Document details

2nd International Conference on Smart Grid and Smart Cities, ICSGSC 2018
20 November 2018, Article number 8541305, Pages 95-99
2nd International Conference on Smart Grid and Smart Cities, ICSGSC 2018; Kuala Lumpur; Malaysia; 12 August 2018 through 14 August 2018; Category numberCFP18URA-ART; Code 142892

Effect of Initial Rotor Position on Rotor Flux Oriented Speed Permanent Magnet Synchronous Motor Control using Incremental Encoder (Conference Paper)

Harini, B.W., Avianto, N., Yusivar, F.

Save all to author list

Electrical Engineering, Universitas Indonesia, Kampus UI Depok 16424, West Java, Indonesia

Abstract

View references (8)

This paper analyzes the effect of the load and initial position of the Permanent Magnet Synchronous Motor Control (PMSM) control system when the PMSM is used as a vehicle on the flat road and uphill. The control system that will be analyzed uses Proportional Integral (PI) as a current controller and incremental encoder as a sensor. The results prove that the initial rotor positions affect the motor current. © 2018 IEEE.

SciVal Topic Prominence

Topic: Sensorless Control | Permanent Magnet Synchronous Motor | Sliding Mode Observer

Prominence percentile: 97.422

Author keywords

current | incremental encoder | initial position | PMSM | synchronization | vector control

Indexed keywords

Engineering controlled terms: Electric currents | Electric power transmission networks | Permanent magnets | Signal encoding | Smart city | Smart power grids | Synchronization | Synchronous motors | Two term control systems | Vector control (Electric machinery)

Engineering uncontrolled terms: Current controller | Incremental encoder | initial position | Initial rotor position | Motor currents | Permanent Magnet Synchronous Motor | PMSM | Proportional integral

Engineering main heading: Electric machine control

Funding details

Cited by 1 document

A synchronization loss detection method for PMSM speed sensorless control

Harini, B.W. , Husnayain, F. , Subiantoro, A.
(2020) Jurnal Teknologi

View details of this citation

Related documents

Funding sponsor	Funding number	Acronym
Universitas Indonesia		UI

Funding text

ACKNOWLEDGMENT This research is funded by Universitas Indonesia research grant of the Publikasi International Terindeks untuk Tugas Akhir Mahasiswa UI (PITTA) 2018.

ISBN: 978-153868102-2
Source Type: Conference Proceeding
Original language: English
DOI: 10.1109/ICSGSC.2018.8541305
Document Type: Conference Paper
Publisher: Institute of Electrical and Electronics Engineers Inc.

References (8)

View in search results format >

All CSV export Print E-mail Save to PDF Create bibliography

1 Edge, E.
(2000) *Synchronous Motor Starting Review*

2 Vas, P.
(1998) *Sensorless Vector and Direct Torque Control*. Cited 2091 times.
Oxford University Press, USA

3 Semiconductor, F.
Sensorless PMSM vector control with a sliding mode observer for compressors using MC56F8013
(2008) *Document Number*

4 Harini, B.W., Subiantoro, A., Yusivar, F.
Study of speed sensorless permanent magnet synchronous motor (PMSM) control problem due to braking during steady state condition

(2017) *QiR 2017 - 2017 15th International Conference on Quality in Research (QiR): International Symposium on Electrical and Computer Engineering*, 2017-December, pp. 184-189. Cited 4 times.
ISBN: 978-150906397-0
doi: 10.1109/QIR.2017.8168479

View at Publisher

5 Jung, D.-H., Ha, I.-J.
An efficient method for identifying the initial position of a PMSM with an incremental encoder

(1998) *IEEE Transactions on Industrial Electronics*, 45 (4), pp. 682-685. Cited 24 times.
doi: 10.1109/41.704901

View at Publisher

☐ 6 Chen, X.E., Gu, S.M., Ye, S.W., Wang, L.
Study on initial rotor position identification of permanent magnet synchronous motor based on high frequency signal injection

(2010) *CAR 2010 - 2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics*, 2, art. no. 5456579, pp. 397-401. Cited 6 times.
ISBN: 978-142445193-7
doi: 10.1109/CAR.2010.5456579

View at Publisher

☐ 7 Mohamed, A.S., Zaky, M.S., El Din, A.Z., Yasin, H.A.
Comparative study of sensorless control methods of PMSM drives
(2011) *Innovative Systems Design and Engineering*, 2, pp. 44-67. Cited 17 times.

