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Research on Application of Genetic Algorithm to AC Vector Control System

Xiuqiong Hu

Panzhihua University, Panzhihua 617000, China

Abstract: Considering the defect of the traditional PID controller as the speed regulator and torque regulator of AC vector control system, a new method to design the speed regulator and torque regulator was proposed. Firstly, the ideal fast starting curve of AC vector control system was provided according to the principle of DC speed adjusting system. Then, in order to make the output curve of speed and torque approximate to the ideal fast starting curve of AC vector control system, the genetic algorithm was combined with the traditional PID controller to design the speed regulator and torque regulator. At the same time, this method was expected to overcome the shortcoming of the traditional PID control. The simulations for the given AC vector control system demonstrated that the proposed method could improve the tracking performance and anti- disturbance performance of AC vector control system.

Keywords AC vector control system; genetic algorithm; speed regulator; torque regulator; PID control

INTRODUCTION

Asynchronous motor is a multi-variable and strong coupling nonlinear system whose parameters are time-varying [Kunder, 1994; Bose, 2013]. The vector control technology can realize the decoupling control of asynchronous motor to some extent. However, the characteristics of the nonlinear and time-varying parameters are remained [Kumar *et al*., 2015; Wang *et al*., 2015]. What's more, during the operation of alternating current (AC) vector control system, there are many unpredictable disturbances [Wang *et al*., 2015]. So, the design of the controllers of AC vector control system, which mainly include speed regulator and torque regulator, are very important. The classical proportional integratal differential (PID) control is usually adopted to design the speed regulator and torque regulator [Mohsen, 2014; Qin *et al.*, 2015; Krobling et al., 2001]. And the parameters of PID, which include proportional parameter as well as integratal parameter and differential parameter, have a great influence on system stability and performance [Mohsen, 2014]. Therefore, the parameter-set method, which is for PID control of speed regulator and torque regulator, has always been the hot spot of the engineering and academic research. So far, the traditional engineering method is usually adopted to set the parameters of PID control. But it is difficult to obtain the excellent parameters of speed controller and torque controller, and the set parameters can't adapt to the practical operation of AC vector control system because of the AC motor parameter changes or disturbances caused by the other outside systems.

Genetic Algorithm (GA), which simulates the genetic and evolutionary process of organisms in the natural environment, is a kind of adaptive global optimization probability search algorithm [Lu *et al*., 2014; Liang *et al*., 2014; Mahmoodabadi *et al*., 2015]. Considering the above problem of the traditional PID control of AC vector control system, the GA will be used to design the speed regulator and torque regulator based on the principle of direct current (DC) speed adjusting system to improve the performance of AC vector control system.

THE STRUCTURE OF THE STUDIED AC VECTOR CONTROL SYSTEM

The structure of the studied AC vector control system is shown in Figure 1. The system includes a speed closed-loop, a torque closed-loop and a flux closed-loop [Kunder, 1994]. In Figure 1, $\omega_r^*, T_e^*, \psi_r^*$ respectively denotes the reference value of speed, torque and flux linkage. ASR, ATR, AψR respectively denotes speed regulator, torque regulator and flux linkage regulator.

In the shown system, the flux linkage isn't coupled with the torque and the speed. Therefore, the design of flux linkage regulator can be designed separately using traditional engineering method. However, the speed is coupled with the torque. This means it is difficult to design speed regulator and torque regulator using the traditional engineering method.

Corresponding Author: Xiuqiong Hu, School of Information and Electric Engineering, Panzhihua University, Panzhihua 617000, China.

