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A New Approach to Direct Torque Control of Induction Motor Drive with GA Controller for Torque Ripple Reduction

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Abstract –The Direct Torque Control (DTC) strategy is one of the best strategies of speed control of Induction Motor Drive (IMD). This scheme is simple in structure and produces fast and robust response in A.C drive system. How ever, this scheme is encountered with the possible problems of high torque, flux and current ripples. The deviation of electromagnetic torque from its reference value causes vibration and noise which reduces the efficiency of the drive. The Genetic Algorithm is recently getting growing importance in soft control applications. This paper focuses on the simulation of a Direct Torque Controlled Voltage Source Inverter-fed Induction Motor Drive employing a Refined Genetic Algorithm Controller (RGAC) to encounter the above problems and to devise a more effective method of speed control. Finally, the simulation results of Conventional DTC and RGAC-DTC drive are compared. It is observed that the torque and flux ripples are less in the proposed scheme and offers improved dynamic response.

Keywords- Direct Torque Control (DTC), Refined Genetic Algorithm Controller (RGAC), Induction Motor Drive (IMD), Torque ripples, Flux ripples, Current ripples, Voltage Source Inverter (VSI).

I. INTRODUCTION

In this era of industrialization for a developing economy, advanced motion control and high performance electric drives play a vital role for the productivity and product quality [1-25]. Although, majority of variable speed drive applications use DC machines, they are progressively being replaced by AC drives, especially, squirrel-cage induction motor drives (IMD).With the recent technological innovation in converters and the development of the complex and robust control algorithms, consistent research effort is devoted towards the development of optimal control technique of speed for induction motor drives. Induction motors have very wide range of industrial applications due to its simple construction, ruggedness, reliability, high efficiency, and high overload capability, low cost and minimum maintenance. However, due to their highly coupled and non- linear structure, high performance control of induction motor is a challenging problem

Direct Torque Control (DTC) and Field Oriented Control (FOC) are two viable schemes for induction motor torque control for high dynamic performance operation [1-11]. FOC involves the transformation of stator current into a synchronously rotating d-q reference frame aligned with one of the stator fluxes, typically the rotor flux so that the torque and flux producing components of stator currents are decoupled, such that the d-axis component of stator currents controls the rotor flux magnitude and q-axis component controls the output torque. Direct Torque Control (DTC), as the name implies, is obtained by the fact that, on the basis of the errors between the reference and calculated values of torque as well as flux errors, it is very much feasible to have a direct control over the inverter states, so as to minimize the torque and flux errors within the prefixed band limits. Hence, it is characterized by directly controlled torque and flux and indirectly stator voltage and current. The DTC regularly applies the appropriate voltage vector so as to maintain both the torque and stator flux within two hysteresis bands [12] resulting in bang bang behaviour and produces a variable switching frequency and considerable amount of ripples in flux and torque and high current distortion.

The significant attributes of DTC is the simple structure, simple control algorithms, acceptably fast dynamic characteristics, free from intricate calculations, low sensitivity to parameter variations, high performance and

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efficiency of industrial drives. The DTC is mostly used to improve the distortion of flux and to have excellent dynamic performances. Despite numerous advantages, this method has the shortcomings like probable difficulties during starting, requirement of torque and flux estimators involving the ensuing parameters identification, and the most disadvantage possession for this method is inherent torque and flux ripples.

In the recent years many efforts have been carried out to devise varieties approach of solutions for the control strategies of induction motor to accomplish accurate and fast torque response and the minimization of stator flux and torque ripples. Amongst all the control strategies taken up, Direct Torque Control technique has played a very important role to achieve these requirements. However, there is a need for further development in the control strategy to opt for the best set of stator winding space vectors. By implementing various novel DTC scheme based on fuzzy logic the torque ripples are diminished and dynamic performance is improved [13-15]. In the design of drives an endeavor has been made to reduce the input data so as to minimize computational time and update the parameters for system dynamic equations. Hence it is preferable to make use of a sensor less drive and to employ such dynamic equations that involve lower number of parameters [16-18].

A new direct torque and flux control based on Space Vector Modulation (DTC-SVM) for sensor less induction motor drive has been introduced which has the better capability for reducing the torque, flux, speed pulsations and the acoustical noise during steady-state [16].

It is reported that a modified DTC Space Vector Modulation based on fuzzy-logic control (Fuzzy DTC-SVM) strategy is able to trim down flux and torque ripples, diminish stator current distortion and exhibits fast response of rotor speed [19]. An improvement in drive performance can be attained by using a new DTC strategy based on a Discrete Space Vector Modulation (DSVM) technique which uses prefixed time intervals within a cycle period causing increased number of voltage space vectors and the choice of space voltage vectors is made suitable with respect to the speed of the rotor, the flux error and torque error [20].

Particle Swarm Optimization technique (PSO) is an Evolution technique that finds the optimal regions of complex search spaces of interaction of individuals in a population of particles and proved to be efficient for solution of continuous non-linear optimization problems. A new PSO based DTC strategy for induction motor employing PSO-PID Controller could be able to minimize the torque ripples and augment system speed and stability [21].

The fuzzy-Genetic Algorithm (GA) Direct Torque Control hybrid model of induction motor enhances the effectiveness and viability of the control system compared to the fuzzy logic stand alone control architecture model [22].The low speed performances of DTC can be enhanced by introducing the intelligent optimization algorithm to fuzzy- neural network controller adopting the direct torque control system. The GA can optimize the weights and encounter the defects and makes the control simple and dynamic response of Torque is fast [23]. A new method is proposed where two types of voltage source inverters are employed on the saturation model of induction motors, first using torque control and the second using speed control. Next GA and PSO technique are incorporated for the improvement of speed control in case of two or three level inverters [24]. In a new strategy the PID parameters of speed regulator is optimized using GA and hence the given torque is improved precisely and the dynamic torque response is more attractive than the conventional DTC [25].