☐ 8 Mohamed, A.S., Zaky, M.S., El Din, A.Z., Yasin, H.A.
Comparative study of sensorless control methods of PMSM drives
(2011) *Innovative Systems Design and Engineering*, 2, pp. 1727-2222. Cited 17 times.

IEEE Catalog Number: CFP18URA-USB
ISBN: 978-1-5386-8101-5

2nd International Conference on Smart Grid and Smart Cities (ICSGSC 2018)

IEEE Catalog Number: CFP18URA-USB
ISBN: 978-1-5386-8101-5

ICSGSC 2018

2nd International Conference on Smart Grid and Smart Cities

Kuala Lumpur, Malaysia
August 12-14, 2018

IEEE

2nd International Conference on Smart Grid and Smart Cities (ICSGSC 2018)

Conference XPLORE COMPLIANT Version

IEEE Catalog Number:	CFP18URA-ART
ISBN:	978-1-5386-8102-2

Conference USB Version

IEEE Catalog Number:	CFP18URA-USB
ISBN:	978-1-5386-8101-5

Publisher: Institute of Electrical and Electronics Engineering, Inc.

Printed in Kuala Lumpur, Malaysia

2nd International Conference on Smart Grid and Smart Cities

(ICSGSC 2018)

August 12-14, 2018

Kuala Lumpur, Malaysia

Conference Committees

International Advisory Committee

Om Malik, University of Calgary, Canada

Conference Committee Chairs

A. R. Al-Ali, American University of Sharjah, UAE
Ab Halim Bin Abu Bakar, University of Malaya, Malaysia

Program Committee Chairs

Suhana Binti Mohd Said, University of Malaya, Malaysia
Wu Jin, Beijing Jiaotong University, China
Jasmine Zhou, Nanyang Technological University, Singapore

Technical Committee Chairs

Aryuanto Soetedjo, National Institute of Technology (ITN) Malang, Indonesia
Bushra Khalid, International Islamic University, Pakistan
Dalhar Susanto, University of Indonesia, Indonesia
Daniel Bernardon， PPGEE Department UFSM Santa Maria-RS, Brasil
Dharmender Singh Kushwaha, MNNIT Allahabad, India
Hartmut Schmeck, Karlsruhe Institute of Technology, Germany
Hui Li, Beijing Information Science & Technology University, China
Jagdish Kumar, PEC University of Technology, India
Jatmiko Wahyudi, BAPPEDA, Indonesia
Joseph D. Stevens, Heriot Watt University, United Arab Emirates
Kouzou Abdellah, Ziane Achour University of Djelfa, Algeria
Mohamad Kamarol Bin Mohd Jamil, University of Science Malaysia, Malaysia
Mohammad Lutfi b. Othman, Universiti Putra Malaysia (UPM), Malaysia
Naran Pindoriya, Indian Institute of Technology Gandhinagar, India
Nashiren Farzilah bt. Mailah, Universiti Putra Malaysia (UPM), Malaysia
Nilofar Asim, Universiti Kebangsaan Malaysia, Malaysia
Noraisyah Binti Mohamed Shah, University of Malaya, MALAYSIA
Nurul Islam, British Columbia Institute of Technology (BCIT), Canada
Rashid Hussain, Hamdard University Karachi, Pakistan
Sun Olapiriyakul, Thammasat University, Thailand
Talal Shaikh, Heriot Watt University, United Arab Emirates
Tan Chia Kwang, University of Malaya, MALAYSIA
Theresita Atienza, Polytechnic University of the Philippines, Philippines
Tzu-Ping Lin, National Cheng Kung University, Taiwan