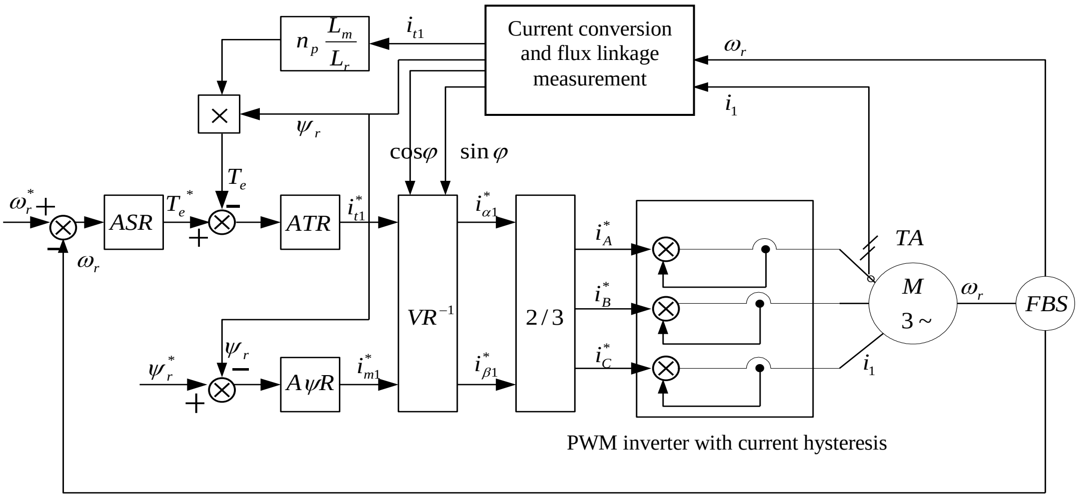

Figure1. Structure of AC vector control system

USING GA TO DESIGN ASR AND ATR

The foundation of designing

According to the structure of AC vector control system in Figure1, when the flux linkage regulator is designed separately, the torque regulator and speed regulator form a double closed-loop control system similar to DC double closed-loop speed adjusting system. Obviously, it is important to reasonably design the torque regulator and speed regulator to make the AC vector control system have the good control performance like DC speed adjusting system. Therefore, an ideal fast starting curve for AC vector control system is given in Figure 2.

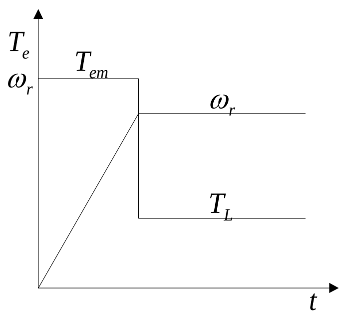

Figure2. The fast starting curve of AC vector control system

In Figure 2, T_e, T_{em}, T_L, ω_r respectively denotes the torque of AC asynchronous motor, the maximum torque, load torque and speed. Then, the GA is used to design the torque regulator and speed regulator to make the output curves of torque and speed approximate to the ideal fast starting curve.

The determination of parameter rang of ASR and ATR

Essentially, the emphasis of using GA to design the ASR and ATR is to use GA to optimize the PID control parameters of ASR and ATR. It must be noted that the proportional parameter and integratal parameter are more important than differential parameter, therefore, the proportional parameter and integratal parameter of ASR and ATR will be optimized. In that way, the parameter range of ASR and ATR must be determined firstly. For example, the parameter range of ASR is expressed by Equation (1).

$$\begin{cases}(1-\alpha)K_{np_0} \le K_{np} \le K_{np0}(1+\alpha) \\ (1-\alpha)K_{ni0} \le K_{ni} \le K_{ni0}(1+\alpha)\end{cases}, \quad 0 \le \alpha \le 1 \quad (1)$$

Where, K_{np}, K_{ni} respectively denotes the proportional parameter and integratal parameter of ASR. Their initial value, which is determined by traditional engineering method, is respectively denoted by K_{np0}, K_{ni0}. And they are the initial values in GA optimization.

According to the above method, the parameter rang of ATR can be determined too.

And then the parameters to be optimized are all encoded with binary code to form a binary string with a certain length known as an individual. All individuals form a collection as a population. Each binary string denotes the feasible solution of the proportional parameter and integratal parameter of ASR and ATR.

The generation of initial population

The initial population, whose number is 60, is generated randomly. The length of each individual in the population is 40 bit. This means each parameter to be optimized is denoted by a string including 10 bit binary code.

