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Control of Induction Motor Using Real-Time Microcontrollers

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ABSTRACT: Three-phase AC motors are widely used in the industry. Therefore, the authors propose a solution to build a standardized hardware system that can interfere with the control structure using the C2000 family microcontroller. The advantage of this solution is that it is inexpensive and allows us to install different algorithms. Besides, it is possible to connect to PC via Matlab/Simulink in real-time control problem.

KEYWORDS:IM, C2000, PWM.

I. INTRODUCTION

For small-scale applications and applications that require operators, it is necessary to intervene in the control structure to customize the technology process. However, it cannot be done with commercially available equipment. Three-phase motor control can be divided into two types: scalar control and vector control [1-16]. The scalar control is simple to implement, but the dynamic quality of the system is not achieved as the vector control. The vector control method for the stator current that uses coordinate transformations is analyzed into two components: torque control and magnetic flux control. Therefore, the quality of control will be improved. However, the control structure of this method is complex and requires computing power of the microcontroller to be strong enough.

II. C2000 REAL-TIME MICROCONTROLLERS

The C2000 real-time controller is a family of high-performance microcontrollers, built to control power electronics and provide digital signal processing in industrial and automotive applications [17]. The C2000 is a 32-bit microcontroller family with integrated peripherals, designed for real-time applications. It can communicate with peripherals using common communication standards: SPI, UART, I2C, CAN and McBSP [18,19].

In motor control applications, the C2000 demonstrates the suitability due to the integration of peripheral sets: enhanced pulse width modulator (ePWM), analog-digital converter (ADC), and enhanced quadrature encoder pulse (eQEP). The function of the C2000 pulse width controller is to create the SOC (Start of Conversion) for ADC, which is neccessary to read the stator current values accurately. Besides, enabling interrupt configuration helps a lot for data processing.

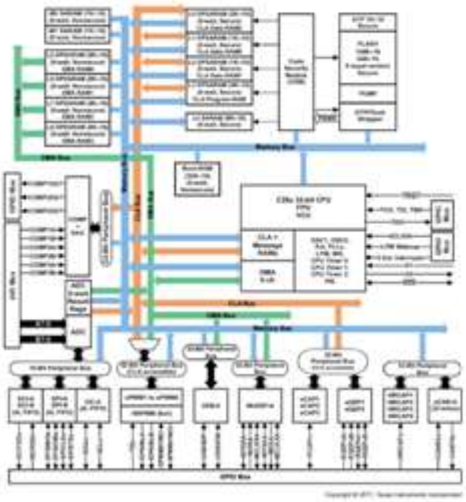

Fig. 1. Function block diagram of TMS320

A special characteristic of the C2000 microcontroller series is that it includes a velocity calculator based on the CPU timer. It allows to perform calculations by both methods of determining velocity: by measuring the number of encoder pulses per unit of time, and by measuring time on a predetermined number of pulses. Furthermore, the high-speed communication interface of up to 5Mb / s allows data to be displayed on the computer quickly [20]. In terms of

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programming, C2000 is able to work with specialized software like Matlab/Simulink. Texas Instrument provides an extension on Matlab/Simulink that allows to compile the controller directly and then embedded in microcontrollers.

III. CONTROL STRUCTURE

There have been some popular control methods implemented in industry: V/f control [21], vector control [22-25], direct or non-direct control magnetic flux (DFOC, IFOC) [26-28], and flux attenuation control [29]. The two most common methods used in practical industry are the V/f control method and FOC control method.

From the engine model on the coordinate system αβ :

$$\begin{cases} u_{s\alpha} = R_s i_{s\alpha} + \dfrac{d\psi_{s\alpha}}{dt} - \omega\psi_{s\beta} \\ u_{s\alpha} = R_s i_{s\beta} + \dfrac{d\psi_{s\beta}}{dt} + \omega\psi_{s\alpha} \end{cases} \qquad (1)$$

The V/f control law for motor torque is as follows:

$$M_e = \frac{L_m}{JL_r}\left(\psi_{r\alpha} i_{s\beta} - \psi_{r\beta} i_{s\alpha}\right) \qquad (2)$$

For the control method based on the rotor flux, derived from the three-phase asynchronous motor model on the dq coordinate system

$$\begin{cases} \dfrac{di_{sd}}{dt} = -\dfrac{1}{T_{sd}} i_{sd} + \omega_s \dfrac{L_{sq}}{L_{sd}} i_{sq} + \dfrac{1}{L_{sd}} u_{sd} \\ \dfrac{di_{sq}}{dt} = -\omega_s \dfrac{L_{sd}}{L_{sq}} i_{sd} - \dfrac{1}{T_{sq}} i_{sq} + \dfrac{1}{L_{sq}} u_{sq} - \omega_s \dfrac{\psi_p}{L_{sq}} \end{cases} \qquad (3)$$

The FOC control law for flux and motor torque is as follows:

$$M_e = \frac{3}{2} z_p \frac{L_m^2}{L_r} \psi'_{rd} i_{sq} \qquad (4)$$

The V/f constant is guaranteed by an amplifier stage with angular velocity input signal ω.

