A Novel Design of Digital Position Servo System

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Abstract: The paper presents a cost effective and increased performance position servo system using the TMS320F240 digital signal processor (DSP) produced by Texas Instruments as microprocessor and Brushless Direct Current Motor (BLDCM) as executor. In order to make up for the drawback of conventional PID controls, the fuzzy PID is employed. The result of simulations and experiments has confirmed that the whole system is simple and reliable; the robustness of system is improved by using fuzzy PID.

Keyword: DSP BLDCM Fuzzy reasoning Fuzzy PID

I. INTRODUCTION

With the rapid development of power electronics and microelectronics, all kinds of new elements of power electronics and microprocessors with higher performance are emerged. At same time, the power drive systems are developed rapidly. So it is possible to realize novel servo system with higher performance. This paper proposes the AC servo system using BLDCM and high speed DSP, which has simple topology, perfect safeguard measurements and feasible fuzzy PID control strategy.

TMS320F240 DSP is a new emerging microprocessor suitable for motor control, which has many useful functions for motor control. Such as six PWM waveform generators, three timers, six interrupts sources, four capture units with quadrature encoder pulse circuits (QEP), two fast 10-bit A/D units, watching dog, serial communication interface, on-chip 16k-word × 16-bit flash EEPROM and 544-word × 16-bit RAM, 50ns instruction cycle and plenty of powerful instruction, etc.

Permanent Magnet Brushless DC motor (BLDCM) is conventionally defined as a permanent magnet synchronous motor with a trapezoidal back EMF waveform shape. BLDCM technology makes it possible to achieve high performance, low cost and short development time. Such motors combine high reliability with high efficiency, and for a lower cost in comparison with brush motors. The brushless characteristic can be applied to several kinds of motors, such as AC synchronous motors, stepper motors, switched reluctance motors, AC induction motors. The research results can be taken example by other motors control, so study on BLDCM is very significant.

The system structure and control strategy are described in details in the following.

II. SYSTEM DESIGN SCHEME

TMS320F240 is specially designed for motion control by Texas Instruments, which has many functions for motion/motor control. The system takes the full advantage of TMS320F240, whose framework is given in Fig.1.

In this system, three-phase inverter composed of six MOSFETs is used as power conversion device. Driving circuit with TLP250 as core is used to drive the MOSFETs. Current sample signal is fed into A/D converter through current sampling and transforming circuit. Pulses from incremental encoder are directly connected with QEP input circuits of the TMS320F240's event manager, where they can be used as position and speed feedback signal.

Safeguard measurements, such as power elements over current safeguard, over voltage and phase-absent safeguard in the inverter, are taken into account in this system. Any safeguard signal can cause an interrupt, in which the cause of interrupt is detected, inverter is disable and alert signal is given by LED. Additionally, display circuits and keyboard circuits are designed simply and practically using serial peripheral interface (SPI) and A/D converter. Serial communication interface (SCI) is used to communicate with supervisor computer.

III. FUZZY PID CONTROL

Model of BLDCM is described in [1], which can be simplified as what is described in [2]. Inner loops of system including current loop and speed loop are designed using conventional PI control, just as described in [3].

Conventional digital PID control is simple to implement, whose parameters are fixed. Conventional PID is enough for servo system if requirements are not very strict. With the system requirements increased, the conventional PID is no longer satisfied, because it can not be robust and adaptive to the parameters and model structure variety. On the other hand, that faster microprocessors are developed