The determination of fitness function.

The aim of using GA to design ASR and ATR is to make the output curves of the speed and the torque approximate to their inputs, and make the AC vector control system can fast response without overshoot. Therefore, the performance index is denoted by Equation (2).

$$J = \sum_{k=1}^{N} \beta_1 |e_1(k)| + \sum_{k=1}^{N} \beta_2 |e_2(k)| + 2t_r \quad (2)$$

where， $e_1(k)$, $e_2(k)$ ， t_r respectively denotes the speed deviation, the torque deviation at the moment k and the rising time of the system, they can be defined by Equation (3).

$$\begin{cases} e_1(k) = \omega_r^*(k) - \omega_r(k) \\ e_2(k) = T_e^*(k) - T_e(k) \end{cases} \tag{3}$$

In Equation (3), ω_r^*, T_e^* respectively denotes the speed reference value and the torque reference value.

In Equation (2), β_1 and β_2 can be expressed by Equations (4) and Equation (5).

$$\text{when} \begin{cases} |e_1(k)| \le \varepsilon \times \omega_r^*, & \beta_1 = 100 \\ |e_1(k)| > \varepsilon \times \omega_r^*, & \beta_1 = 1 \end{cases} \tag{4}$$

$$\text{when} \begin{cases} |e_2(k)| \le \varepsilon \times T_e^*, & \beta_2 = 100 \\ |e_2(k)| > \varepsilon \times T_e^*, & \beta_2 = 1 \end{cases} \tag{5}$$

In Equations (4) and Equation (5), ε is a constant denoting the tolerated error. And the value of ε is set to be 0.1 in this paper.

The fitness function is expressed by Equation (6).

$$F = e^{-J} \tag{6}$$

The operation steps of GA

The operation steps of GA are as follows:

1) Firstly, determine the rang of the parameter to be optimized, the length of chromosomes substring of each parameter to be optimized, the size of the population, crossover probability as well as mutation probability and the maximum generation of evolution.
2) Generate the initial population randomly.
3) Determine the fitness function, and calculate the fitness value of each individual according to Equation (6). Sort all the individuals according to their fitness values.
4) Check whether it is necessary to generate new individuals. If no necessary, go to step 5. If necessary, keeping the best individuals, regenerate the rest individuals, and calculate fitness values of the regenerated individuals, then go to step 5.
5) Clone the best individuals to the next generation. Use the roulette method to select the matching individuals of the rest individuals.
6) According to the determined crossover probability, adopt the method of multi-point crossover to implement the crossover of the selected matching individuals.
7) Calculate the fitness values of the new generation of individuals, and sort the individuals according to their fitness values.
8) Implement the mutation of the new generation of individuals according to the mutation probability.
9) Check whether it is satisfied for the termination conditions. if it is satisfied, then turning to step 10; conversely, returning to step 5.
10) Obtaining the optimal solution, and go to the end.

SIMULATIONS

The AC squirrel cage motor is selected for simulation. The parameters of the motor are as follows: the reference value of the rotor speed is 75rad/s; the reference value of rotor flux linkage is 1Wb; the rated load of the motor is 24N•m; the overloaded ratio is 1.5; the phase number of the motor is 3; the paired number of magnetic poles is 4; the given frequency is 50Hz; the resistance of the stator is 6.03Ω; the resistance of the rotor is 6.085Ω; the leakage inductance of the stator is 0.0299H; the leakage inductance of the rotor is 0.0299H; the mutual inductance between the stator and the rotor is 0.4893H; the moment of inertia of the motor is 0.0487 N•m^2.

During the simulation process, the maximum generation of GA is 300; the number of individuals in the population is 60. Each parameter to be optimized is encoded using binary code of 10 bit. The crossover probability is 0.8, the mutation probability is 0.03. The simulation is carried out using MATLAB, and the sample time is 0.002s. During the simulation, the torque measurement is assumed to be accurate without considering the influences resulting from the change of rotor resistance.