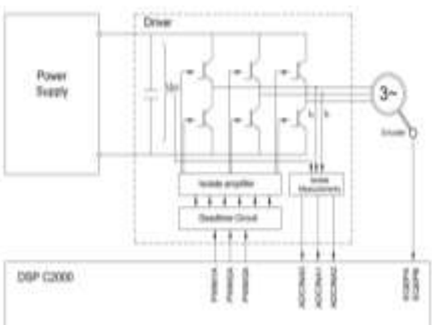

Fig. 2. Structure of the experimental setup

The output the controller is the control signal sent to the engine. Using an integrator, the rotation angle value of the voltage vector is calculated. The product of the torque constant with the angular velocity is the voltage applied to the motor. The control structure according to the V/f control method has been designed in Matlab/Simulink software, compiled and embedded in C2000 microcontroller.

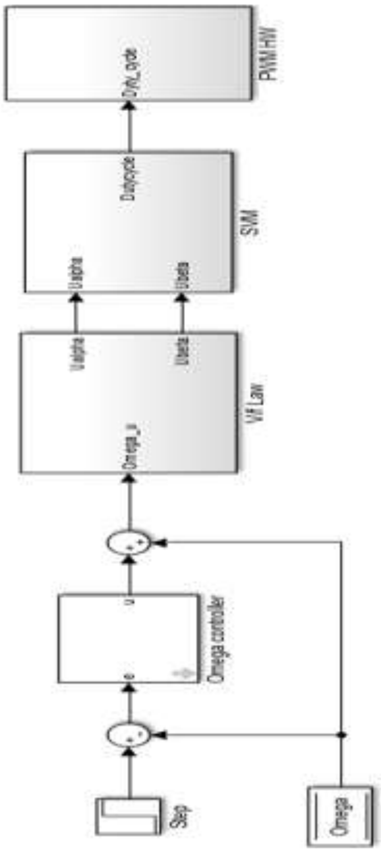

Fig. 3. Control structure of IM

Experimental results are shown in Fig. 4. The Figure show that the speed of the motor tracks to the speed reference closely. The current waveform illustrates the ability to control and extract the sample accurately with the implemented sampling method.

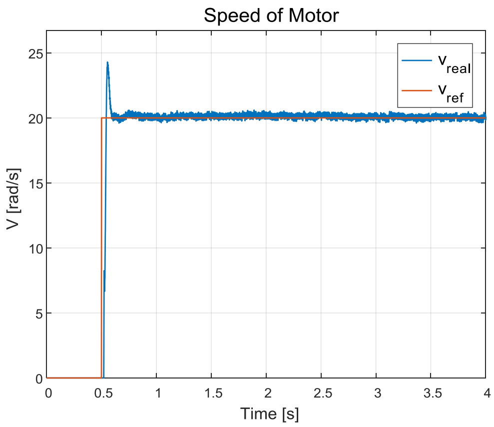

Fig. 4. Experimental results of speed

IV. CONCLUSIONS

The implemented hardware system shows the working capability of the C2000 microcontroller, satisfying with the V/f control method in asynchronous motor control. With the open structure of C2000, the intervention of control structure and algorithm setting becomes more convenient. Experimental results demonstrate the ability to meet the requirements of asynchronous three-phase motor control using C2000 series microcontrollers. By empirical results, the ability of real-time operating has been proven. This ensures the implementation of applications in practice as well as the implementation of different algorithms.

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REFERENCES

[1]. Quang NP, Dittrich JA (2008) Vector Control of Three-Phase AC Machines – System Development in the Practice. Springer Berlin Heidelberg.

[2]. Ion Boldea, Syed A. Nasar (2002), The Induction Machine Handbook, CRC Press

[3]. Pabitra Kumar Behera, Manoj Kumar Behera, Amit Kumar Sahoo (2014), Speed Control of Induction Motor using Scalar Control Technique, International Journal of Computer Applications (0975 – 8887), International Conference on Emergent Trends in Computing and Communication (ETCC-2014)

[4]. El-Faouri, Fares & Mohamed, Omar & Abu-Elhaija, Wejdan. (2017). D-Q model and control of a three-phase induction motor considering mutual flux saturation effect. 1-6. 10.1109/JIEEEC.2017.8051400.

[5]. Tabasian, R., Ghanbari, M., Esmaeli, A., & Jannati, M. (2020). Control of three-phase induction machine drives during open-circuit fault: A review. IETE Journal of Research, 1-18.

[6]. Wang, L., Mishra, J., Zhu, Y., & Yu, X. (2019). An improved sliding-mode current control of induction machine in presence of voltage constraints. IEEE Transactions on Industrial Informatics, 16(2), 1182-1191.

