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Original Article

A New Technique for Operating Multiple Induction Motors Using a Single Inverter

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Abstract

This article suggests a new method for operating multiple induction motors using a single inverter. A new technique, based on random selection, is applied to the Master-Slave method. In this research, one of the motors is randomly selected as the master and other motors are considered as slaves. The Field Oriented Control (FOC) method has been used to operate the drives. The motors are simulated with different horsepower characteristics and non-similar load torque. 5-hp and 3-hp motors are used in the modeling process, and to implement the suggested idea, MATLAB software has been employed.

Key words: FOC method, Induction motor, Master-Slave method, Random selection

INTRODUCTION

In addition to providing a background for precise control in motor processes and making the user more innovative, using inverters can improve the production efficiency and save energy in applications such as fans, pumps, compressors and other factory drivers. Inverters match the load characteristic with motor characteristics, and since they need a small reactive power from the grid, the requirement of load coefficient revision is eliminated. On the other hand, in addition to reducing the electric tensions on the grid and the operating current, operating soft inverters can prevent the mechanical shocks applied to the load and thus slacken the depreciation of mechanical parts, ball bearings and couplings, gearbox and finally some parts of the load [1-3].

In this research, the inverter can operate two induction motors. Motors are considered unlike and with non-similar load torque. There are three methods to operate induction motors: Master and Slave method, Average method and Weighting method. In Master and Slave method, one of the motors is selected as the Master and other motors are considered as Slaves. It should be noted that the response from Slave motors is uncontrollable and the control of Master motor can affect the Slave motors.

In the Average method, the effect of all motors is considered to be equal. In this method, the average speed, current, torque and flux of all motors is calculated and used in modeling. In the weighting method, each motor is given a km weight, which can vary between 0 and 1. This weight is determined according to torque and output speed of the motors.

This paper is structured as follows: in Section 2, the research background and a comparison of the methods is presented. Section 3 contains the suggested system model, and Section 4 presents the simulation results. Finally, Section 5 concludes the paper.

RESEARCH BACKGROUND

There are three suggested methods for operating multiple induction motors using a single inverter: 1- the Master-Slave method, 2- the Average method, and 3- the Weighting method. These three methods are explained in the following subsections [4-10].

The Master-Slave Strategy

In this strategy, the Master motor is controlled. In DTC method, the motor with the highest flux (and lowest load)

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is selected as the master. In FOC method, the motor with the highest torque is selected as the master. The responses from Slave motors cannot be controlled and any changes in the master motor load is reflected on slave motors and the torque response occurs in a swinging manner for slave motors. The Master-Slave strategy for FOC and DTC methods is illustrated in Figures 1 and 2 [6-8].

Where $N_{r\text{-}pri}$ and $T_{em\text{-}pri}$ are the primary speed and torque, respectively. They are estimated from Estimation Equations block. $N_{r\text{-}ref}$ and $\psi_{x\text{-}ref}$ are reference speed and flux, respectively.

The Average Strategy

In this strategy, currents and speeds of both motors are abstracted and their average are used to estimate torque and flux in DTC and FOC methods. This method uses the average block, flux estimation block, and PI controller and torque. In this method, the two motors play an equal role in control.

In FOC, initially the average current and speed of both motors are abstracted and then the torque and flux are estimated. While in DTC method, first the flux and torque of both motors are calculated and then the averages are obtained. Figures 3 and 4 show this process [5,7-8].

Where $N_{r\text{-}avg}$ and $T_{em\text{-}avg}$ are the estimated speed and torque, respectively, and $i_{abc\text{-}avg}$ is the average of the three phase current, and $\psi_{x\text{-}avg}$ denotes the average flux.

Ψ_{s1} and ψ_{s2} are the flux obtained in the first and second motors, T_{est1} and T_{est2} are the calculated torque for the first and second motors, and T_{estavg}, W_{ravg} and ψ_{savg} denote the average torque, speed and flux, respectively.

The Weighting Method

In the weighting method, a coefficient (*km*)is determined, which can vary between 0 and 1. In this method, the torque, flux and speed are calculated by the following equations [10]. In this method, *km* coefficient determines the motor with higher effect on control.

$$Te = km \times Te1 + (1-km)\times Te2$$

$$\psi = km \times \psi 1 + (1-km)\times \psi 2 \qquad (1)$$

$$W = km \times W1 + (1-km)\times W2$$

The weight of *km* is consisted of two parts: torque-related weight and speed-related weight, which are defined by *kmt* and *kms*, respectively. *Kmt* is the weight associated with load unbalance; and *kms* is used to prevent the problems resulted from heavy loads in different speeds.