The simulation results are shown in Figure3-Figure 8. In these figures, curve 1 denotes the speed curve whose value is one-eighth of actual speed, curve 2 denotes the torque curve whose value is one third of actual torque. The overshoot of speed is expressed by M_1, the overshoot of torque is expressed by M_2.

1) Before using GA to design ASR and ATR, the starting curve of the given system without load is shown in Figure 3. And the M_1 is 9.9420%, M_2 is 5.2525%. After using GA, the starting curve of the given system without load is shown in Figure 4. And the M_1 is 0.8696%, M_2 is 0. The results show that the overshoots of speed and torque all are lower after using GA.
2) When the given system is steady after starting without load, the speed curve and torque curve with rated load are shown in Figure 5 and Figure 6. In Figure 5, the GA isn’t used, and the maximum dynamic speed decent is 81.4104%, the recovery time is 0.2s. In Figure 6, the GA is used, and the maximum dynamic speed decent is 50.5312%, the recovery time is 0.15s. It means the response time is faster after using GA.
3) When the given system is steady with rated load, the speed curve and torque curve with reducing half of the rated load are shown in Figure 7 and Figure 8. The moment of reducing half load is at 0.9s. In Figure 7, the

GA isn't used to design the ASR and ATR. In Figure 8, the GA is used to design the ASR and ATR. The results show that the wave motion is less after using GA when reducing half of the rated load.