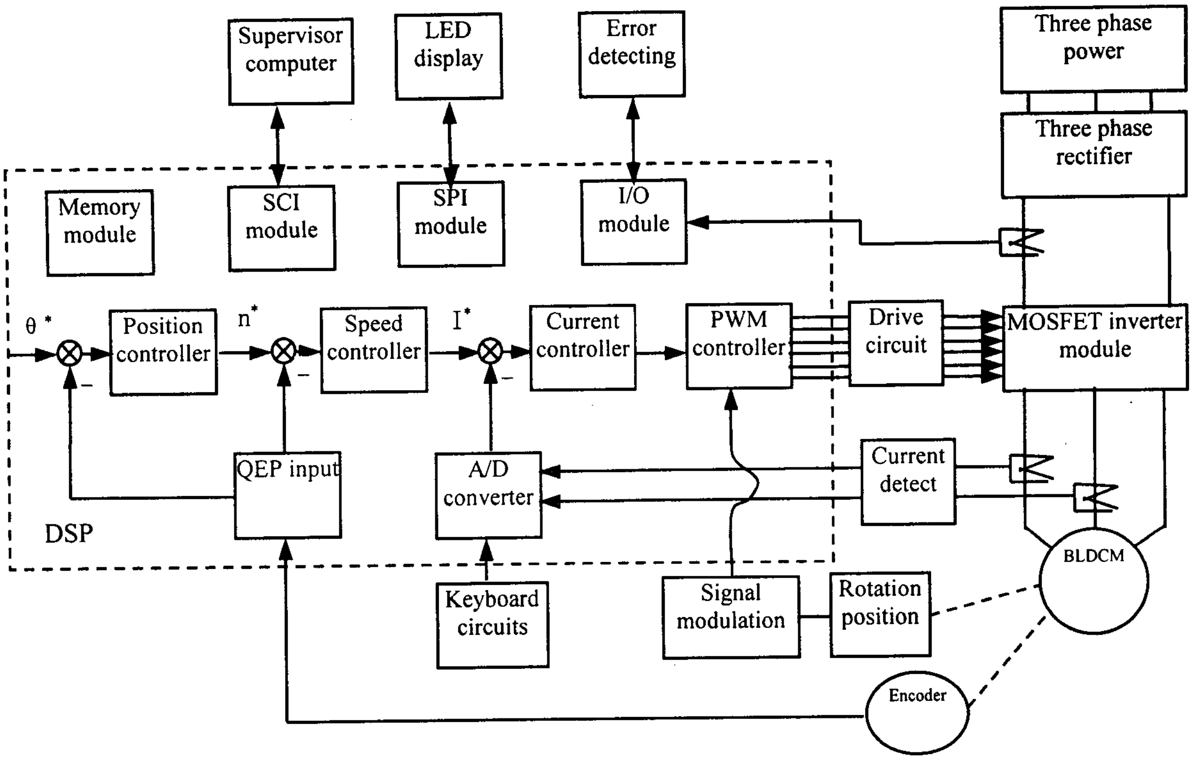


Fig.1 System framework

makes the more complex control algorithms become feasible, therefore, fuzzy PID is designed in the system described above.

To deal with the system with fixed model and parameter conventional PID is enough, but fixture is relative, in fact, the parameters of the system are variable in a definite range, therefore the controller must has robustness to obtain high performance. For this purpose, fuzzy reasoning is used to adjust the factors of PID, by this way the PID factors can be adjusted according to the changes of system state and plant parameters. Fig.2 is the fuzzy PID control system structure diagram. algorithm is described in details in the following:

In the same way, three outputs of fuzzy adapter, proportional gain (Up), integral gain (Ui) and differential gain (Ud), can be quantified through the scaling factors Kup,Kui and Kud respectively as follows:

{Up}=[-3，-2，-1，0，1，2，3]

{Ui}=[-3，-2，-1，0，1，2，3]

{Ud}=[-3，-2，-1，0，1，2，3]

Suppose that there are seven language variables of output, these are PB、PM、PS、0、NS、NM、NB, built a table in which language variables are given corresponding value, the control rules can be derived from fuzzy reasoning and manual operation rules, for example, when error of the system output is PB then proportional gain should be PB,