To highlight the activities of each section, this paper is organized as follows. Section II describes the Principle of DTC. In section III, Digital simulation of Conventional DTC has been described. In section IV, Implementation of GA in DTC has been introduced. In section V, Results and discussions are presented. Conclusions are then summarized in last section.

II. DIRECT TORQUE CONTROL PRINCIPLE [3]

The most familiar technique to achieve the DTC is the use of popular switching table based DTC strategy that stores the switching information in a three dimensional look -up table. The three variables are the flux and torque errors and the spatial position of the flux vector linking the stator winding [1-6].

Table I represents a typical switching table, where S_λ is the flux logic. Logic '1' and logic '0' denote an increase and decrease in flux magnitude respectively, shown in Table II. Similarly, S_T denotes the torque logic. Logic '1', '0' and '-1' denote the control action carried out towards increase, to maintain as it is and decrease of the developed motor torque shown in Table III. S_θ corresponds to one of the six spatial sectors; the instantaneous stator-linked flux lies in. The required inverter output vector is stated on the above table using roman numerals according to the three input variables (S_λ, S_T *and* S_θ). There are six active voltage vectors (I-VI) and two null vectors (VII & VIII) specified by the corresponding switching pattern (within small brackets) shown along with the numeral representing space voltage vector.

The six active space vectors and all the six spatial sectors <6>, <5>, <4>, <3>, <2> and <1> move in the anti-clock wise direction in the d-q plane depicted in Fig a. Each voltage vector is placed at the centre of corresponding sector.

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In all the reported work the switching table based DTC has been realized with the help of some fast digital processor like, DSP or some PC. The actual motor currents and the dc link voltages are properly sensed and fed to the computing device. On the basis of the switching output pattern by PC or DSP and the knowledge of dc link voltage, the instantaneous magnitude of line voltages of three-phase motor are computed.

TABLE I
DTC SWITCHING TABLE

S_λ	S_T	S_θ					
		<1>	<2>	<3>	<4>	<5>	<6>
1	1	VI (110)	I (100)	II (101)	III (001)	IV (011)	V (010)
1	0	VIII (111)	VII (000)	VIII (111)	VII (000)	VIII (111)	VII (000)
1	-1	II (101)	III (001)	IV (011)	V (010)	VI (110)	I (100)
0	1	V (010)	VI (110)	I (100)	II (101)	III (001)	IV (011)
0	0	VII (000)	VIII (111)	VII (000)	VIII (111)	VII (000)	VIII (111)
0	-1	III (001)	IV (011)	V (010)	VI (110)	I (100)	II (101)

The q and d- axis voltage and currents are decided from three-phase (a, b, c) quantities as per (1) to (4), given by,

$$v_{qs} = v_{an} = \frac{2}{3} v_{ab} + \frac{1}{3} v_{bc} \qquad (1)$$

$$v_{ds} = \frac{1}{\sqrt{3}} \left(- v_{bc} \right) \qquad (2)$$

$$i_{qs} = i_{as} \qquad (3)$$

$$i_{ds} = \frac{1}{\sqrt{3}} . \left(i_{cs} - i_{bs} \right) \qquad (4)$$

Similarly, the q and d axis stator flux linkages are given by (5) and 6), [1] .

$$\lambda_{qs} = \int \left(v_{qs} - R_s i_{qs} \right) dt \qquad (5)$$

$$\lambda_{ds} = \int \left(v_{ds} - R_s i_{ds} \right) dt \qquad (6)$$

Where , λ, v, R, i and t represent the flux, voltage, resistance, current and time respectively.

The subscripts d, q and s represent the direct, quadrature and stator respectively.

The resultant flux linking the stator winding is

$$\lambda_s = \sqrt{\left(\lambda_{ds}^2 + \lambda_{qs}^2 \right)} \qquad (7)$$

The electromagnetic Torque developed by motor is given by,

$$T_e = \frac{3}{2} . \frac{P}{2} . \left(\lambda_{ds} . i_{qs} - \lambda_{qs} . i_{ds} \right) \qquad (8)$$

Now λ_s and its reference magnitude are compared and its flux error logic state S_λ is shown in the Table II. λ_{er} is the difference between the reference and actual magnitude of stator linked flux and $\delta\lambda_s$ is the defined error band .

TABLE II
FLUX-ERROR LOGIC STATE TABLE

Condition	S_λ
$\lambda_{er} > \delta\lambda_s$	1
$\lambda_{er} \le \delta\lambda_s$	0

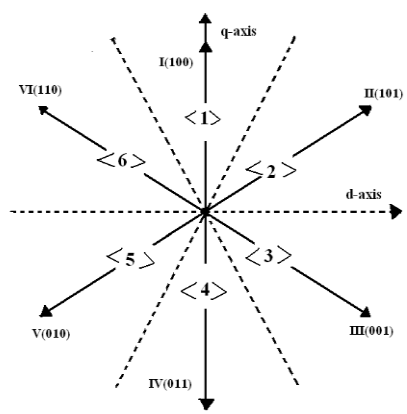

Fig. a. Space voltage vectors and spatial sectors

TABLE III
TORQUE- ERROR LOGIC STATE

Condition	S_T
$\left(T_e^* - T_e \right) > \delta T_e$	1
$-\delta T_e \le \left(T_e^* - T_e \right) \le \delta T_e$	0
$\left(T_e^* - T_e \right) < \left(-\delta T_e \right)$	-1

