Torque Ripple Reduction Of Direct Torque Controler Of Induction Motor Using Lightning Search Algorithm And Gravitational Search Algorithm

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Abstract - **This paper purposes design & simulation of Direct Torque Control(DTC) induction motor based on Quantum Lightning Search Algorithm (QLSA) and Global Search Algorithm(GSA) algorithm. The developed QLSA is implemented for generation of suitable input to the controller. QLSA minimizes the mean absolute error which improves the performance and speed of the induction motor. The GSA algorithm is used for parameter calculation such as resistance of rotor, varying time inductances and stator current. The performance of both the algorithm is simulated in the Simulink and Matlab software. Different parameters are calculated such as speed control, Torque Ripple control and stator current of the induction motor.**

keywords - **Direct Torque Controller,Quantum lightning Search Algorithm,Gravitational Search Algorithm,Induction Motor**

I. INTRODUCTION

Induction motor are highly used in many industries for various purposes the reason for it is good performance quick flux and torque responses, high torque at slow speed and different speed range. The induction motor has much application due to its well known advantages like brushless structures, low costs and reliable performances. The induction motor is controlled with power switches by which controller can be configured by DSP, microcontrollers and FPGA. Performance of the induction motor depends on which type of technique is used to control the speed like scalar or vector to control the voltage, current, flux, torque, and speed.

Conventional controllers such as PI,PD, and PID were used for controlling induction motor parameters. But this controller has many limitation and disadvantages like trial- and-error, process upset, need calculation, and different mathematical models. To overcome this fuzzy logic controller and direct torque controller are used in scalar and vector control.

By using these controllers the complex calculation and the mathematical model problems are overcame. Space vector pulse width modulation (SVPWM) is used to provide input to the controller which reduces switching loss and harmonic output signals produced by the inverter.

Many attempts have been made to optimize the parameters using different algorithm like GA, PSO and etc. This process are also time consuming to get result system is to pass through various iteration. So to reduce all this parameter the Gravitational algorithm is proposed which is based on Newton's law of motion and gravity which is very competent to the GA and PSO algorithm. And it provides good result in less iteration compared to above algorithm. The GSA algorithm uses four agents position, mass of inertia, active gravitational mass, and passive gravitational mass.

While implementing hardware induction motor uses dSPACE, FPGA and DSP controller. The dSPACE and FPGA are very expensive for implementation and are not reliable for the operation of standalone performances. DSP is used in many applications due to high speed response very less power consumption, calculation power and higher density compared to other processors.

In this work the QLSA and GSA algorithm has been modeled on the DTC of induction motor in MATLAB and SIMULINK.

II. DIRECT TORQUE CONTROLLER PRINCIPLE

The basic working DTC which is used for implementation of the DTC controller is shown in the Fig 1. 3-phase AC supply is provided to the bridge rectifier which produces the DC voltage.A capacitor is used to remove and reduce the ripple content of the DC voltage. The output is filtered DC voltage which is supplies to the inverter switches. The IGBT inverter switches are controlled by the direct torque controller. The output of the inverter is finally connected to the stator terminal of the induction motor which controls the different parameter of induction motor as shown in the below Fig 1.