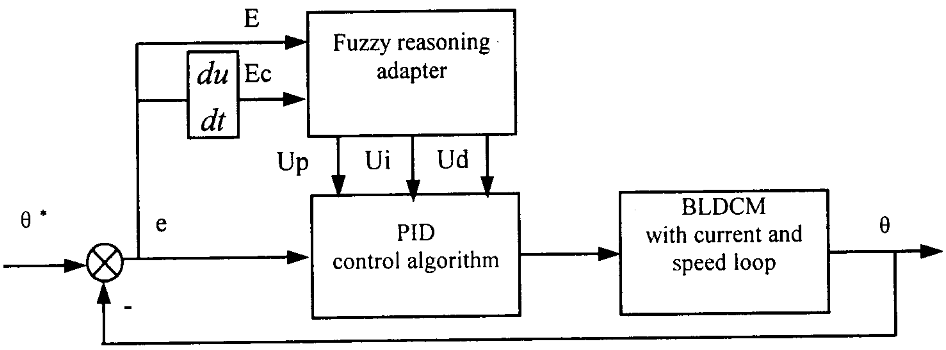


Fig.2 Fuzzy PID control system structure diagram

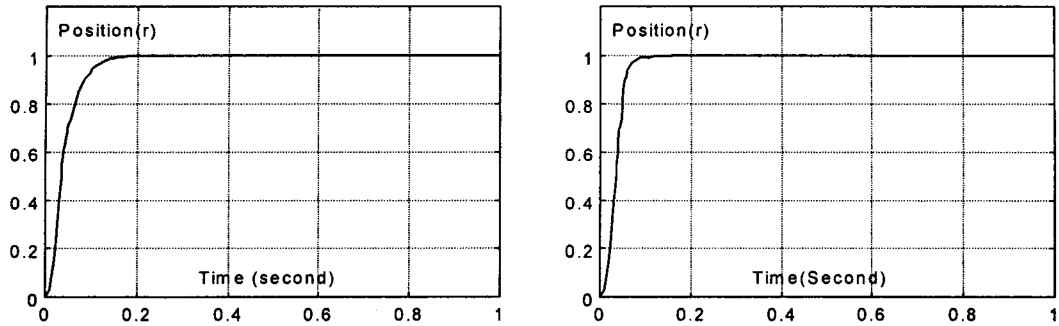
Assuming that error (E) and error change (Ec) are the inputs of adapter, they can be quantified through the scaling factors Ke and Kec as follows:

{E}=[-3，-2，-1，0，1，2，3]

{Ec}=[-3，-2，-1，0，1，2，3]

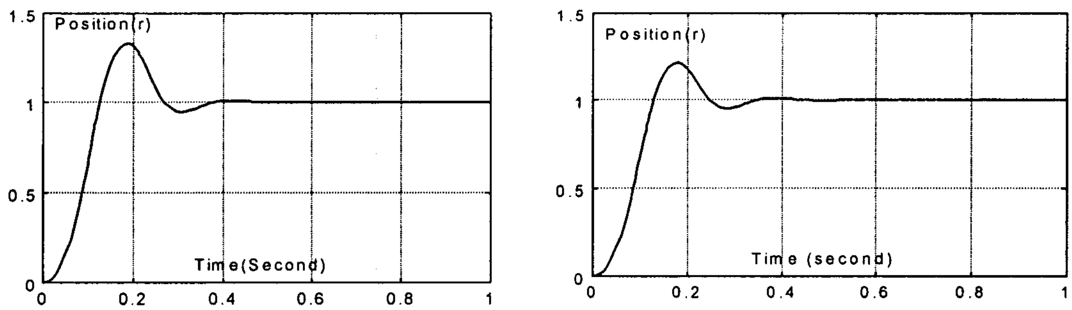
differential gain and integral gain may be 0; if error is PS then the integral gain and differential gain should be PB or PM, the proportional gain should be PS, etc. The max-membership method is employed to defuzzify the fuzzy variable; according to different conditions the poll table is built, so that real time implement is very fast. It is proved that the above adaptive PID algorithm is different from the conventional PID because the former PID factor is derived from lookup table according to the system error change while the latter's is fixed.