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TABLE IV
SECTOR SELECTION ALGORITHM

Θ_{fs}	Sector No.(S_θ)
$0 \le \theta_{fs} \le \frac{\Pi}{3}$	<2>
$-\frac{\Pi}{3} \le \theta_{fs} \le 0$	<3>
$-\frac{2\Pi}{3} \le \theta_{fs} \le -\frac{\Pi}{3}$	<4>
$-\Pi \le \theta_{fs} \le \frac{-2\Pi}{3}$	<5>
$\frac{2\Pi}{3} \le \theta_{fs} \le \Pi$	<6>
$\frac{\Pi}{3} \le \theta_{fs} \le \frac{2\Pi}{3}$	<1>

III. DIGITAL SIMULATION FOR CONVENTIONAL DTC [10]

Digital simulation of Direct Torque Control induction motor drive is executed in "MATLAB" environment. As regards to simulation steps, firstly, all variables are initialized and all machine constants are assigned their numerical values obtained from the name plate of laboratory type induction motor. The machine is simulated for rated flux operation and the reference template of torque command, described bellow and is fed to the simulation programme. The torque error as well as flux error are computed. The hysteresis error band is assumed ±2% and ±1% for rated torque and rated flux on either side respectively. Table IV will decide the stator flux position. According to the torque and flux error and position of stator flux, the inverter switching is assumed and the possible pole voltages are determined with respect to the DC negative bus as in Table I. The three-phase voltages obtained from inverter are properly transformed into q and d axis as discussed previously in (1) & (2). The stator and rotor d-q axis currents in stationary reference frame are obtained by solving (9) to (12). Similarly machine flux is calculated by using (5) & (6) and the torque is calculated by using (8). The motor speed is calculated by solving (13), (the mechanical equation) based on the torque developed.

$$\frac{di_{qs}}{dt} = \frac{L_r\left(v_{qs} - R_s i_{qs}\right) - \omega_r L_m^2 i_{ds}}{\left(L_s L_r - L_m^2\right)} + \frac{L_m R_r i_{qr} - \omega_r L_r L_m i_{dr}}{\left(L_s L_r - L_m^2\right)} \quad (9)$$

$$\frac{di_{ds}}{dt} = \frac{L_r.\left(v_{ds} - R_s i_{ds}\right) + \omega_r L_m^2 i_{qs}}{\left(L_s L_r - L_m^2\right)} + \frac{L_m R_r i_{dr} + \omega_r L_r L_m i_{qr}}{\left(L_s L_r - L_m^2\right)} \quad (10)$$

$$\frac{di_{qr}}{dt} = \frac{L_m.\left(v_{qs} - R_s i_{qs}\right) - \omega_r L_s L_m i_{ds}}{\left(L_m{}^2 - L_s L_r\right)} + \frac{L_s R_r i_{qr} - \omega_r L_r L_s i_{dr}}{\left(L_m{}^2 - L_s L_r\right)} \quad (11)$$

$$\frac{di_{dr}}{dt} = \frac{L_m.\left(v_{ds} - R_s i_{ds}\right) + \omega_r L_s L_m i_{qs}}{\left(L_m^2 - L_S.L_r\right)} + \frac{L_s R_r i_{dr} + \omega_r L_r L_s i_{qr}}{\left(L_m^2 - L_s L_r\right)} \quad (12)$$

For equations (9) to (12), L and ω represent the inductance and electrical angular frequency respectively. The subscripts r and m stand for rotor and magnetic branch respectively. The initial values of rotor speed and currents are assumed zero. Assuming constant speed inside the inner loop, the current, flux and torque are obtained using Runge-Kutta 4th order method. The differential equation describing the mechanical motion of the drive system is given by,

$$J\frac{d\omega_r}{dt} + B\omega_r = \frac{P}{2}.\left(T_e - T_L\right) \quad (13)$$

Where J is the moment of inertia of the drive, B is the damping coefficient and T_L is the load torque. In the present simulation study, T_L has been assumed as frictional torque. The rotor speed is found by solving the above mechanical equation at the outer loop using the above method. The rotor speed obtained from the above is used in calculation of next set of inner loop quantities. The inner loop runs for 32 consecutive time-step of smaller magnitude before proceeding to the outer speed loop. The simulation continues till the final specified time is achieved. The simulation results so obtained for voltage, current, speed, flux and torque are plotted using Microsoft Excel package

IV. IMPLEMENTATION OF GA IN DTC [22-25]

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Genetic Algorithm (GA) is a kind of stochastic global search optimization technique inspired from genetic and evolution mechanisms observed in the natural systems. Presently, GA is regarded as an effective and efficient technique for selection of optimization problems. It outweighs the other optimization techniques like simulating annealing technique and random search method techniques in avoiding the local minima which is the foremost issue for non-linear systems**.** Moreover, the key feature of GA is that it is a derivative free optimization technique and goes well with the applications that involve smooth less or noisy signals. In searching a large state -space, multi-modal state-space or n-dimensional surface, a GA offers substantial benefits over more typical search of optimization techniques. The motto of the GA is the survival of the fittest among the string structures to form a search algorithm with some of the innovative flair of the human search. GA starts with an initial population containing a number of chromosomes, where search member could represent a solution of the problem of which is judged by a fitness function, the index of performance. Basically, GA includes three main stages: selection, crossover and mutation. The basic operations of all these stages are the creation of new individuals that could be better than their parents. Then the algorithm gets repeated for many generations and the process comes to an end when reaching individuals that validate the optimum solution of the problem. A typical Genetic Algorithm Architecture for DTC is illustrated in Fig b and a Refined Genetic Algorithm (RGA) Controller is implemented in the Conventional DTC scheme as shown in Fig c.

