Auto PID-Tuning controller based on genetic algorithm for speed control of synchronous motor

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Abstract This paper presents proportional-integral-derivative (PID) controller to control the speed of Permanent Magnet Synchronous Motors PMSM using genetic algorithm.
Mathematical model of PMSM can be simulated abc to dq blocks and PMSM closed loop speed control can be designed. and we can implement this model by Matlab Simulink. Result of simulation explain control method can control PMSM more successful and it can give better dynamic performance. PMSM motor will expose to some disturbance in torque and by using genetic algorithm will face it .

Index term: Permanent magnet synchronous motor, PID control, Genetic algorithms.

INTRODUCTION

Permanent magnet synchronous motor (PMSM) has speed stability, small size and high efficiency and better dynamic performance, it can be more suitable for application that load not depend on speed, PMSM is the most widely used daily life in national defense, agriculture and we Can be obtain complicated function relation from The output torque and stator current. we can be decouple magnetic field to obtain a good performance. Simulation model of PMSM control method and can make optimization of this control system this is by make mathematical model of PMSM analyzation by aiding of matlab simulink and we study disturbance that the system will exposed , we illustrate it in wave forms simulation .PMSM control system consist of independent functional module as PMSM module ,inverter module, transformation module, SVPWM module when we combine it .it will produce permanent magnet synchronous motor control system.Vector control easy to be implemented less affected by the rotor parameters and PMSM is nonlinear, multivariable and high coupling system.

There are other paper that deal with the control of PMSM motor by different ways such as it use PID *to* control the speed of multi PMSM the master / slaves. we can applied control in synchronous controller of double then triple PMSMs. In double one motor is chosen as the master motor, reference value slave motor is taken from the output speed of the master motor ,we find that any change in the motion of the master motor, the slave motor will follows it but not happen In the opposite[8-9]. Decoupled control strategy using time-varying sliding surface-based sliding-mode controller for speed control of permanent magnet synchronous motor (PMSM). a simple way to achieve asymptotic stability for a PMSM is happened by decoupled method , and this will provides by dividing the system into two subsystems electrical and mechanical systems. We can get effectiveness and robustness The simulation results for PMSM are presented .the same motor a decoupled sliding-mode control (DSMC)design strategy is used to control the speed of PMSM. And for achieving desired speed, The motor system is divided into two subsystems with different switching surfaces .to control the motor torque and flux values it use current controllers in an proper reference frame. The DTC technique does not any current controllers [7-8].

Vector control is known as decoupling or field orientated control. it allows direct control of flux and torque because it decouples three phase stator current into two phase d-q axis current, one producing flux and other producing torque so, consider PMSM is equivalent to a separately excited dc machine. PMSM model is non linear when using vector control PMSM model will be linear [8].
This paper presents proportional-integral-derivative (PID) controller to control the speed of Permanent Magnet Synchronous Motors PMSM using genetic algorithm.
Mathematical model of PMSM can be simulated and we can implement this model by Matlab Simulink. Result of simulation explain control method can control PMSM more successful and it can give better dynamic performance. PMSM motor will expose to some disturbance in torque and by using genetic algorithm will face it.

Construction

Three phase stator coil placed on stator, have two layer spreaded and across coil magneto motive force and the motion voltage approximate to form of sinusoidal , permanent magnet inside rotor can achieve rotor magnetization and this cause minimal of magnetization current so, we can obtain high level of efficiency ,energy cost, saving on operating from result in excitation and low losses of rotor .This is shown in figure 1.

PMSM can be constructed by replacing coils of induction coil of the rotor by permanent magnet where magnetic flux on rotor is supplied by magnets, it can be produce rotating magnetic field by connected AC supply to windings on the stator. Permanent magnet synchronous motors are similar to brushless DC motors because of synchronous speed which rotor poles lock to rotating magnetic field. These motors require a variable-frequency power source to start. It can't use induction winding for starting because magnetic field in rotor is constant. The rotor is the main difference between a permanent magnet synchronous motor and asynchronous motor.

Advantage of PMSM are Reliability, long life ,high power density, high torque and high efficiency.