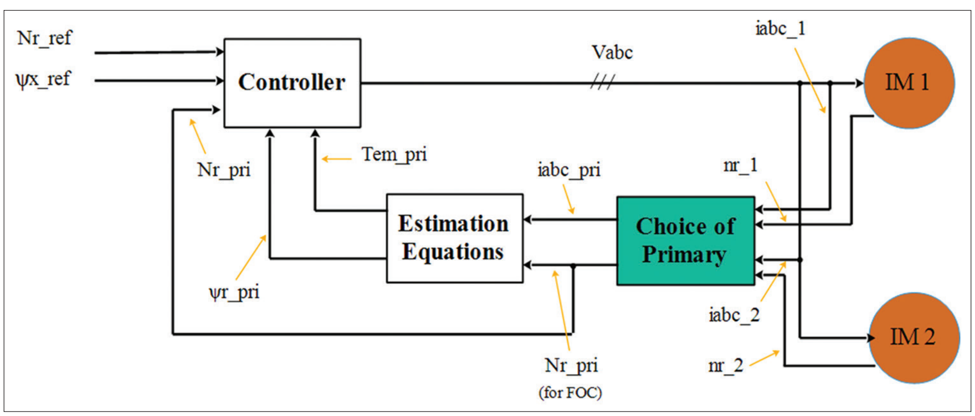


Figure 1: Master-Slave control strategy for FOC method

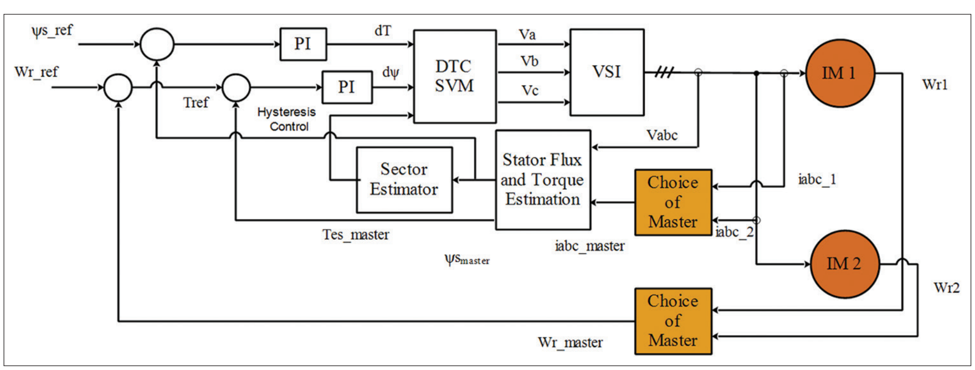


Figure 2: Master-Slave control strategy for DTC method

$$\text{Kmt}=\frac{T1}{T1+T2} \quad (2)$$

$$\text{Kms}= \text{Kms} + \text{sign(Kmsd)dp.Kmsd} \geq \text{dx} \quad (3)$$

$$\text{Kms}= \text{Kms} - \text{sign(Kmsd)dn.Kmsd} < \text{dx}$$

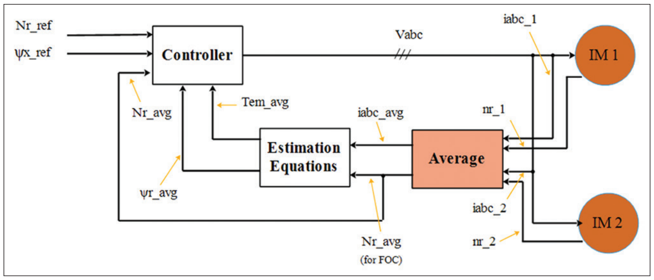


Figure 3: The average strategy in FOC method

Where d_x is the critical slip in the induction motor, and d_p and d_n are the ascending and descending steps of k_{ms} coefficient, which are estimated from motor parameters in working conditions. All the stages of weighting method are summarized in Figure 5 [10].