[7]. Santisteban, J. A., & Stephan, R. M. (2001). Vector control methods for induction machines: an overview. IEEE Transactions on Education, 44(2), 170-175.

[8]. Robyns, B., Francois, B., Degobert, P., & Hautier, J. P. (2012). Vector control of induction machines. In Vector control of induction machines (pp. 75-121). Springer, London.

[9]. Telford, D., Dunnigan, M. W., & Williams, B. W. (2000, June). A comparison of vector control and direct torque control of an induction machine. In 2000 IEEE 31st Annual Power Electronics Specialists Conference. Conference Proceedings (Cat. No. 00CH37018) (Vol. 1, pp. 421-426). IEEE.

[10]. Kubota, H., & Matsuse, K. (1994). Speed sensorless field-oriented control of induction motor with rotor resistance adaptation. IEEE Transactions on Industry Applications, 30(5), 1219-1224.

[11]. Poddar, G., & Ranganathan, V. T. (2004). Sensorless field-oriented control for double-inverter-fed wound-rotor induction motor drive. IEEE Transactions on Industrial Electronics, 51(5), 1089-1096.

[12]. Jin, S., Wei, Z., & Zhenyi, H. (2004, November). One novel scalar control scheme for induction machine. In 30th Annual Conference of IEEE Industrial Electronics Society, 2004. IECON 2004 (Vol. 1, pp. 347-352). IEEE.

[13]. Costa, C. A., Costa, M. A. A., de Azambuja Turqueti, M., Rossa, A. J., Nied, A., & Nogueira, F. G. (2019). Enhanced braking control for the induction machine using scalar control. IEEE Transactions on Industrial Electronics, 67(11), 9133-9142.

[14]. Zhang, Z., & Bazzi, A. M. (2019, May). Robust sensorless scalar control of induction motor drives with torque capability enhancement at low speeds. In 2019 IEEE International Electric Machines & Drives Conference (IEMDC) (pp. 1706-1710). IEEE.

[15]. Derouich, A., & Lagrioui, A. (2014). Real-time simulation and analysis of the induction machine performances operating at flux constant. International Journal of Advanced Computer Science and Applications, 5(4), 59-64.
[16]. García, J. M., & Domínguez, J. A. (2005). Comparison between Fuzzy logic and PI controls in a Speed scalar control of an induction machine. In CIRCE–ge3–Departamento de Ingeniería EléctricaC. PS, Universidad de Zaragoza, Conf. Paper.
[17]. Shi, Ling-Feng & Liu, Fu-Bo & He, Hui-Sen & Mao, Xiang-Yu & Lai, Xin-Quan. (2013). Design of adaptive dead-time control circuit for resonant half-bridge driver. International Journal of Electronics. 100. 10.1080/00207217.2012.743084.
[18]. Bilal Akin, Chris Clearman (2010), Digital Motor Control Methodology for C2000™ Real-Time Control Microcontrollers, Texas Instruments.
[19]. Texas Intruments, TMS320F2806x Piccolo™ Microcontrollers datasheet (Rev. G),
[20]. Texas Intruments, Launchxl - F28069 Overview
[21]. Texas Intruments, Scalar (V/f) Control of 3-Phase Induction Motors (2013), Application Report, SPRABQ8–July 2013.
[22]. Azzoug, Y., Sahraoui, M., Pusca, R., Ameid, T., Romary, R., & Cardoso, A. J. M. (2021). High-performance vector control without AC phase current sensors for induction motor drives: Simulation and real-time implementation. ISA transactions, 109, 295-306.
[23]. Kang, M. H., & Park, Y. C. (2006). A real-time control platform for rapid prototyping of induction motor vector control. Electrical Engineering, 88(6), 473-483.
[24]. Diab, A. A. (2014). Real-time implementation of full-order observer for speed sensorless vector control of induction motor drive. Journal of Control, Automation and Electrical Systems, 25(6), 639-648.
[25]. Ferdiansyah, I., Rusli, M. R., Praharsena, B., Toar, H., & Purwanto, E. (2018, July). Speed control of three phase induction motor using indirect field oriented control based on real-time control system. In 2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE) (pp. 438-442). IEEE.
[26]. Karrar, E.K., & Ajang, S.M. (2010). Field Oriented Control of Induction Motor.
[27]. Popescu, M. (2000). Induction motor modelling for vector control purposes (p. 144). Espoo, Finland: Helsinki University of Technology.
[28]. Beres, Z., & Vranka, P. (2001). Sensorless IFOC of induction motor with current regulators in current reference frame. IEEE Transactions on Industry Applications, 37(4), 1012-1018.
[29]. Dong, Zhen & Yu, Yong & Li, Wenshuang & Wang, Bo & Xu, Dianguo. (2018). Flux-Weakening Control for Induction Motor in Voltage Extension Region: Torque Analysis and Dynamic Performance Improvement. IEEE Transactions on Industrial Electronics. PP. 10.1109/TIE.2017.2764853.