Disadvantage of PMSM: While PMSM suffers from Above curie temperature cause loss of magnetization ,high cost for using high flux density ,there are change with time in magnetic characteristics and loss flexibility of control of field flux

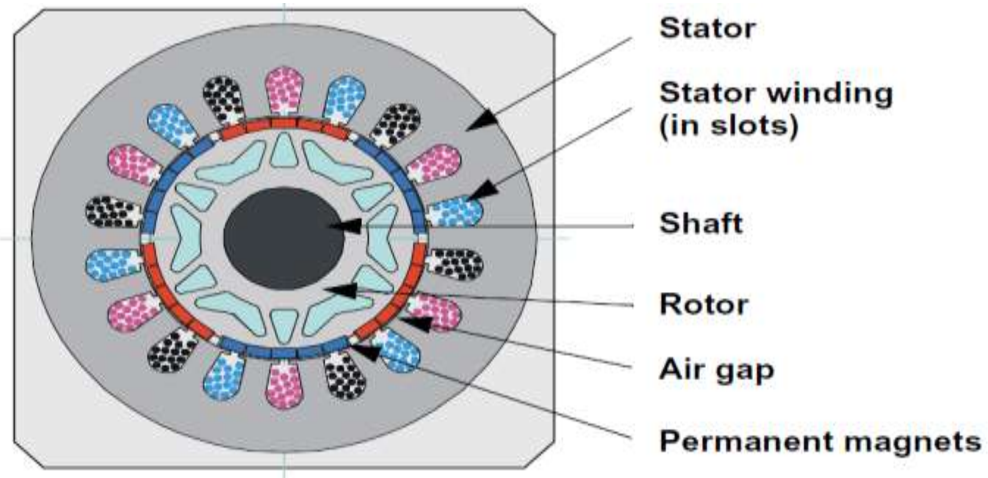

Fig 1 : permanent magnet synchronous motor construction

Mathematical model:

Vd=Rs*Id+ d/dt (Ld*Id) - ω*Lq*Iq (1)

Vq=Rs*Iq + d/dt (Lq*Iq) + ω*Ld*Id (2)

J*d/dt(ω) =Te-B*ω -Tl (3)

d/dt (θ) =ω

Te=1.5*(p/2)*[Φ*Iq+(Ld-Lq)*Iq] (4)

Where Vd, Vq rotor voltage Is, Iq : rotor current in amper θ: electrical rotor position in rad ω: angular velocity of motor shaft Rs,Rq: winding resistance ΩLd,Lq: inductance in henry Φ : rotor magnet flux linkage in wibre J: rotor and shaft interia Kg m^2 B: coefficient of friction N.m.s P: number of permanent magnet pole pairsTl: disturbing external torque N.m Te: motor torque N.m

GA is the best technique based on selection GA is the global adaptive search optimization technique.it the most efficient technique to solve optimization problems.
GA starts with initial population that contain number of chromosomes .each one of this chromosomes represents a solution of the problem and by using fitness function we can evaluate performance. Basically, we have three component of genetic algorithm Selection, Crossover and Mutation when apply these operation ,it will create of new individuals that may be better than their parent. we will repeated this algorithm for many generation until reaching to optimum solution to problem ,we stop .