Comparison of the Methods

The Master-Slave strategy for DTC motors is reported to be better than the average control method, and despite the average method, it can control the flux less than or equal to the nominal value [5,7-8]. Selecting the Master motors is a serious problem in speed and torque oscillation in both motors.

Using the Master-Slave control in FOC, if the deficient motor is chosen as the Master motor, then there would

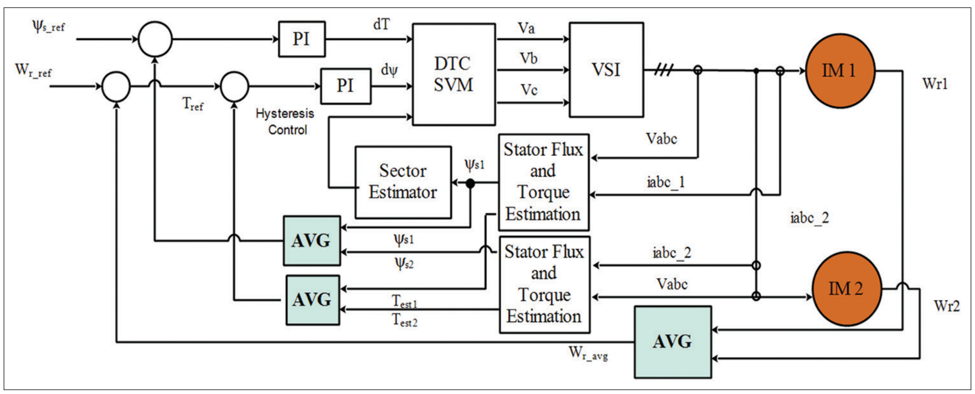


Figure 4: The average strategy in DTC method

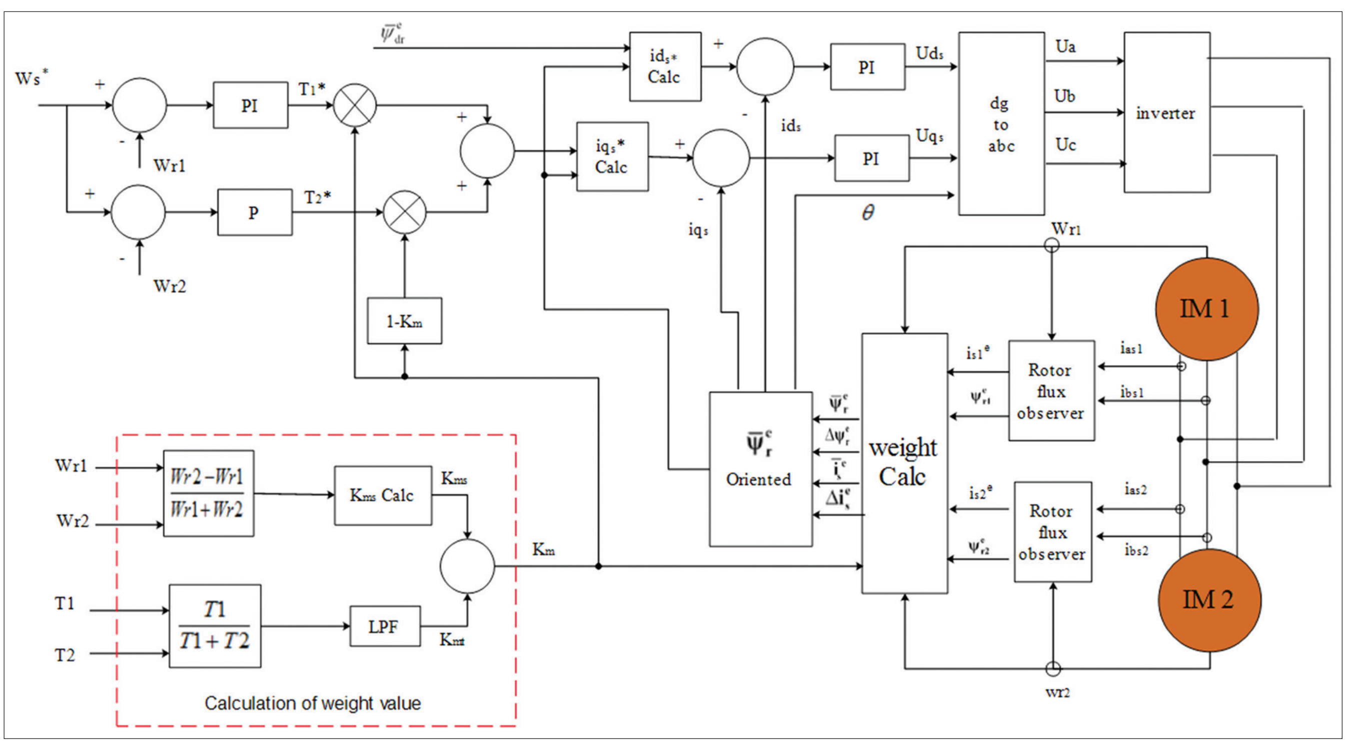


Figure 5: The weighting coefficient strategy

be oscillations in the torque of both motors. So it is not recommended to use Master-Slave control with deficient motors [6,11]. Nevertheless, the average control is preferred as a better solution for FOC controlling method [8,12].

In Master-Slave strategy, the motor with higher flux is selected as the Master motor in DTC, and the motor with high torque is considered to be a Slave motor in FOC. It should be noted that, the response from the slave motor cannot be controlled.

The weighting method is better than the abovementioned methods, but it is mathematically more complicated.

THE SUGGESTED SYSTEM MODELLING

The objective of the suggested method is to select the Master motor randomly. With this idea in mind, both motors have a 50% chance of being selected as the Master motor. In next subsections the model is explained and an approach is suggested along with the simulation results.

The Motor Model