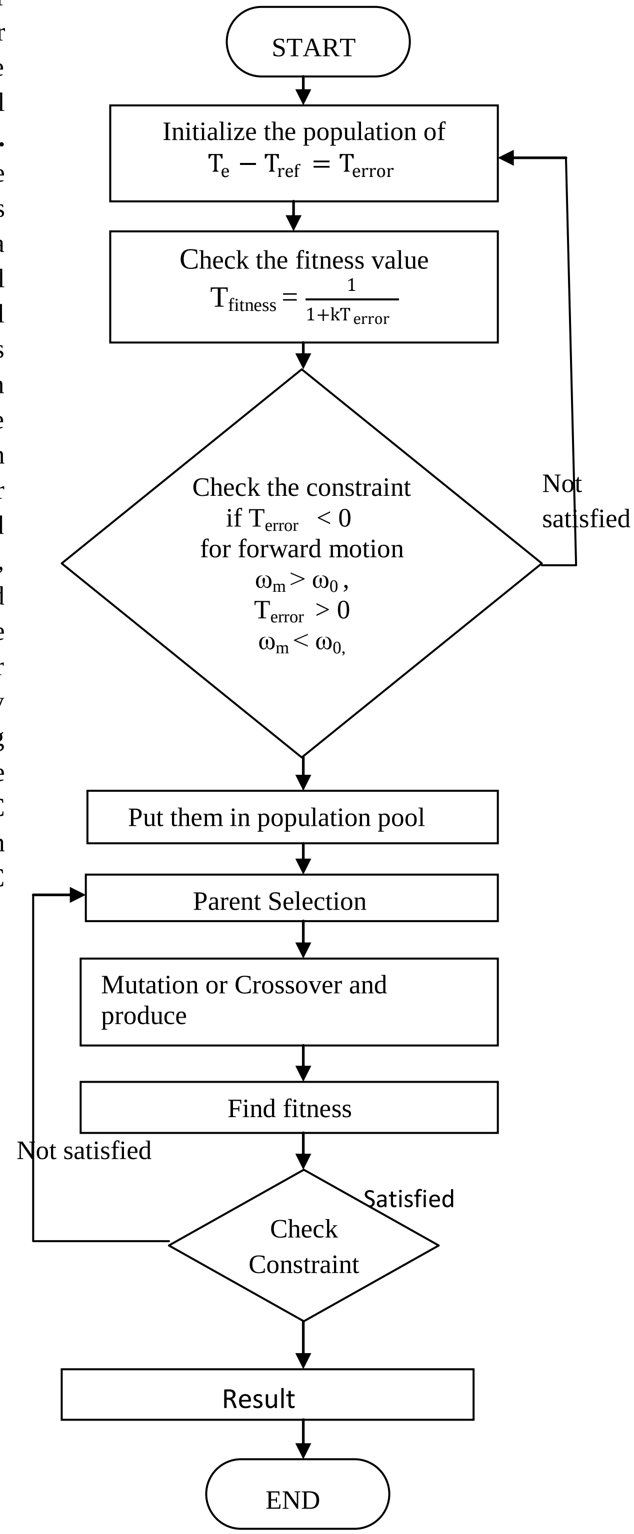

Fig. b. Refined Genetic Algorithm Architecture for DTC

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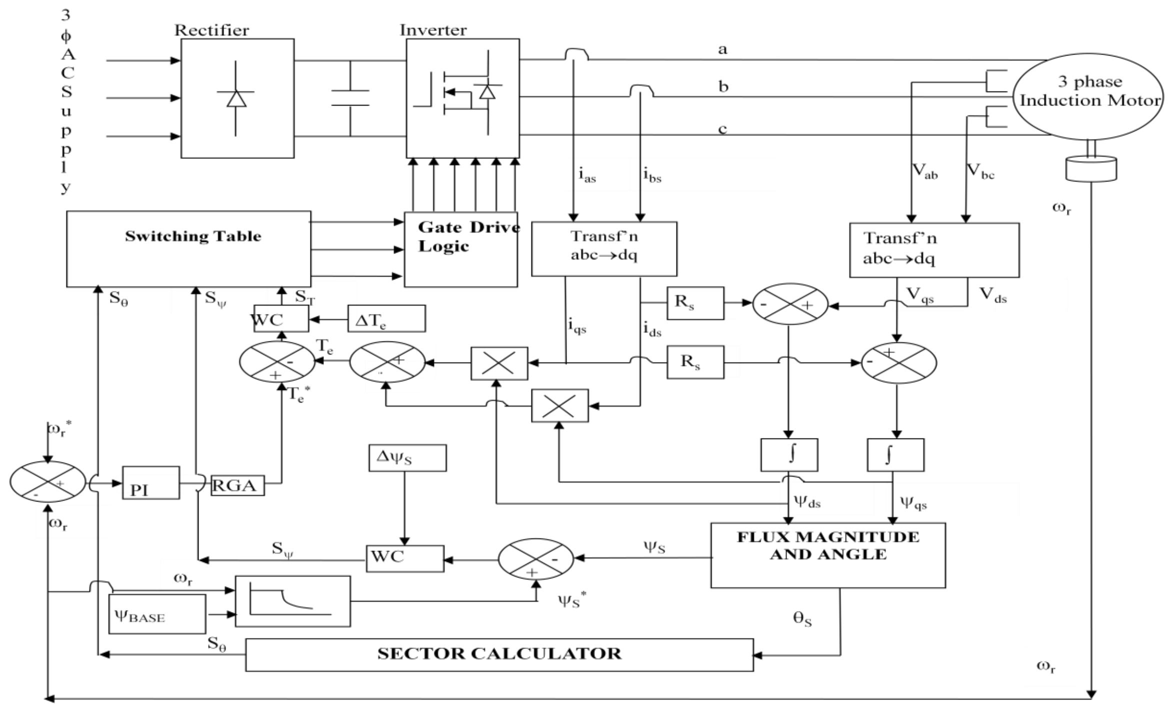

Fig. c. DTC Scheme with Refined Genetic Algorithm (RGA) Controller

V. RESULTS AND DISCUSSION

In order to illustrate the effectiveness of the proposed work a comparative study is done between conventional DTC and a new Refined Genetic Algorithm based DTC (RGAC-DTC), shown in Table V. The study and analysis is made on simulation in MATLAB platform for a three-phase, 220V, 50 Hz, 0.75 KW rating IMD. In fact, the GA based approach is principally used to optimize torque error along with other controllers used in DTC.