The suggested PMSM Speed controller

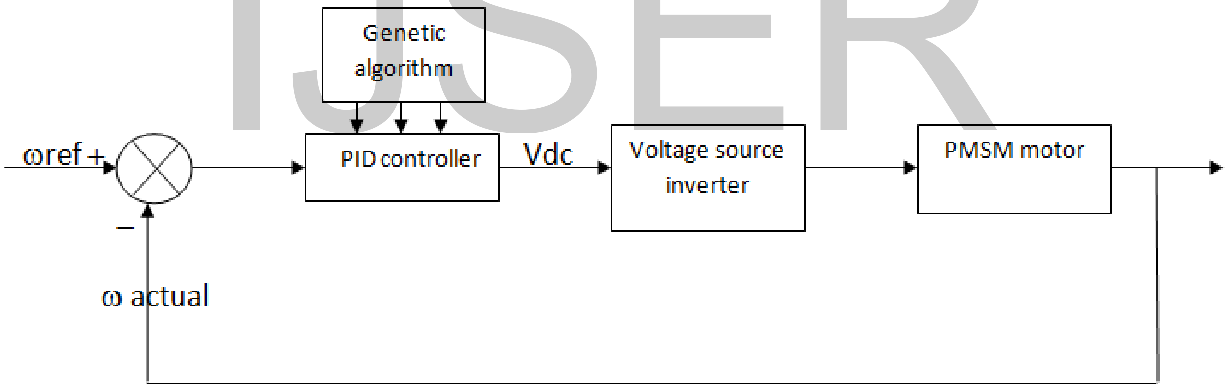

Fig 2:Block diagram of PID controlled PMSM

Block diagram of PMSM control system is consist of some component connected together first PID controller block that consist of three parameter proportional ,derivative and integral terms in which speed of motor compare with reference speed and output of speed controller entered to motor after we affected genetic algorithm on it by using fitness function that give us three parameter proportional ,integral and derivative that necessary to PID .we make Tuning of PID parameters , the process of tuning is iterative and for achieve desired performance we want to complete optimization. Genetic algorithm (GA) is the best tool for optimization used to get parameter of PID necessary for speed control of PMSM. For evaluating the fitness function we use different error models. We can get over optimization problems by GA that has efficient technique to solve this problem. GA starts with an initial population " number of chromosomes "each chromosome

represents a solution of the problem. We have three main stages of genetic algorithm: Selection, Crossover and Mutation that when apply it ,allows creation of new individuals that may be better than their parents. We still repeated for many generations and stop only when reach to optimum solution to problem. After this using inverter that used to generate required voltage necessary to feed the motor, this inverter is used to control the waveforms of currents and voltages that will be applied to the motor.
Model of PMSM matlab simulink compare reference speed 700 rpm by output of speed controller that gives to motor by using pid controller We use dq2abc transformation block that transform between 3 phase current Iabc and dq current Idq

$$I_{dq} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} Ia \\ Ib \\ Ic \end{bmatrix}$$

Circuit Description

PWM inverter is feeding three-phase motor 220 V, 1.1 kW, 3000 rpm. FirstPWM inverter is built by Simulink blocks. before output of PWM inverter applied to the PMSM block's stator windings Its goes through Controlled Voltage Source blocks. The load torque applied to the machine's shaft is originally set to initial value 3 N.m and final value 1 N.m at step time 0.04 s.We have two control loops" **inner loop and outer loop**"first inner loop regulates the currents of the motor's stator. We can control the speed of motor by the outer loop .

Demonstration

Which is to be expected when using PWM inverters.the stator currents are quite noisy. At t = 0.04 sAmplitude of these currents decreases, when the load is decreased. The effect of noise introduced by the PWM inverter will appear in electromagnetic torque waveform Te. However, this noise can be prevent from appearing in the waveform of motor speed by motor's inertia .

Simulation result:

$$fcn = U(1) * \cos(U(4)) + U(2) * \sin(U(4)) + U(3)$$

$$fcn1 = U(1) * \cos\left(U(4) - \frac{2\pi}{3}\right) + U(2) * \sin\left(U(4) - \frac{2\pi}{3}\right) + U(3)$$

$$fcn1 = U(1) * \cos\left(U(4) + \frac{2\pi}{3}\right) + U(2) * \sin\left(U(4) + \frac{2\pi}{3}\right) + U(3)$$

three-phase motor rated 1.1 kW, 3000 rpm. The load torque applied to themachine’s shaft is originally set to its nominal value (3 N.m)and steps down to 3 N.m at t 0.1 s. The desired speed is300 rad/s.**figure 3** illustrate when using pid controller with genetic algorithm without any disturbanceat ref speed =700 rpm we affected by genetic algorithm using fitness function y=-(5*x(1)^3 + 2*x(1)*x(2) +4*x(2) *x(3) + 8*x(2)^2 + 4*x(3)^2) its equation give three parameters that necessary for PID proportional, integral, derivative parameter equal 25.586, 15.363, 0.014 then we get for three curve first for rotor speed ωe(rad/sec) in which curve take time to stable in 700 rpm , second for stator current Is_a,Is_b,Is_c (A), third for elctromagnetic torque Te(N.m)