Smart Grid and Power System

Electrical Engineering and Energy

Effect of Initial Rotor Position on Rotor Flux Oriented Speed Permanent Magnet Synchronous Motor Control using Incremental Encoder

Bernadeta Wuri Harini, Nanda Avianto, Feri Yusivar
Electrical Engineering
Universitas Indonesia
Kampus UI Depok 16424, West Java, Indonesia
e-mail: yusivar@yahoo.com

Abstract— **This paper analyzes the effect of the load and initial position of the Permanent Magnet Synchronous Motor Control (PMSM) control system when the PMSM is used as a vehicle on the flat road and uphill. The control system that will be analyzed uses Proportional Integral (PI) as a current controller and incremental encoder as a sensor. The results prove that the initial rotor positions affect the motor current.**

Keywords— PMSM; vector control; incremental encoder; initial position; current; synchronization

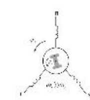
I. INTRODUCTION

Permanent Magnet Synchronous Motor (PMSM) is an AC motor that the rotor runs at the same speed as the rotation of the stator magnetic field. The rotor is locked to a rotating field. The rotor has to operate at synchronous speed for all load states. Increasing the load causes a loss of torque and the motor loses synchronization. The motor will stop if the rotor is pulled out of the synchronism when the mechanical load of the motor is increased [1].

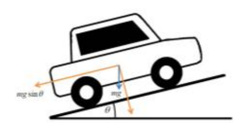
As for DC machines, torque control in AC machines is achieved by controlling the motor currents. However, both the phase angle and the modulus of the current in an AC machine have to be controlled. It means that the current vector has to be controlled. This is the reason for the terminology of 'vector control'. With vector control, the torque and flux-producing current components are decoupled. One of the vector control types is rotor-flux-oriented control[2]. In decoupling process, the three-phase mathematical model of PMSM will be changed into the two-phase mathematical model using Clarke and Parke transformations[3]. The Clarke transformation converts the balanced three-phase quantities into two-phase stationary reference frame. The Park transformation converts from stationary reference frame into a rotating reference frame.

When PMSM is used as a driving force in an electric vehicle, this out of synchronization can cause problems. When the vehicle is moving on a flat road as shown in Fig. 1.(a), due to the effect of vehicle loads, there can be a magnetic slip, as shown in Fig. 1.(b). Although the direction of the flux is the same, with different speeds ($\omega_e \rangle\rangle \omega_m$), the motor will be asynchronous. Not only on flat roads, the asynchronous condition also occurs in vehicles that are moving on uphill roads, as shown in Fig.1.(c). Because of the effects of gravity, where the vehicle gets as much force in the opposite direction, the vehicle can run backward. This condition is dangerous for the passenger of the vehicle. In Fig.1.(d), a magnetic slip condition is indicated when the vehicle is on an uphill road. Unlike when a vehicle moves on a flat road where the direction of the stator flux is equal to the rotor flux, the magnetic slip condition when the vehicle is running on an uphill has a stator flux direction that is not equal to the rotor flux.

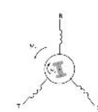
(a) Flat road



b) Magnetic slip on the flat road



(c) Uphill road



(d) Magnetic slip on the uphill road

Figure 1. The illustration of the vehicle on the road

If the initial position of the rotor (θ_r) differs from the controller's initial position, it can cause problems, especially if the PMSM is used as an electric vehicle, as illustrated in Fig. 1. This condition increases if the motor gets a large load. A large load on the motor can also cause problems. As explained by Harini, B.W. et al[4], the electric vehicle actually moves in the wrong direction when a large load that has reverse torque direction is given to the motor. Different from that paper where the system used a sensorless system, this paper will present the effect of initial position and load on PMSM if the system uses incremental encoder sensor.