The red and blue colours have been used for the reference and actual quantities respectively for both speed as well as the torque. Here, reference speed is set at 310 rad/sec. In Fig 1(a) for Conventional DTC, the actual speed is 308.6 rad/sec, where as in Fig 1(b), in RGAC-DTC, the actual speed is 309.85 rad/sec. Obviously, the speed error is more in conventional DTC as compared to the RGAC-DTC, where both the reference and actual speed is almost merged and this scheme is more attractive than the Conventional one.

Fig 3(a) and 3(b) are the magnified version of Fig 2(a) and Fig 2(b).If we study the behaviour of Ids1 and Iqs1 in Fig 3(a) , for conventional DTC and Fig 3(b), for RGAC-DTC, it is found that the current in both the d and q axes are sinusoidal and quadrature to each other and the frequencies of both components of stator current change while their respective amplitudes remain identical and constant, but distortion is slightly less in RGAC-DTC. A very similar trend of flux distortion between d-axis flux and q-axis flux in Fig 4(a) and Fig 4(b), is observed with d- flux leading. From above, it is seen that the frequency of current and stator flux varies gradually in tune with increasing rotor speed. The stator flux and current have been maintained constant. It is observed that the ripple contents in flux are less in RGAC-DTC than Conventional DTC.

From Table V it is evident that the torque control within the recommended reference values, RGAC-DTC is established to have better range of torque control with improved dynamic response. The ripple content is also less compared to the Conventional DTC, depicted in Fig 5(b) and Fig 5(a) respectively.

In Fig 6(a) and Fig 6(b), all the stator currents are sinusoidal and the current magnitudes and the frequencies vary in response to the torque command. However, the ripple contents are less in RGAC-DTC than conventional DTC with the increase in time. The harmonic current and voltage have small impact on the rotor flux thus having a nearly sinusoidal shape. The output of the hysteresis

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controllers with values 0 and 1 determine the inverter voltage vector depending on the different switching technique control algorithm. Fig 7(a) and Fig 7(b) show the inverter switching voltages for all the phases for both the scheme. Similarly, Fig 8(a) and Fig 8(b) illustrate the behaviour of d-axis and q-axis voltage for both the schemes. It is also seen that in Fig 9(a) and Fig 9(b), the flux trajectories are close to a circle and approximately similar in both the cases. However, there is a smaller deviation from the circular path of progress marked in RGAC-DTC than the Conventional DTC.

This is because; the proposed RGAC-DTC strategy for the IMD has reduced the level of harmonic contents in the stator fluxes.

TABLE V
COMPARATIVE STUDY OF CONVENTIONAL DTC AND RGAC-DTC

Conventional DTC	RGAC-DTC
ω=308.6 rad /sec	ω =309.85 rad /sec
T_{act} =1.5 - 0.2 N-m	T_{act} =1.5 - 0.26 N-m
T_{ref} =1.6 – 0.5 N-m	T_{ref} =1.6 – 0.3 N-m
I=1.3-1.9 Amp	I=1.3–1.9 Amp
λ=0.57 Wb	λ=0.57 Wb

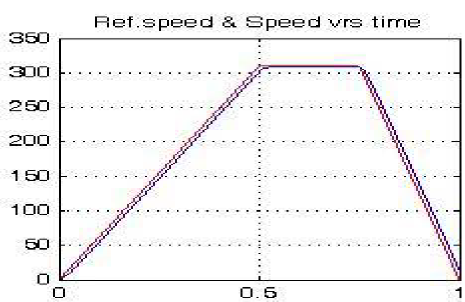

Fig. 1(a) Variation of Reference speed (rad/sec) and Actual speed (rad/sec) vrs time (sec) for Conventional DTC.

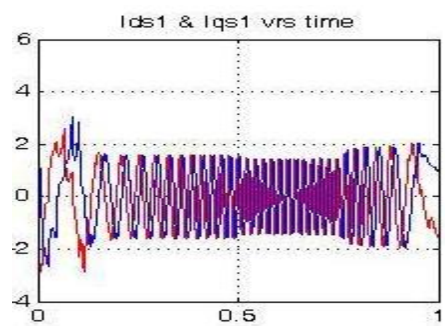

Fig. 2(a). Variation of Ids1 (Amp) and Iqs1 (Amp) vrs time (sec) for Conventional DTC.

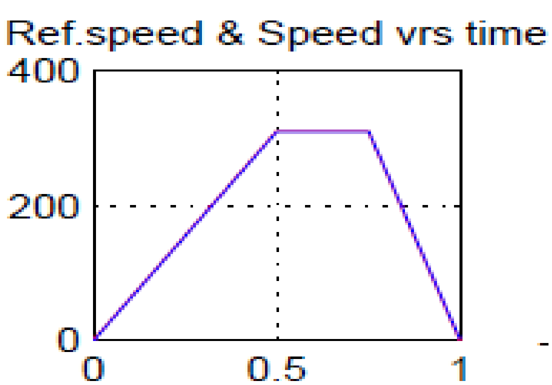

Fig. 1(b). Variation of Reference speed (rad/sec) and Actual speed (rad/sec) vrs time (sec) for RGAC-DTC.