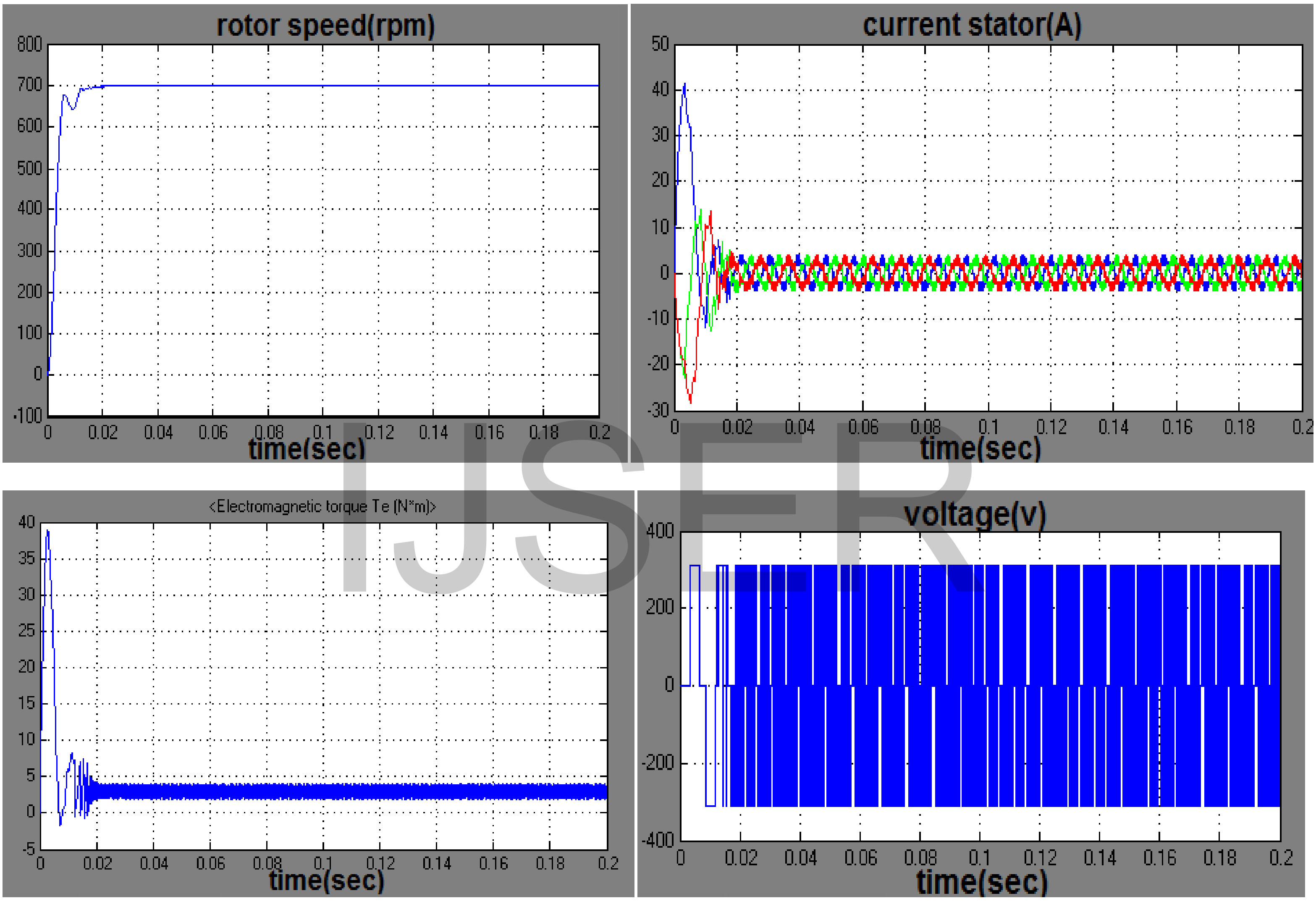

Fig3 :illustrate when using pid controller with genetic algorithm without any disturbance

When using genetics with torque Tm at time=0.1 to be 3 N.m and still continue to 3N.mwe find in curve of speed that speed start to still at time 0.025 sec .

In the curve of current max value of current at 41.4A and at min value at -28.422 A.

In the curve of torque max value of torque at 38.9 N.m and min value at -1.681N.m

The motor start without any disturbance and it give good wave form ,then we expose it to some effect to study the behavior of motor under this disturbance

Disturbance effect: We make disturbance in torque it happen in two ways first when make Tm increase second when make Tm decrease it changes by ±66% this will happen in fig 4,fig5

Fig 4illustrate When using genetics with change in torque that cause disturbance in torque by make Tm step function it start from 3N.m and continue until reach time 0.03 sec it increase to 5N.m then continue .