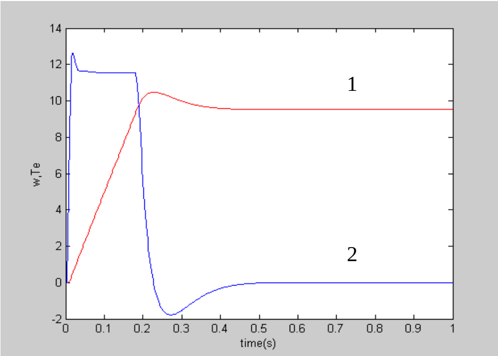

Figure3. Starting curve without load before using GA

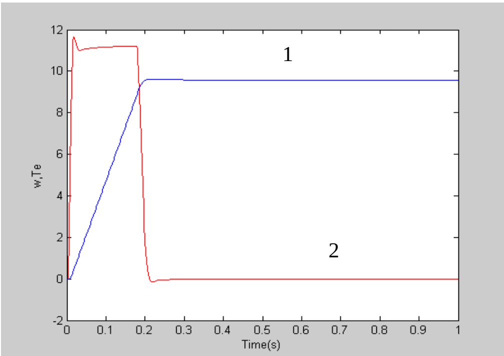

Figure4. Starting curve without load after using GA

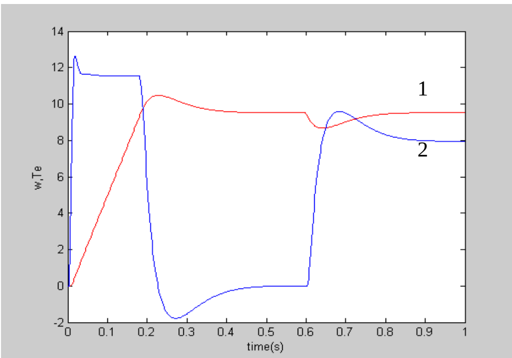

Figure 5. Output curve with rated load before using GA

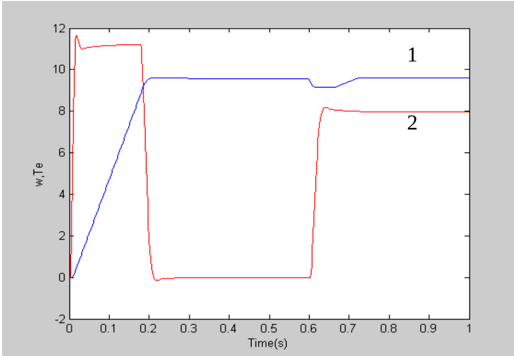

Figure 6. Output curve with rated load after using GA

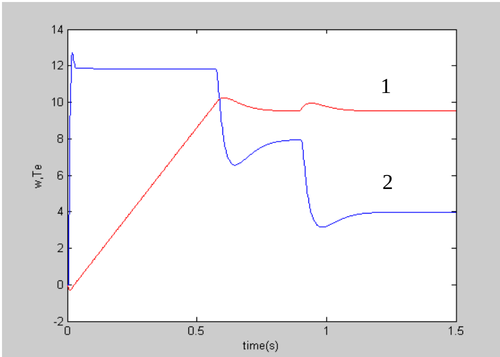

Figure 7 Output curve with reducing half load before using GA

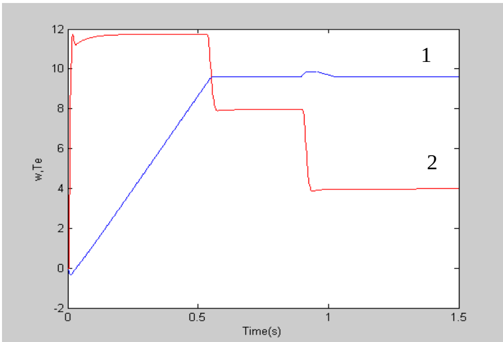

Figure 8 Output curve with reducing half load after using GA

CONCLUSION

The above simulation results showed that the starting curve of the given AC vector control system approximated to the ideal fast starting curve after using GA to design the ASR and the ATR. And the tracking performance and anti-disturbance performance of the given system were improved too. Moreover, when using GA to design the ASR and ATR, the definition of the system performance index is simple and easy to calculate. This means the proposed method is easy to be carried out in actual operation of AC vector control system.

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REFERENCES

Bose, B K, 2013, “modern power electronics and ac drives”, PHI Learning Private Limited, New Jersey.

Krobling R.A., Rey J.P., 2001, “Design of optimal disturbance rejection PID controllers using genetic algorithms”, IEEE Transactions on Evolution Computation, vol.5, pp 78-82.

Kumar R, Sukanta D, Prasid S, Kumar A. C., 2015,“Review on model reference adaptive system for sensorless vector control of induction motor drives”, IET Electric Power Applications, vol.9, no.7, pp 496-511.

Kunder P, 1994, “power system stability and control”, McGraw- Hill.

Liang Dong, Xu Jianjun, Sun Zhigang, 2014, “Research on method of total transfer capability based on immune genetic algorithm”, Journal of applied science and engineering innovation,vol.1, pp 33-38.

Lu Yun, Li Weijia, Tian Wenzhuo, Zhou Kai, 2014 ,“Fuzzy Entropy Thresholding Method Using Adaptive Genetic Algorithm”, Journal of applied science and engineering innovation, vol.1,no.1, pp 1-6.

Mahmoodabadi M.J., Taherkhorsandi M., Talebipour M, Castillo-Villar K.K., 2015,“Adaptive robust PID control subjective to supervisory decoupled sliding mode control based upon genetic algorithm optimization”, Transactions of the institute of Measurement and control, vol.37,no.4, pp 505-514.

Mohsen F, 2014, “Design of PID controller using multi-objective genetic algorithm for load frequency control in interconnected power systems”, Journal of Intelligent & Fuzzy Systems, vol.2, pp 709-716.

Qin Gang, Liu Mushuang, Zou Jianxiao, Xin Xiaoshuai, 2015, “Vector control algorithm for Electric vehicle AC induction motor based on improved variable gain PID controller”, mathematical problems in engineering, vol.10,pp 1-9.

Wang Shunyuan, Tseng Chwanlu, Lin Shouchuang, Chiu Chunjung, Chou Jenhsiang, 2015, “An adaptive supervisory sliding fuzzy cerebellar model articulation controller for sensorless vector- controlled induction motor drive systems”, Sensors, vol.15, pp 7323-7348.