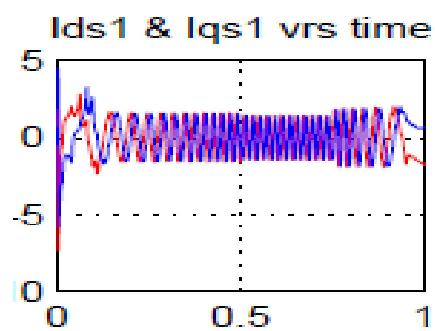

Fig. 2(b).Variation of Ids1 (Amp) and Iqs1 (Amp) vrs time (sec) for RGAC-DTC .

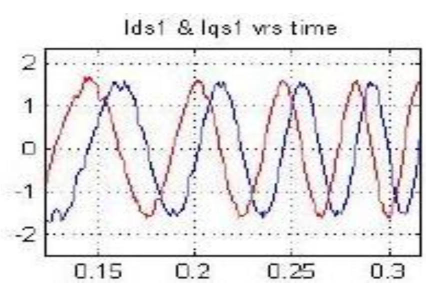

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Fig. 3(a). Variation of Ids1 (Amp) and Iqs1 (Amp) vrs time (sec) for Conventional DTC(magnified)

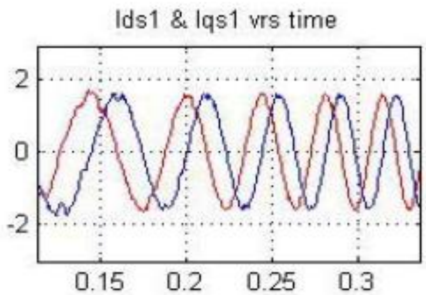

Fig. 3(b). Variation of Ids1(Amp) and Iqs1(Amp) vrs time, (sec) for RGAC-DTC(magnified).

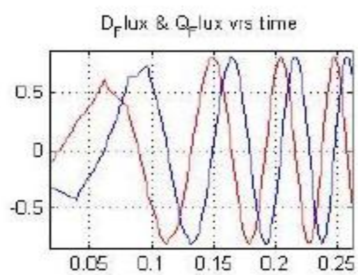

Fig. 4(a). Variation of D_{Flux} (Wb) and Q_{Flux} (Wb) vrs time (sec) for Conventional DTC

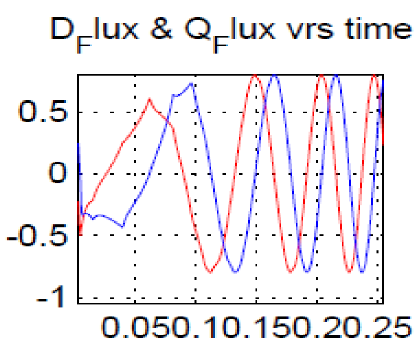

Fig. 4(b). Variation of D_{Flux} (Wb) and Q_{Flux} (Wb) vrs time (sec) for RGAC-DTC

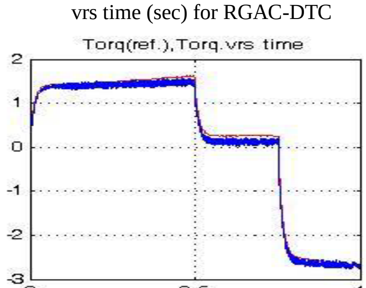

Fig. 5(a).Variation of Reference Torque (N-m) and Actual Torque (N-m) vrs time(sec) for Conventional DTC.

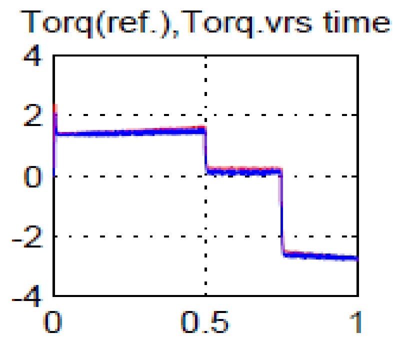

Fig.5(b). Variation of Reference Torque (N-m) and Actual Torque (N-m) vrs time (sec) for RGAC-DTC.

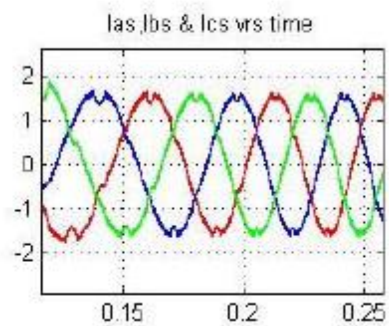

Fig. 6(a). Stator currents (Amp) vrs time (sec) for Conventional DTC

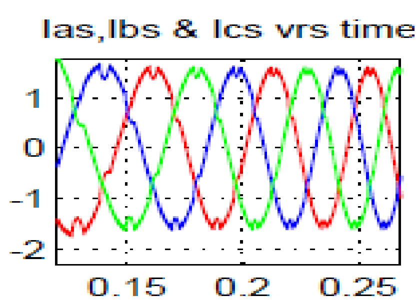

Fig. 6(b). Stator currents (Amp) vrs time (sec) for RGAC-DTC

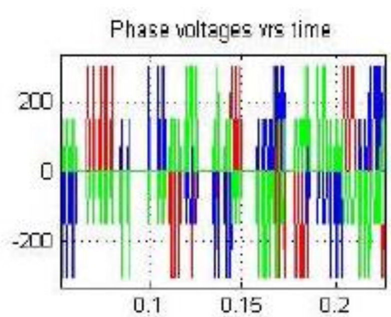

Fig.7(a). Phase voltage (Volt) vrs time (sec) for. Conventional DTC

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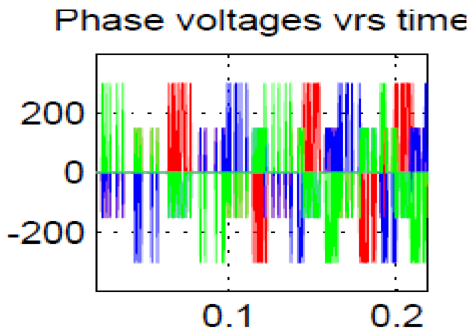