Most of the induction motors are introduced by features such as horsepower, nominal speed, voltage and frequency. The motors used in this study are non-similar and their parametric characteristics are shown in Tables 1 and 2. As it can be seen, the power of these motors are 3 and 5 hp, their frequency is 60 Hz, and they have 460 volts.

The inverter considered in this paper is a 6-transistor IGBT [13-14]. The DC source is connected to the motor thorough a 6-switch inverter. The inverter should change the DC power to AC. The *spwm* switching controls these 6 switches. The DC source is set in 600 volts.

Table 1: Paramedic characteristics of the first motor with 5 hp

Motor 5 hp, 1750 rpm, 460 v	
Rotor resistance=1.083	Stator resistance=1.115
Rotor inductance=0.0059	Stator inductance=0.0059
Inertia=0.02	Mutual inductance=0.203
Friction factor=0.005752	Pole pairs=2

Table 2: Paramedic characteristics of the first motor with 3 hp

Motor 3 hp, 1725 rpm, 460 v	
Rotor resistance=0.816	Stator resistance=0.435
Rotor inductance=0.002	Stator inductance=0.004
Inertia=0.089	Mutual inductance=0.0693
Friction factor=0	Pole pairs=2

The Suggested Approach

Simulation in discrete mode is conducted in MATLAB software. In the suggested idea, the Master motor is selected randomly in each iteration. That means each motor can be selected as the Master randomly; while in the classic Master-Slave method, the motor with higher torque is selected as the Master motor. The suggested approach is shown in Figure 6.

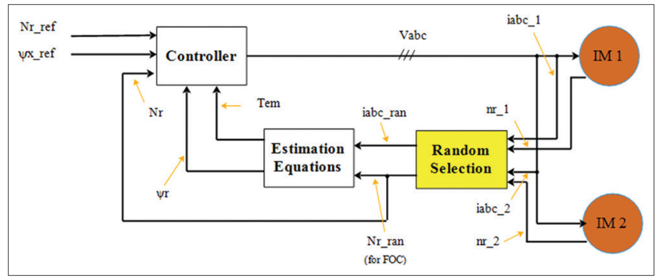


Figure 6: The suggested system

THE SIMULATION RESULTS

Figures 7 to 12 present the results of implementing the suggested system. Torque and speed of both motors are measured.