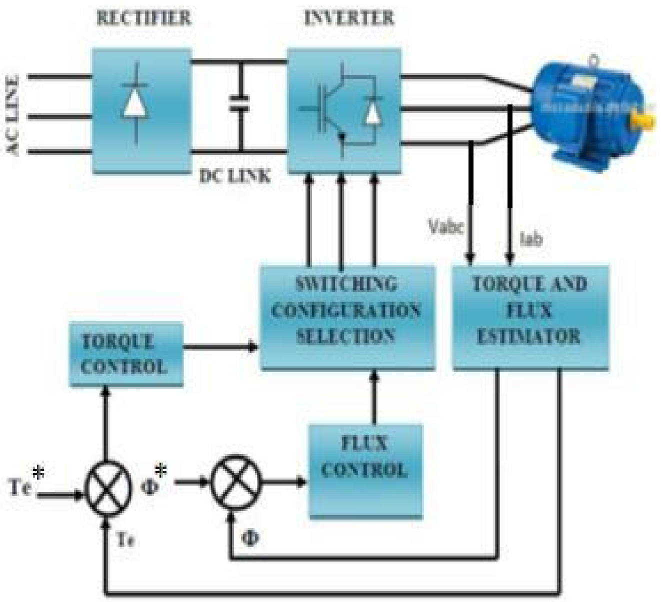

Fig 1 Schematic of basic Direct Torque Controller

I.TORQUE AND FLUX ESTIMATOR

Feedback flux and torque are calculated from the terminal of machine by using it's voltage and current.The phase voltage and currents in stationary references are given by

$$V_{s\alpha}=V_a \text{ and } V_{sb}=-1/\sqrt{3}(V_a+2V_b) \quad (1)$$

$$I_{s\alpha}= I_a \text{ and } I_{s\beta}=-1/\sqrt{3}(I_{sa}+2I_b) \quad (2)$$

The components of stator flux is given by

$$\Phi_{s\alpha}= \int (V_{s\alpha} - R_s I_{s\alpha})\,dt \quad (3)$$

$$\Phi_{s\beta} =\int (V_{s\beta} - R_s I_{s\alpha})\,dt \quad (4)$$

The stator flux magnitude is estimated by

$$\Phi_s=\sqrt{((\Phi_{s\alpha})^2+ (\Phi_{s\beta})^2)} \quad (5)$$

$$T_e=3/2p/2(\Phi_s I_{s\beta}- \Phi_{s\beta} I_{s\alpha}) \quad (6)$$

By using equation (6) the electromagnetic torque can be estimated easily.

II.TORQUE AND FLUX CONTROLLER

Different instantaneous values are calculated from the torque and flux estimator and the torque and flux values are compared and errors are processed by the hysteresis band controller. Following two are the flux loop controller two level digital equations

$$H_\Phi=1 \text{ for } E_\Phi>HB_\Phi \quad (7)$$

$$H_\Phi=-1 \text{ for } E_\Phi<-HB_\Phi \quad (8)$$

The actual stator flux is constrained within the hysteresis band and tracks the command flux. Torque control loop has three levels of digital outputs and it is given by

$$H_t=1 \text{ for } E_t>HB_t \quad (9)$$

$$H_t=-1 \text{ for } E_t>-HB_t \quad (10)$$

$$H_t=0 \text{ for} -HB_t<E_t<+HB_t \quad (11)$$

III..QLSA BASED DTC CONTROLLER

A.Quantum Lightning Search Algorithm

The DTC controller is used in linear as well as non linear control system due to its performance and it does not need mathematical model. In this research a quantum lightning search lightning algorithm is used to find the best input and output membership function (MFs) for the controller(QLSAF)
is explained below.

In this algorithm the attraction and the convergence of each step leader is achieved with a global minimum searches best position by relying the schotastic attractor of the step leader pj as given in following equation

$$pi^t j = \frac{(ai^t j.P^t j.best+b^t ij.GsI^t ij)}{c^t ijSF} \quad (1)$$

for $i = 1,2, \dots, N$, $j = 1,2, \dots, D$, and $t = 1,2, \dots, T$, where N is the population size, D is the problem dimension, and T is the maximum number of iterations, respectively; for the j t $h$dimension of step leaders, *a, b*, and *c* are the three uniformly distributed random numbers on the range of (0,1)*; P i j ,b e s t t* is the best step leader for each population; *G s l i j t* is the best global step leaders used to obtain the minimum value of the evaluation of the best step leaders, and *S F* is scale factor.