Fig.7(b). Phase voltage (Volt) vrs time (sec) for RGAC-DTC.

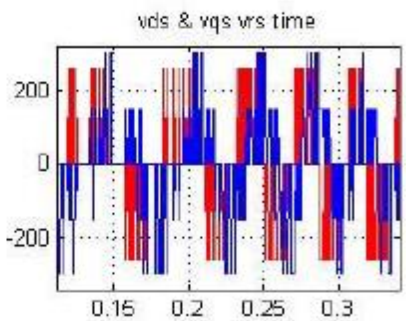

Fig. 8(a). Vds (Volt) and Vqs (Volt) vrs time (sec) for Conventional DTC

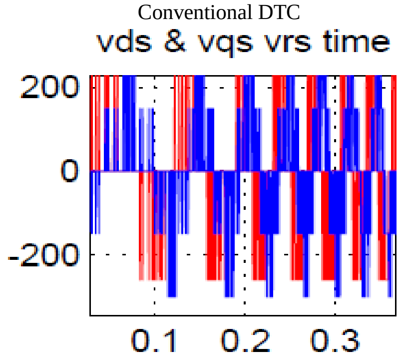

Fig. 8(b). Vds (Volt) and Vqs (Volt) vrs time (sec) for RGAC-DTC

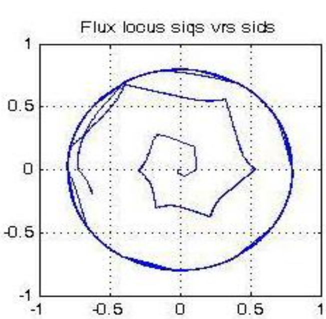

Fig. 9(a). Flux locus Siqs (Wb) vrs Sids (Wb) for Conventional DTC

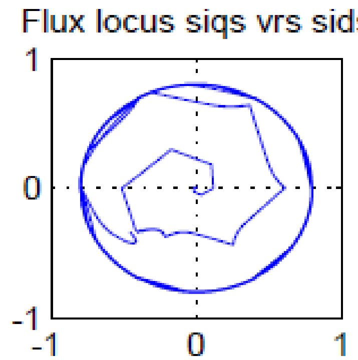

Fig. 9(b). Flux locus Siqs (Wb) vrs Sids (Wb) for RGAC-DTC

VI. CONCLUSION

In this investigation, a GA based controller has been developed and incorporated with the conventional DTC (RGAC-DTC) for a three-phase IMD and discussed in details. The major problem associated with Conventional DTC hysteresis band torque controller is the presence of high torque and flux ripples. The results of both the schemes were compared to assess the performance of drive in terms of speed, torque, flux, and current ripples. From simulation results, it is concluded that, with the proposed controller, the ripples of electromagnetic torque, flux and currents are significantly reduced and very close control up to the base speed is possible. Further, this new strategy shows that both steady state and transient responses have significantly improved and the overall performance of the drive is satisfactory.

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APPENDIX

Induction motor parameters:

Rated power:0.75 KW;3-phase,Stator: 220 V, 50 Hz, Star connected, 3 A, Rated Torque:1.5 N-m; Rated flux:0.57 Wb; Rated speed:1440 RPM; rs=12.03 Ω; rr = 7.17 Ω: Lm=0.5460 H;Ls=0.5653 H; Lr=0.5896 H; Moment of inertia J=0.0044 Kg-m^2;Damping Coefficient B =0.0008 N.m.sec/rad.

REFERENCES

[1] Isao Takahashi, Tashhiko Nagauchi, “A new quick response and high efficiency control strategy of an induction motor “, IEEE Trans. on Ind. Appl., Vol. 1A-22 , No.5, pp. 820-827, 1986.

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ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 1, January 2014

[2] I. Takahashi, Y. Ohmori, "High performance Direct torque control of an induction machine", IEEE Trans. on Ind. Appl., Vol. 1A-25, No. 2, pp. 257-264, 1989

[3] Bibhu Prasad Panigrahi, Dinkar Prasad ,Sabyasachi SenGupta, "A simple Hardware realization of switching table based direct torque control of induction motor", Electrical Power System Research ,Vol. 77, Science Direct, pp. 181-190, 2007.

[4] A. Ba-Razzouk, A. Cheriti, P. Sicard, "Implementation of a DSP based Real time estimator of induction motor rotor time constant, "IEEE Trans. on Power Electron., Vol. 17, No. 4, pp. 534-542, 2002.