It change by rate +66%

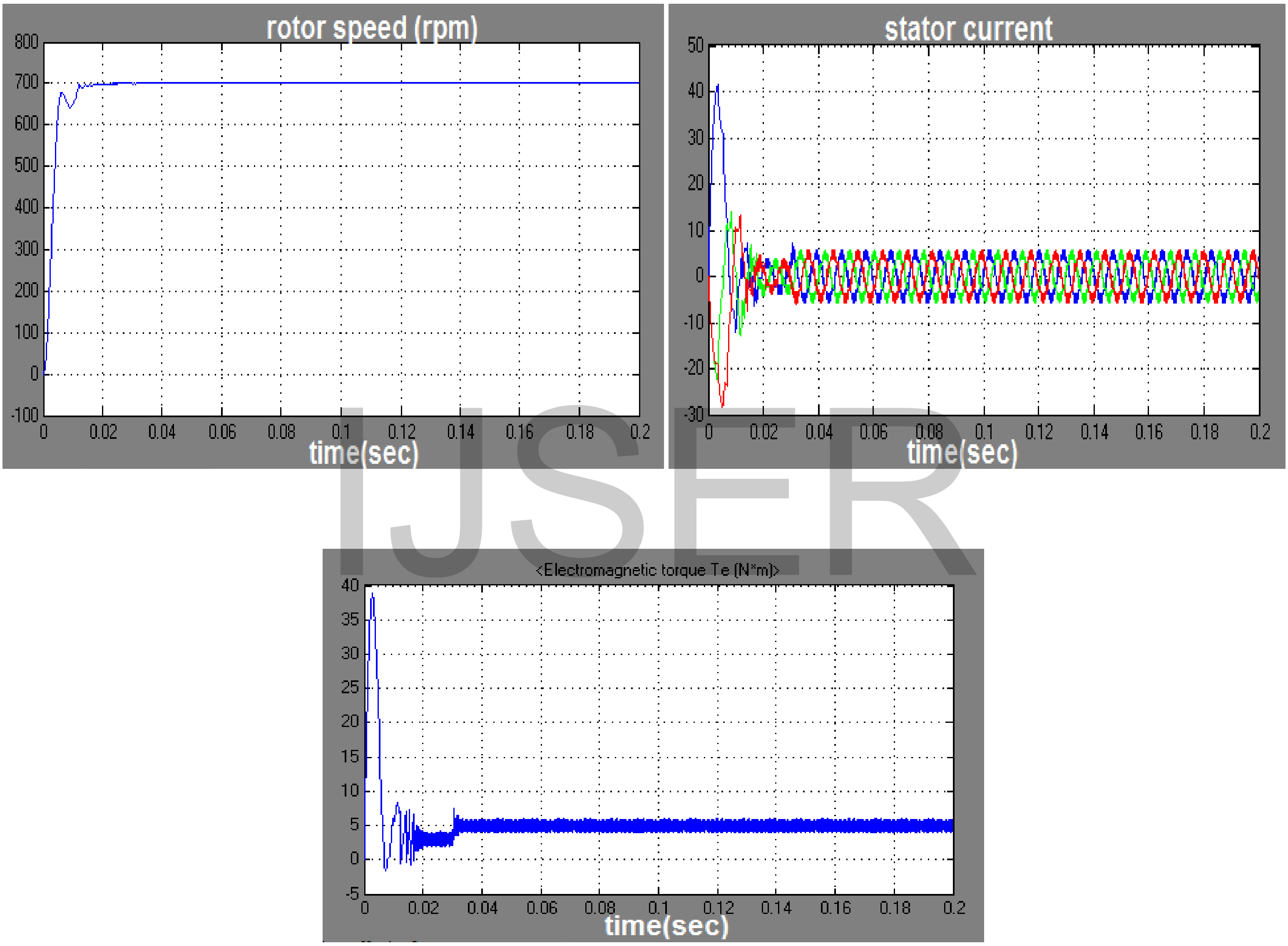

Fig 4: illustrate When using genetics with change in torque that cause disturbance in torque by make Tm step function it start from 3N.m and continue until reach time 0.03 sec it increase to 5N.m

Fig5illustrate When using genetics with change in torque cause disturbance in torque by make Tm step function it start from 3N.m and continue until reach time 0.03 sec it decrease to 1 N.m then continue it change by rate -66% we notice that the effect of disturbance in torque on the curve and the great difference in curves. the rate of change is ±66% from the total torque