The initial position of the rotor is very important in the control of PMSM. Jung, D.H. et al have described an efficient method for identifying the initial position of a permanent magnet synchronous motor (PMSM) with an incremental encoder, even when a brake and/or a constant load torque is being applied[5]. However, in this paper, there is no explanation of the effect of the initial position on the motor current. Lei, Wang et al have proposed a method to identify the rotor position polarity[6]. This paper didn't describe the effect of the initial position on the motor current. All papers didn't research the phenomena as illustrated in Fig.1.

The control system that will be analyzed uses Proportional Integral (PI) as a current controller and incremental encoder as a sensor. The effect of the load and initial position on PMSM control will be analyzed on both road condition, as illustrated in Fig.1.

II. PMSM MODEL

The Park transformation converts from stationary reference frame into a rotating reference (d, q, 0) frame using (1).

$$\begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} = \begin{bmatrix} \cos\theta_r & \sin\theta_r \\ -\sin\theta_r & \cos\theta_r \end{bmatrix} \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \quad (1)$$

The PMSM mathematical model in the d-q frame [2] is

$$\begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} = \begin{bmatrix} R_s + pL_s & -N\omega_r L_s \\ N\omega_r L_s & R_s + pL_s \end{bmatrix} \begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} + \begin{bmatrix} 0 \\ N\omega_r \psi_F \end{bmatrix} \quad (2)$$

where v_{sd} is the stator voltage in d-axis, v_{sq} is the stator voltage in q axis, i_{sd} is the stator current in d-axis, i_{sq} is the stator current in q-axis. The equation (5) can be stated as

$$\frac{d}{dt} i_{sd} = \frac{V_{sd} - R_s i_{sd} + N\omega_r L_{sq} i_{sq}}{L_{sd}} \quad (3)$$

$$\frac{d}{dt} i_{sq} = \frac{V_{sq} - i_{sd} N\omega_r L_{sd} - R_s i_{sq} - N\omega_r \psi_F}{L_{sq}} \quad (4)$$

The electric torque of PMSM is

$$T_e = \{\psi_F i_{sq} + (L_{sd} - L_{sq}) i_{sd} i_{sq}\} \quad (5)$$

where L_{sd} is the stator inductance in d-axis and L_{sq} is the stator inductance in q-axis.

The mechanical model of PMSM [7] is

$$\frac{d\theta_r}{dt} = N\omega_r \quad (6)$$

where

$$\frac{d\omega_r}{dt} = \frac{T_e - T_L}{J} \quad (7)$$

where θ_r is the position of the rotor, ω_r is the speed, T_L is the load torque and J is the inertia of the motor.

III. PMSM SENSOR CONTROL

Block diagram of the PMSM sensor control system is shown in Fig. 2. Each part will be explained below.

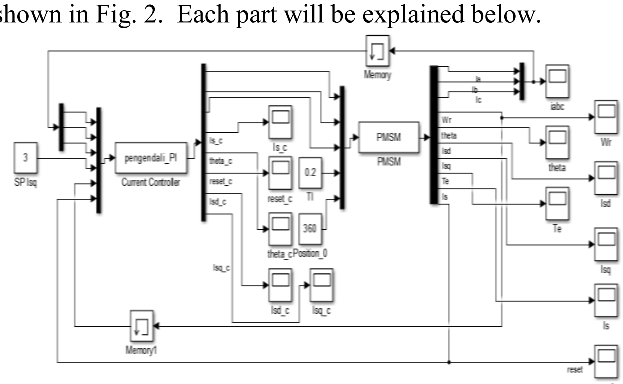


Figure 2. Block diagram of the PMSM sensor control

A. Decoupling

Decoupling part is used to decouple cross-coupling between d and q-axis components (ω and i) which is not linear. This is necessary because the PI controller can only control the linear equations. The decoupling equations [8] are

$$V_{sd} = U_{sd} - N\hat{\omega}_r L_{sq} i_{sq1} \quad (8)$$

$$V_{sq} = U_{sq} + N\hat{\omega}_r L_{sd} i_{sd1} + N\hat{\omega}_r \psi_F \quad (9)$$