In this concept, the quantum behaviour is exhibited in each step leader within its quantum state formulated by a wave function (ψ w), which moves between points, , t and G s l i j t . The wave function, as iteration (t + 1), is represented

$$L^{t}ij = 2\beta|\ Mbest^{t}j - P^{t}j| \quad (2)$$

In each iteration, the distance between step leaders and M b e s t j t directs the new position distribution. Thus, the new position of the step leaders, P i j t +1 is updated as follows.

$$P^{t+1}ij = p^{t}ij \pm \beta|\ Mbest^{t}j - P^{t}j|\ln(1/uij) \quad (3)$$

B.Algorithm Flow of the QLSA Speed Controller

The QLSA is having the fast convergence of solution compared with the other compared conventional optimization techniques because it is inspired by natural phenomenon of lightning. However, it has some limits and disadvantages such as easily trap in local minima, and need the best search for the new position of step leader. The main objective of the QLSA speed controller is to find the best values of the MFs parameters. The parameters used in these algorithms are the number of iterations (T) is 200, and the population size (P) is 30. The QLSAF optimization technique is applied to improve the DTC speed controller and implement into induction motor.

IV. GRAVITATIONAL SEARCH ALGORITHM (GSA)

A. Gravitational search algorithm

The gravitational algorithm uses the Newton's law of gravity and motion. That is stated as gravitational force between two particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. In this algorithm particles considered as objects and their performance has evaluated with their masses. In GSA, each particle has associated with four specifications: particle position, its inertial mass, active gravitational mass and passive gravitational mass. The position of particles provides the solution of problem while fitness function is used to calculate the gravitational and inertial masses. The Gravitational Force is given by '

$$F^{d}ij(t) = G(t) * \frac{Mp^{i}(t) * Ma^{j}(T)}{R^{ij}(t) + e} * (xj^{d}(t) - xi^{d}(t)) \quad (1)$$

In the equation F denotes the gravity, G denotes gravitational constant.M1 and M2 shows the inertial masss of two particles and R is the Eucledian distance between two particles.

$$G(t) = Go\ e^{-(\frac{at}{T})} \quad (2)$$

Where Go is the initial gravitational constant, a is an constant and T is the total number of iteration of the algorithm.The acceleration of particle i on d according to Newton's second law at time t for the acceleration is given by

$$ai^{d} = \frac{Fi^{d}(t)}{Mi(t)} \quad (3)$$

Here Mi(t) is the inertial mass of particle i. The masses has been calculated [13, 14,15]and the max fit and min fit values are also evaluated. With these values the velocity and then the fitness function is updated with the same.

$$vi^{d}(t + 1) = rand * vi^{d}(t) + ai^{d}(t) \quad (4)$$

B. Development of Stator And Rotor Model

The FOC based IM have been designed in MATLAB SIMULINK and simulated with sampling time duration of 1 seconds according to Stanley IFOC model. The three phase power supply is given to the system which is feed as input to the 3phase induction motor and then to the Voltage Source Inverter. The gate signals are controlled by the FOC block where all the axis transformation, flux vector, theta calculation and gate firing angle equations etc which are all function of time varying inductances and rotor resistance. A speed sensor is present which senses the actual speed and this signal is fed back to the controller block as well as FOC block for generation of the unit vector shown in the Fig 2

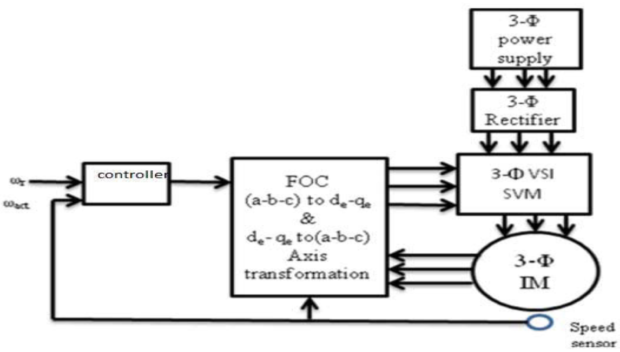

Fig 2. Block Diagram of FOC based induction motor

V. SIMULATION RESULTS

The torque ripple reduction in three phase induction motor is modeled in MATLAB SIMULINK and simulated with sampling time 2 microseconds for a time duration 2 seconds. For Simulink model three phase squirrel cage induction motor is considered. The MATLAB SIMULINK model is shown in figure 3.