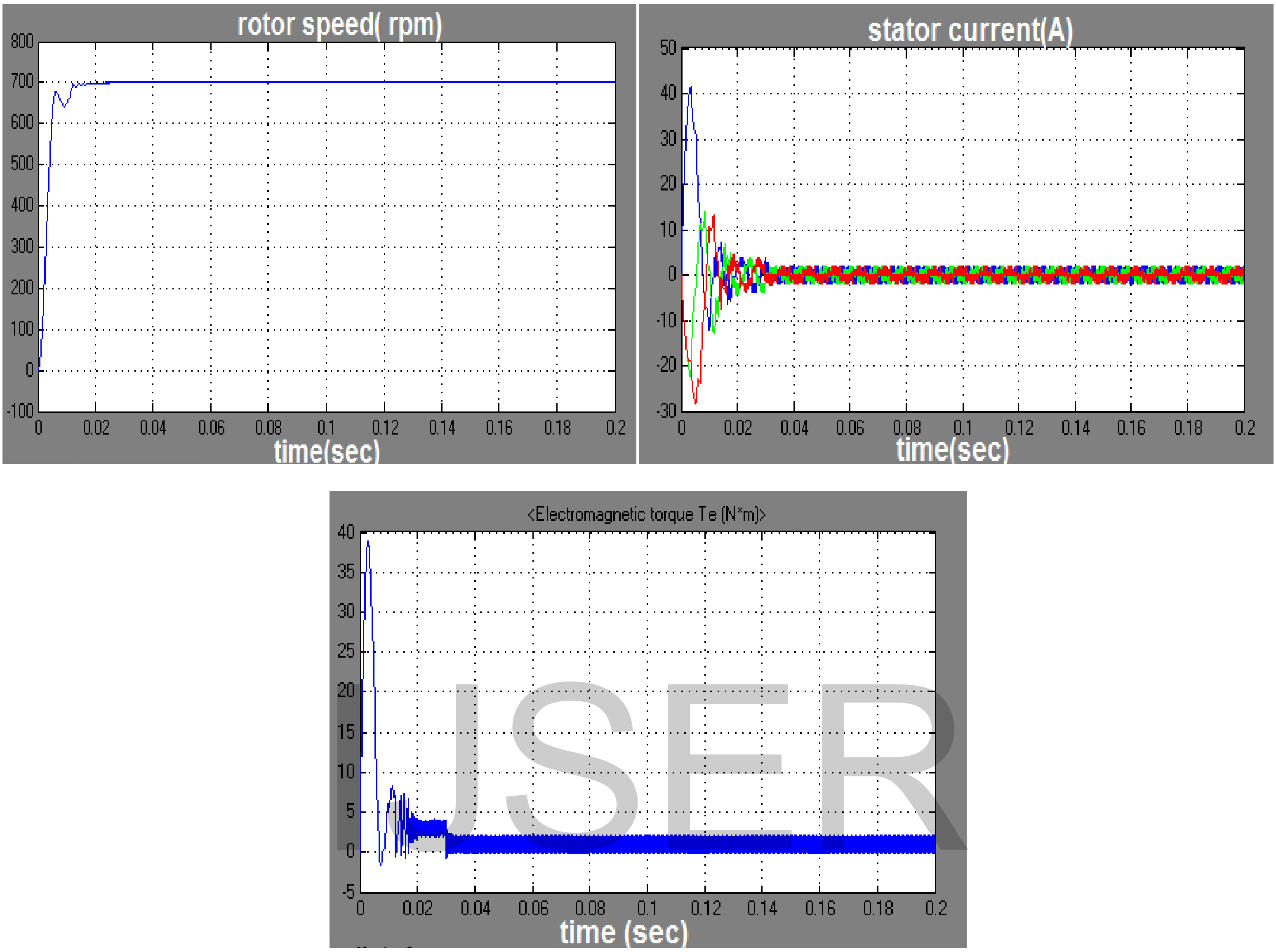

Fig 5: illustrate When using genetics with change in torque cause disturbance in torque by make Tm step function it start from 3N.m and continue until reach time 0.03 sec it decrease to 1 N.m

Comparative study:

We compare between fig6 and fig7 that using PID controller with genetic and pulse width module of Permanent Magnet Synchronous Motor when using reference speed 300,three term of PID controller proportional, integral, derivative equal 25.586, 15.363, 0.014

In fig 6

In the curve of current max value of current at 43.9 A and at min value at -28.7838 A.