Mode 1: The first motor with 15 NM load and the second motor with 10 NM load

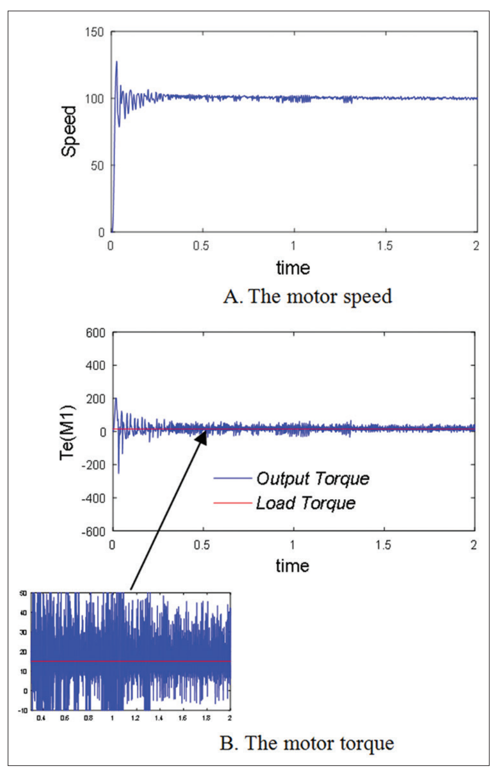
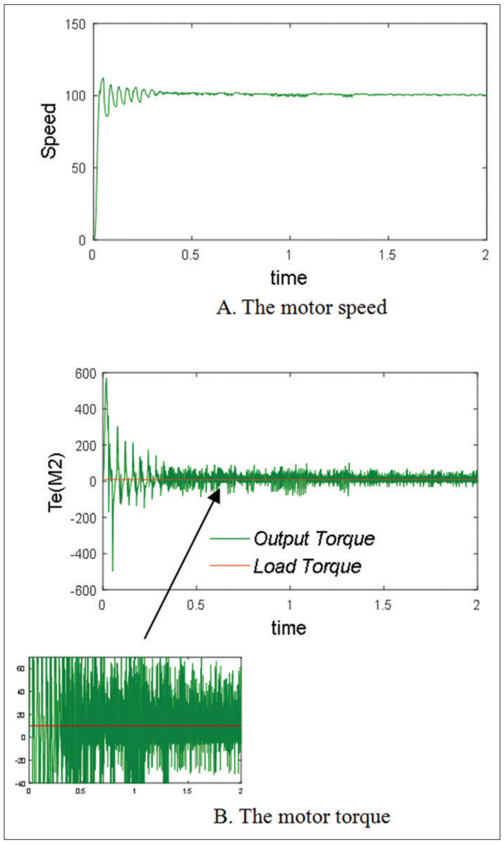


Figure 7: The speed and torque for Motor 1

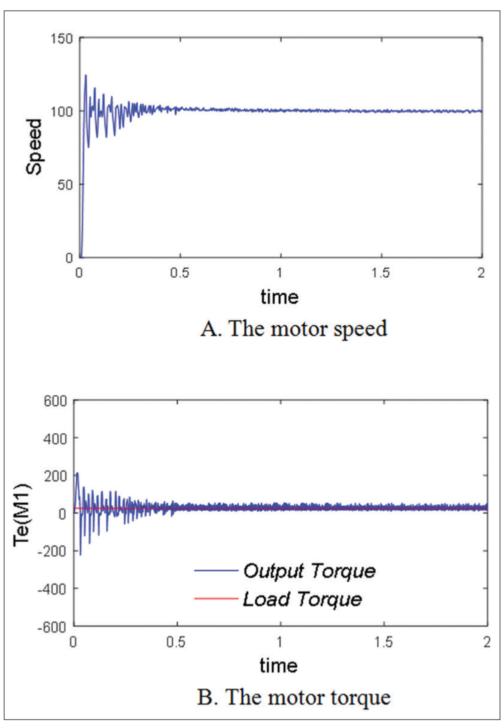


A. The motor speed

B. The motor torque

Figure 8: The speed and torque for Motor 2

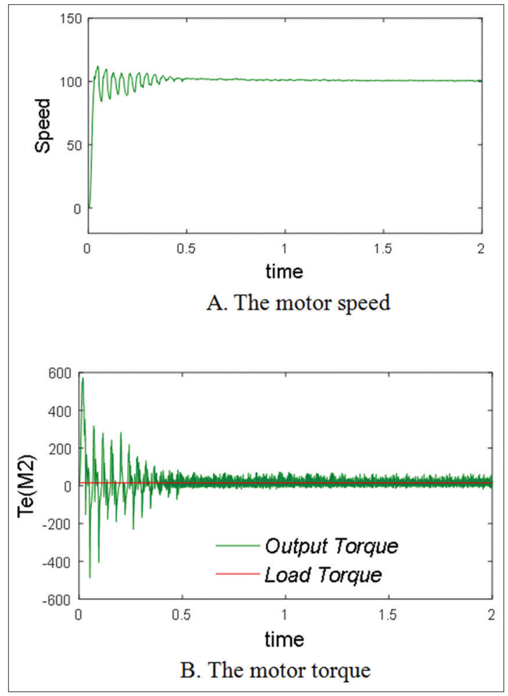
Mode 2: The first motor with 25 NM load and the second motor with 15 NM load