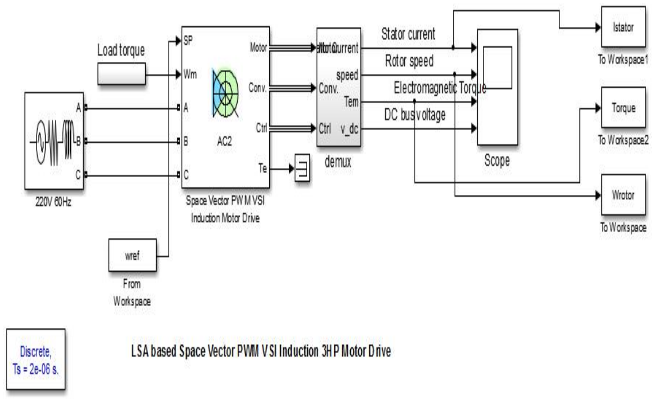

Fig.3 MATLAB SIMULINK model for QLSA & GSA system

The torque ripple can be reduced by controlling the stator current of induction motor. For lightning search algorithm the output speed is taken as feedback and accordingly new optimized set of parameters are provided to space vector PWM Figure 4 shows stator current, speed, torque and DC bus voltage of three phase induction motor.

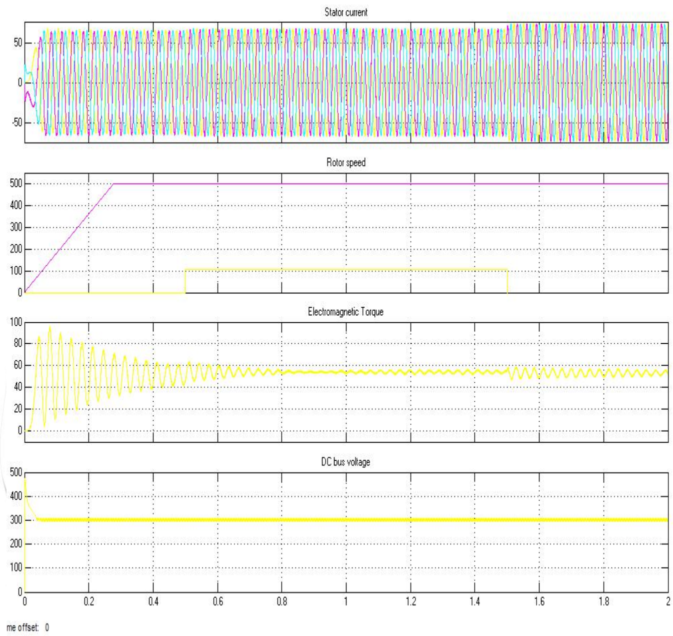

Fig 4. Torque-Speed control of induction motor using QLSA algorithm

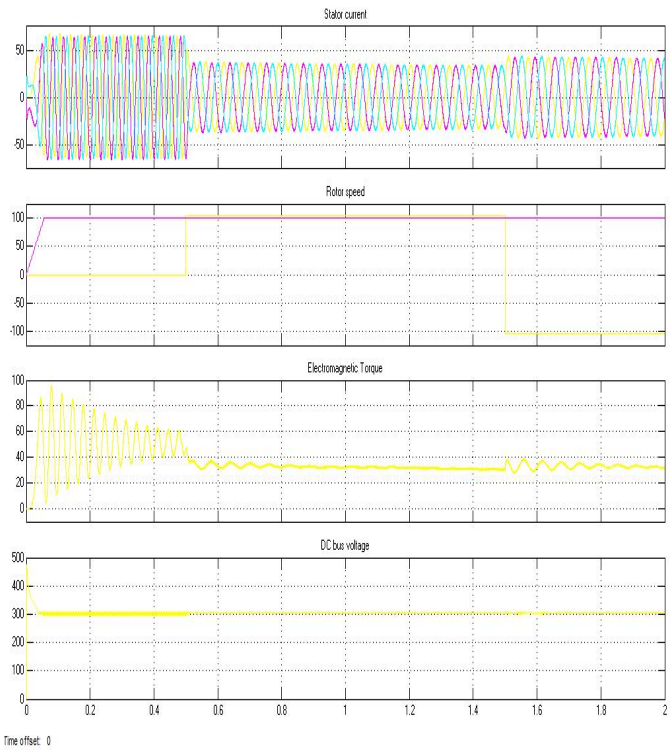

FIG 5. TORQUE-SPEED CONTROL OF INDUCTION MOTOR USING GSA ALGORITHM

VI. CONCLUSION

After observing both the output it can be concluded and observed that the different parameters such as rotor speed, electromagnetic torque, stator current, DC voltages, are quite different. The stator current in GSA is less as compared to QLSA algorithm, due to which the electromagnetic torque ripple also get reduced compared to QLSA algorithm. Thus the speed can be easily controlled in the GSA algorithm. And the design complexity is also less for GSA algorithm as in QLSA algorithm it requires MAF for every step leader which increases the time complexity of the designed system.

REFERENCES

[1] M. A. Hannan, J. A. Ali, A. Hussain, F. H. Hasim, U. A.U. Amirulddin, M. N. Uddin, F. Blaabjerg,, “A Quantum Lightning Search Algorithm based Fuzzy Speed Controller for Induction Motor Drive” ,2169-3536 (c) 2017 IEEE.

[2]Tista Banerjee, Jitendranath Bera, Gautam Sarkar, “Parameter Estimation of Three Phase Induction Motor using Gravitational Search Algorithm for IFOC”, Michael Faraday IET International Summit: MFIIS-2015, September 12 – 13, 2015.