where

$$\frac{d}{dt} i_{sd1} = \frac{1}{T_d} i^*_{sd} - \frac{1}{T_d} i_{sd1} \quad (10)$$

$$\frac{d}{dt} i_{sq1} = \frac{1}{T_d} i^*_{sq} - \frac{1}{T_d} i_{sq1} \quad (11)$$

$$\frac{d}{dt} X_{sd} = i^*_{sd} - i_{sd} \quad (12)$$

$$\frac{d}{dt} X_{sq} = i^*_{sq} - i_{sq} \quad (13)$$

where i^*_{sd} is the set point of i_{sd} and i^*_{sq} is the set point of i_{sq}.

B. Current Controller

The phase angle and the modulus of the current in an A.C. machine have to be controlled. It means that the current vector has to be controlled [2], so the torque and flux producing current components are independently controlled. This is done by controlling the stator current in the d-q reference frame using Proportional Integrator (PI). The current controller equations [8] are

$$u_{sd} = K_{pd}(i^*_{sd} - i_{sd}) + K_{id}\int (i^*_{sd} - i_{sd})dt \quad (14)$$

$$u_{sq} = K_{pq}(i^*_{sq} - i_{sq}) + K_{iq}\int (i^*_{sq} - i_{sq})dt \quad (15)$$

where K_{pd}, K_{id}, K_{pq}, and K_{iq} are the current controller gain in the d-q frame. The values of each gain are

$$K_{pd} = \frac{L_{sd}}{T_d} \qquad K_{id} = \frac{R_s}{T_d} \qquad K_{pq} = \frac{L_{sq}}{T_d} \qquad K_{iq} = \frac{R_s}{T_d} \quad (16)$$

IV. METHODS

PMSM that we are used has parameters shown in Table I. The sensorless control system of PMSM is simulated using Matlab. The system is analyzed in two conditions. They are

a. The vehicle runs on the flat road. The flat road is represented by a zero load. ($T_L = 0$)
b. The vehicle runs on the uphill. The uphill path is represented with a non-zero (T_L) load, in which case the test is performed for $T_L = 0.16$ N.m.

The tests of both conditions were conducted at different starting positions ($\Delta\theta$), ie 0^0, 45^0, 90^0, 135^0, 180^0, 225^0, 270^0, 315^0, and 360^0. $\Delta\theta$ is the difference between θ_r and θ_c. The variables tested are the i_d and i_q values when the initial rotor position is the same and different.

TABLE I. PMSM PARAMETERS

Parameters	Quantities	Unit	Description
Td	0.01	second	Time constant of current controller
dt	0.0001	second	Sampling time of controller
N	4		Number of pole pairs
R_s	0.14710296	Ω	Stator resistance
L_{sd}	0.29420592	mH	Stator inductance in *d*-axis
L_{sq}	0.382467696	mH	Stator inductance in *q*-axis
Ke	0.055977	Vpeak/rad/s	Electrical constant
psi (ψ_F)	0.0133994	Ke/N	Magnet flux linkage
J	0.01	kgm^2	Motor inertia

The control system uses

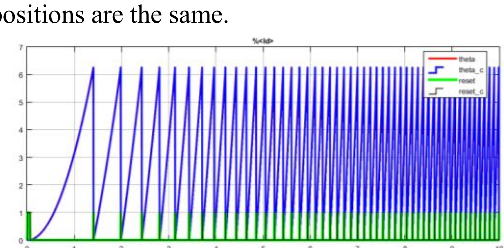
a. An incremental encoder as the speed sensor.
b. The Proportional Integral (PI) controller is used for the current control
c. The constants of the current controller are obtained from the formula in equation 16.
d. The set point of i_{sd}^* is 0A.
e. The set point of i_{sq}^* is 1.86A.