In the curve of torque max value of torque at 41.862N.m and min value at -3.4723N.m

The reference speed is 300 rad/s, the motor speed stabilized at 0.02 s.
Max deviation of torque 8.9125N.m min deviation 6.9225N.m
Max deviation of current between ±8.5A

From **fig 6**

Reaching time	0.02 sec
Max deviation of speed	300.357rpm
min deviation	300.162rpm

Table 1:illustrate max deviation of speed and min deviation for fig 6

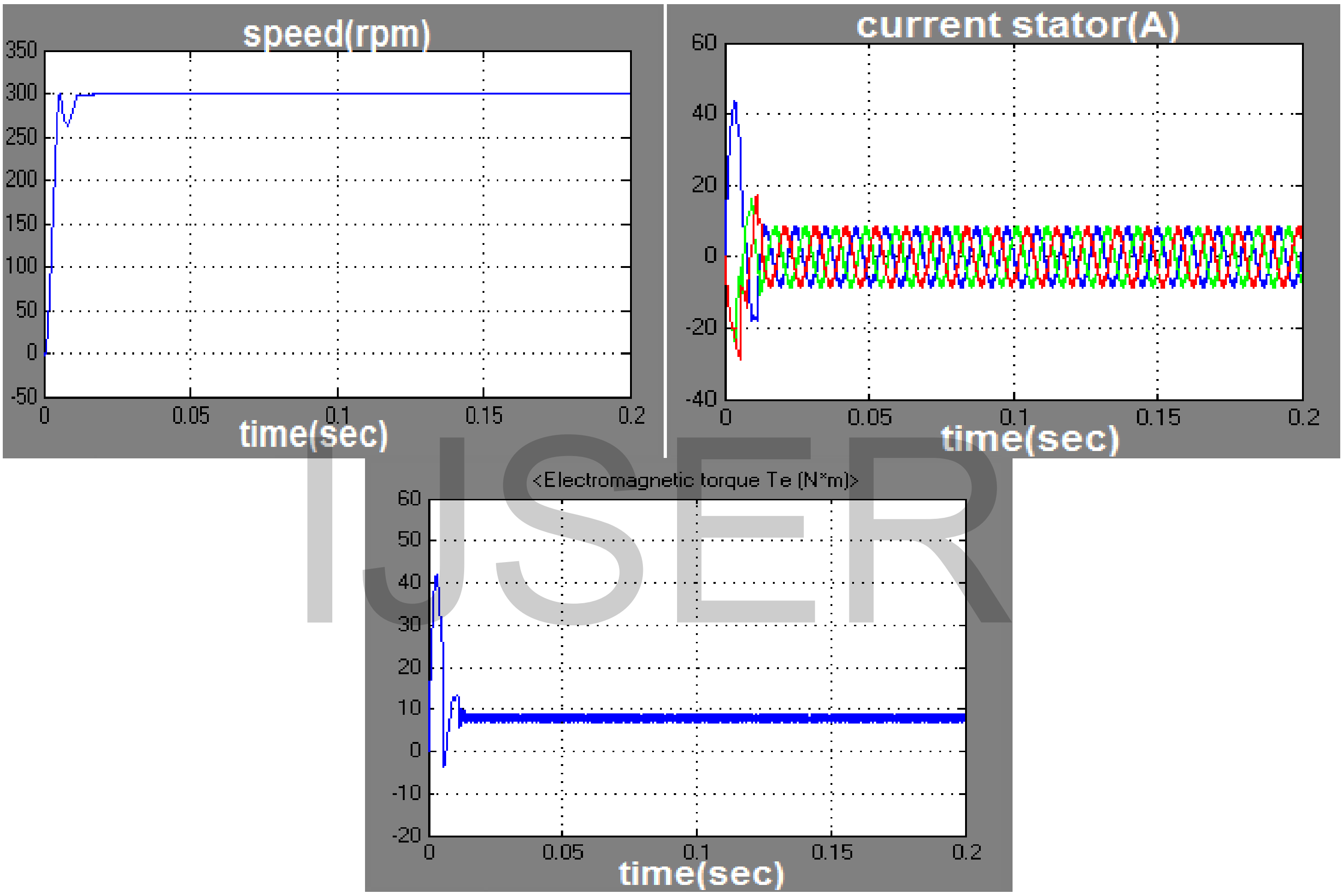

Fig 6 :when using PID controller with genetic and pulse width module of Permanent Magnet Synchronous Motor when using reference speed 300,three term of PID controller proportional, integral, derivative equal 25.586, 15.363, 0.014