[5] J. Holtz and J. Quan, "Sensorless vector Control of induction motors at very low speed using a non-linear inverter model and parameter identification", IEEE Trans. on Ind. Appl., Vol. 38, No. 4, pp. 1087-1094, 2002

[6] J. Luukko, M. Niemela, j. Pyrhonen, "Estimation of the flux linkage in a Direct-Torque-controlled device", IEEE Trans. on Ind. Electron., Vol. 50, No. 2, pp. 283-28, 2003

[7] J. Faiz, M. B. Bannae Sharifian, A. Keyhani, A. B. Proca, "Sensorless Direct Torque Control of induction motors used in electric vehicle", IEEE Trans.on Energy Convs., Vol. 18, No.1, pp. 220-227, 2003

[8] G. S. Buja, M.P. Kazmierkowski, "Direct Torque Control of PWM inverter-fed AC motors-A survey", IEEE Trans. on Ind. Electron. Vol. 51, No. 4, pp. 744-757, 2004

[9] Domenico Casadei, Member, IEEE, Francesco Profumo, Senior Member, IEEE, Gioovanni Serra, Member, IEEE, Angelo Tani, " FOC and DTC: Two Viable Schemes for Induction Motors Torque Control" IEEE Trans. on Power Electron", Vol. 17, No. 5.pp. 779-787, 2002

[10] Bibhu Prasad Panigrahi, Dinkar Prasad, Sabyasachi SenGupta,"Digital Simulation and PC Based Implementation of Switching Table Based Direct Torque Control of Induction Motor Drive",National Power Conference, NPEC,2005,Indian Institute of Technology, Kharagpur, pp. 1-6,2005

[11] D. Prasad,B.P. Panigrahi, S.SenGupta, " Digital Simulation and hardware implementation of a simple scheme for Direct Torque Control of an Induction Motor", Energy Conversion and Management, Vol. 49, No. 4, pp. 687-697, 2008

[12] Lokanatha Dhall Samanta, Bibhuti Bhusan Pati, Bibhu Prasad Panigrahi, "Direct Flux and Torque Control of Induction Motor Drive Changing the Hysteresis Band Amplitude", International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, Vol.1, Issue 9, pp.421- 424,December 2013

[13] Ramon C. Orost, Guillermo O. Forte, Luis Canal " Scalar Speed Control of d-q induction motor model using fuzzy logic cotroller",IEEE, 2007.

[14] Guohan Lin, Zhiwei Xu, "Direct Torque Control of Induction Motor based on Fuzzy Logic", 2010 IEEE 2nd International Conference on Computer Engineering & Technology, Vol. 4, pp. 651-654. 978-1-4244-6349-7/10/$26.00 _©2010 IEEE

[15] M. Nasir Uddin, Senior member, IEEE, Muhammed Hafiz, "FLC based DTC Scheme to improve the Dynamic Performance of Induction Motor Drive", 978 -1-4244-6395-4/10/ $26.00©2010 IEEE

[16] Christian Lascu, Ion Boldea, Frede Blaabjerg, " A Modified Direct Torque Control for Induction Motor Sensorless Drive", IEEE Trans. on Ind. Appl., Vol. 36.No. 1.pp. 122-130, 2000

[17] Kyo -Beum Lee, Member, IEEE, Frede Blaabjerg, Fellow, IEEE, "Sensorless DTC-SVM for Induction Motor Driven by a Matrix Converter using a parameter Estimation Strategy", IEEE Trans. on Ind.Electron., Vol. 55, No. 2, pp. 512-521, 2008

[18] Yongchang Zhang, Member, IEEE Jianguo Zhu, Senior member, IEEE, Zhengming Zhao, Sr. Member ,IEEE, Wei Xu, Member, IEEE, David G. Dorrell, Senior member, IEEE."An Improved Direct torque Control for Three-level inverter for Induction Motor Sesorless Drive", IEEE Trans. on Power Electron. Vol. 27, No. 3, pp. 1502-1513, 2012

[19] Hassan Farhan Rashag, S.P. Koh, Ahmed N. Abdalla, Nadia M.L. Tan, K.H. Chong. "Modified Direct Torque Control using Algorithm of control stator flux Estimation and space vector modulation based on fuzzy logic control for achieving high performance from induction motors ", Journal of Power Electronics, Vol.13, No. 3, pp. 369-380, 2013.

[20] Domenico Casadei, Giovanni Serra , Angelo Tani, " Implementation of a Direct Torque Control Algorithm for Induction Motors Based on Discrete Space Vector Modulation", IEEE Trans. on Power Electronics, Vol. 15, No.4, pp. 769-777, 2000

[21] Bo Zhou, XiaoFei Zing, "Application of Particle Swarm Optimization on DTC for Induction Motors", Fourth International Conference on Natural Computation, pp. 472-476 , 2008 IEEE

[22] [22] Rahul Malhotra, Narindar Singh, Yaduvir Singh, "Non-linear and optimal Direct Torque Control of AC Drive using Fuzzy-GA", IJCSNS International Journal of Computer Science and Network Security. Vol. 9, No. 8, pp. 209 -215, 2009

[23] Cheng-Zhi Cao, Guang-Hua Weii, Qi-Dong Zhang, Xin Xang, "Optimization Design of Fuzzy Neural Network Controller in Direct Torque Control System", Proceedings of the third International Conference on Machine Learning and Cybernetics, Singhai, pp. 378-382, 2004

[24] Mohamad. M. Ismail, "Improving the performance of the DTC Saturated Model of The Induction Motor in case of Two Level and Three Level VSI using GA and PSO algorithms", 2012 Japan-Egypt Conference on Electronics , Communications and Computers, pp. 79-84, 978-1-4673-0484-9/12/ $31.00 ©2012 IEEE

[25] Fenn Pan, Rucheng Han, Runsheng Zhang, "An Optimal Controller based on GA for Direct Torque Control" , 2009 Third International Conference on Genetic and EvolutionaryComputing, pp. 52-55, 978- 0-7695-3899-0/09$29.00©2009 IEEE, DOI 10.1109/WGEC.2009.59