Simulations using MATLAB5.2 are performed under different conditions, whose results are given in Fig.3 and Fig.4:



(a) (b)

Fig.3 system position response under the condition of fixed parameters



(a) (b)

Fig.4 system position response when moment of inertia become double

Fig.3 is simulation under condition of fixed parameters, in Fig.3 (a) and Fig.3 (b), conventional PID control and fuzzy PID are used respectively. Fig.3 shows that when parameters are fixed, fuzzy PID control has shorter rising time (Tr) comparing with conventional PID.

Fig.4 shows the system position response when moment of inertia becomes double, in Fig.4 (a) and Fig.4 (b), conventional PID and fuzzy PID are used respectively. It can be seen from Fig.4 that fuzzy PID has shorter regulating time and less overshoot, when the parameter of system changed.

The reason of the simulation results listed above (Fig.3 and Fig.4) can be analyzed as follows:

(1) Fuzzy PID can adopt different parameter of PID according to different time of output of system, so that it is possible for controller to use bigger proportional gain at beginning time of response, therefore, using fuzzy PID control can shorten Tr.

(2) When parameter of system changes, because parameter of fuzzy PID controller may be change at different time of system response, using fuzzy PID makes it possible that system robustness is enhanced. Therefore fuzzy PID control can obtain shorter regulating time and less overshoot.

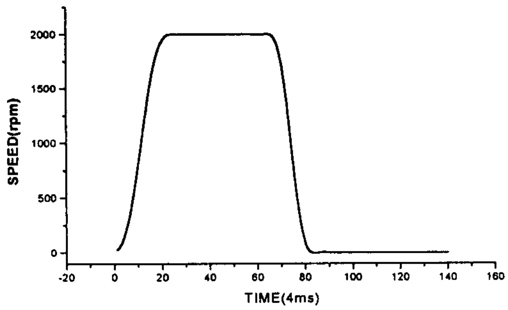
Besides advantages listed above, other advantages of this fuzzy PID are that it is simple and fast to implement by using lookup table, and it is suitable to operate on TMS320F240 DSP which uses fixed point operation by using simple algorithm.

In fact, the fuzzy PID divides the factors of PID into several discrete groups. According to the plant output error, different groups of factor is used, in this way the control system represents robustness.

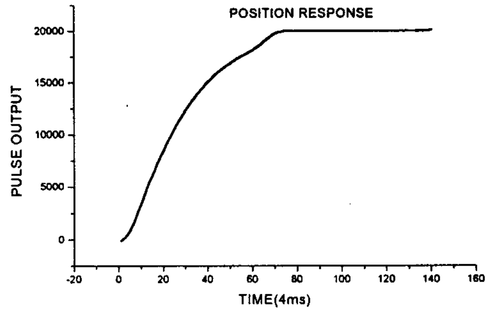
IV. EXPERIMENTAL RESULT

Experiments have been performed in the lab. The parameters of motor used in experiments are given as follows: (1) rated torque: 0.8Nm; (2) max speed: 2000r/min; (3) rated current: 1.4A; (4) output pulses of encoder per rotation: 2500; (5)winding resistance: 1.1 Ω; (6) winding inductance: 5.6mH; (7) back EMF coefficient: 0.0475V • min/r; (8) electromechanical time constant: 86ms.

Fig.5 is real system response curves, Fig.5 (a) and Fig.5 (b) is speed response and position response respectively when



(a)



(b)

Fig.5 Experimental output of real system using fuzzy PID

position given value is 20000 pulses. It can be derived from the curves that the system has good response by using system designed above and fuzzy PID control.

V. CONCLUSION

In this paper, a novel simple, reliable and full digital BLDCM position servo system is designed using a series of functions provided by TMS320F240 digital signal processor. The robustness of the system is improved by using Fuzzy PID. It is proved by simulations and experiments that the system design is correct, feasible and effective.

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