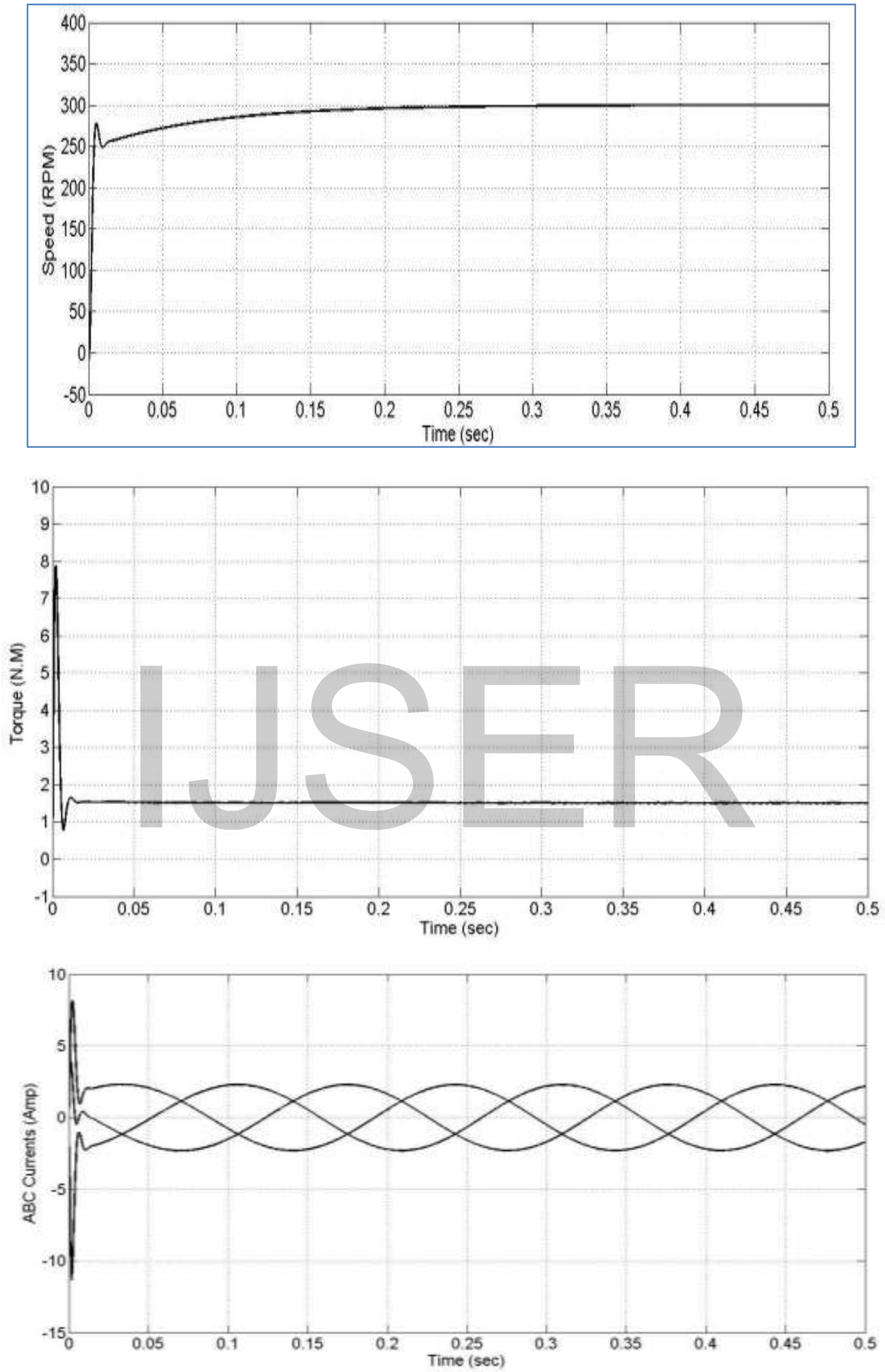

Fig 7: figure of paper that we compare between it and fig 6

Fig6	**Fig7**
Reaching time at 0.02 sec	Reaching time at 0.2 sec
Nominal torque 8.9 N .m	Nominal torque 1.5N.m
Nominal current ±8.5 A	Nominal current ±2 A
Voltage =300v	Voltage =270v and take time 0.2 sec to stable at 300v

Table 2 : illustrate the comparative result between fig6 and fig7

CONCLUSION

This paper present controlling the speed of permanent magnet synchronous motor using PID controller with genetic algorithm from this using fitness function .Simulation results illustrate the effectiveness of the suggested controller with the aid of MATLAB/ Simulink. The model of this proposed system has been presented to control the speed of these motors. The modeling are described and simulation results are presented in all status to reach to the best form of speed control that able us to be more suitable and preferable.

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