[3] Anjana Manuel1, Jebin Francis, “Torque Ripple Reduction of Direct Torque Controlled Induction Motor Drive by using Space Vector Modulation”, Vol. 2, Special Issue 1, December 2013,IJAREEIE.

[4] KUN QIAN , WEI LI, AND WEIYI QIAN, “Hybrid Gravitational Search Algorithm Based on Fuzzy Logic”, Vol 5, 2017,2169-3536 2017 IEEE.

[5]Jamal Abd Ali,M A Hannan3, Azah Mohamed,“Optimized Speed Controller for Induction Motor Drive Using Quantum Lightning Search Algorithm”, 978-1-5090-2547-3/16/$31.00 ©2016 IEEE.

[6] Hussain Shareef, Md. Mainul Islam , Ahmad Asrul Ibrahim , Ammar Hussein Mutlag, “A Nature Inspired Heuristic Optimization Algorithm Based on Lightning”, 2015 Third International Conference on Artificial Intelligence, Modelling and Simulation, 978-1-4673-8675-3/15 $31.00 © 2015 IEEE.

[7] J. A. Ali, M. A. Hannan, and A. Mohamed, "PSO algorithm for Three Phase Induction Motor drive with SVPWM Switching and V/f Control," in Power and Energy (PECon), 2014 IEEE International Conference on, 2014, pp. 250-254.

[8] M. Demirtas, "DSP-based sliding mode speed control of induction motor using neuro-genetic structure," Expert Systems with Applications, vol. 36, pp. 5533-5540, 2009.

[9] A. Hazzab, I. K. Bousserhane, M. Zerbo, and P. Sicard, "Real Time Implementation of Fuzzy Gain Scheduling of PI Controller for Induction Machine Control," in Information and Communication Technologies, 2006. ICTTA '06. 2nd, 2006, pp. 1416-1421.

[10] J. A. Ali, M. Hannan, and A. Mohamed, "Improved Indirect Field- Oriented Control Of Induction Motor Drive Based Pso Algorithm," Jurnal Teknologi, vol. 78, 2016.

[11] S. Hazra and P. S. Sensarma, "Self-excitation and control of an induction generator in a stand-alone wind energy conversion system," IET Renewable Power Generation, vol. 4, pp. 383-393, 2010.