A. The motor speed

B. The motor torque

Figure 9: The speed and torque for Motor 1

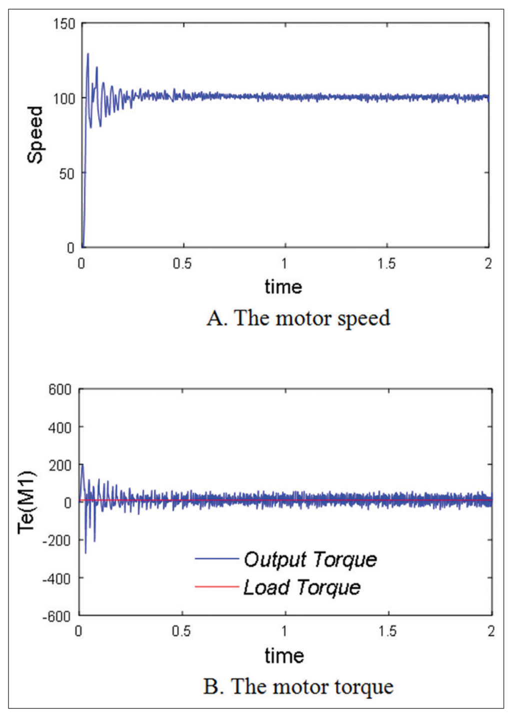


A. The motor speed

B. The motor torque

Figure 10: The speed and torque for Motor 2

Mode 3: Both motors with similar load of 15 NM



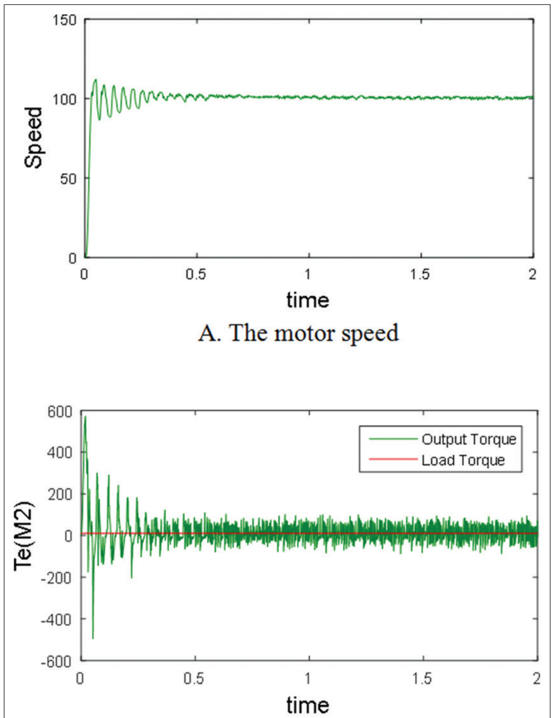
A. The motor speed

B. The motor torque

Figure 11: The speed and torque for Motor 1

CONCLUSION

In the present research, a new approach is suggested to randomly select the Master and Slave motors. This selection



A. The motor speed

B. The motor torque

Figure 12: The speed and torque for Motor 2

for induction motors is conducted using FOC method. The selected motors are unlike in terms of horsepower. Three different modes are considered for simulation: in mode 1 the first motor has 15 NM load – the second motors has 10 NM load; in mode 2 the first motor has 25 NM load – the second motor has 15 NM load; in mode 3 both motors have an equal load of 25 NM. In each mode, the electromagnetic torque and speed are observed. Given the responses obtained from the two motors, it can be said that the speed has reached 100 rad/s. As such, the electromagnetic torque in both motors has reached to the reference load torque. According to the simulation results, it can be said that the suggested method can provide a better performance.

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