino, G.-A. (2009), “Diagnosis of Broken-Bar Fault in Induction Machines Using Discrete Wavelet Transform without Slip Estimation” IEEE Transactions on Industry Applications, Vol.45, No.4, pp1395 –1404.

[5]. Levent Eren, Member, IEEE, and Michael J. Devaney, Member, “IEEE Bearing Damage Detection via Wavelet Packet Decomposition of the Stator Current”, IEEE transactions on instrumentation and measurement, VOL. 53, NO. 2, April 2004.

[6]. O. A. Mohammed, Fellow, IEEE, N. Y. Abed, and S. Ganu Modeling and Characterization of Induction Motor Internal Faults Using Finite-Element and Discrete Wavelet Transforms. IEEE transactions on magnetic, VOL. 42, NO. 10, October 2006.

[7]. Shahin Hedayati Kia, Humberto Henao, Senior Member, IEEE, and Gérard-André Capolino, Fellow, IEEE Diagnosis of Broken-Bar Fault in Induction Machines Using Discrete Wavelet Transform Without Slip Estimation.

[8]. Pinjia Zhang, Member, IEEE, Yi Du, Student Member, IEEE, Thomas G. Habetler, Fellow, IEEE, and Bin Lu, Senior Member, IEEE A Survey of Condition Monitoring and Protection Methods for Medium-Voltage Induction Motors. IEEE transactions on industry applications, VOL. 47, NO. 1, January/February 2011.

[9]. Alejandro Ordaz-Moreno, Rene de Jesus Romero-Troncoso, Jose Alberto Vite-Frias, Jesus Rooney Rivera-Gillen, and Arturo Garcia-Perez. Automatic Online Diagnosis Algorithm for Broken-Bar Detection on Induction Motors Based on Discrete Wavelet Transform for FPGA Implementation. IEEE transactions on industrial electronics, VOL. 55, No. 5, May 2008.

[10]. Khalaf Salloum Gaeid Dept. of Electrical Engg. University of Malaya Lembah Pantai, 50603, Kuala Lumpur, Malaysia. Fault Tolerant Control of Induction Motor. Modern Applied Science Vol. 5, No. 4; August 2011.

[11]. Niaoqing Hu, A, Yue Zhang, Fengshou Gu, A, Guojun Qin, B. Andrew Ball, “B1 School of Mechatronics Engineering and Automation”, National University of Defense Technology”, Changsha, Hunan, Conf. on Artificial Intelligence, Knowledge Engineering and Data Bases (AIKED'08), University of Cambridge, UK, Feb 20-22, 2008.