V. RESULTS AND DISCUSSION

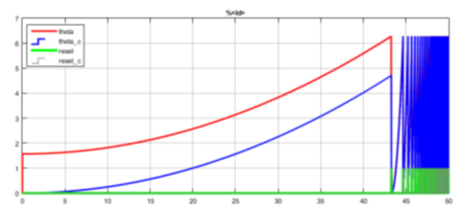
The system is tested on two conditions, i.e. the system is tested on the flat and uphill road. In this test, the initial position of PMSM is set at a certain angle. Speed (ω_r) is measured using an incremental encoder. The controller output position (θ_c) is reset so that the control position is equal to the rotor position (θ_r).

A. Testing on a Flat Road

When the vehicle runs on a flat road, the motor is applied a zero load ($T_L = 0$). Fig. 3.a shows the reset process with an initial position of 0^0. It appears that the position of the rotor and the output position of the controller from the start are the same. Fig. 3.b shows the reset process with an initial position of 90^0. It appears that the start is at the rotor position of 90^0 or 1.57 radians while the controller output position (θ_c) is at position 360^0 (6.28 radians). When at position 0^0, it is reset so that it is at position 0^0. After reset, both positions are the same.



a. $\theta_{r0} = 0^0$

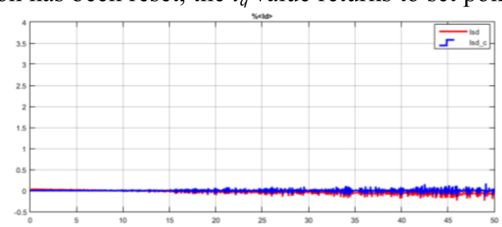


b. $\theta_{r0} = 90^0$

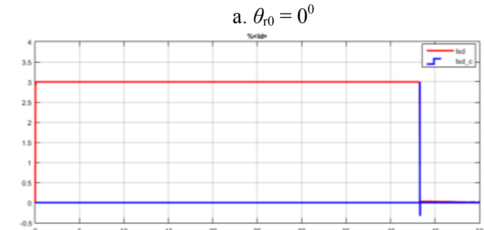
Figure 3. Reset process under load conditions = 0 N.m.

This condition also affects the i_d and i_q values. Fig. 4.a shows the i_d values when the starting position is the same. Fig. 4.b shows the i_d values when the starting position is different. The problem occurs when the initial position of the rotor differs from the controller's output position. It appears that the i_d current overshoots to 3 A for 43 seconds. At the 43rd seconds where the controller output position has been reset, the i_d value returns to set point (0 A).

This condition also occurs at the i_q value, as shown in Fig. 5. When the initial position of the rotor differs from the controller's output position, the i_q current drops to 0 A for 43 seconds. At the 43rd seconds where the controller output position has been reset, the i_q value returns to set point (3 A).

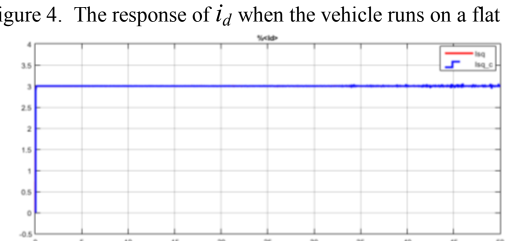


a. $\theta_{r0} = 0^0$

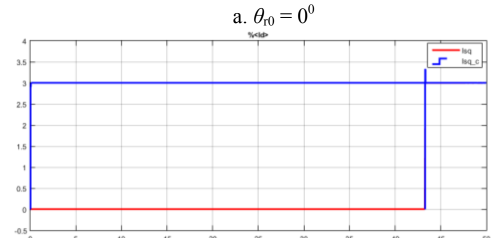


b. $\theta_{r0} = 90^0$

Figure 4. The response of i_d when the vehicle runs on a flat road



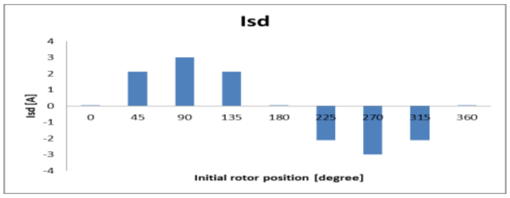
a. $\theta_{r0} = 0^0$



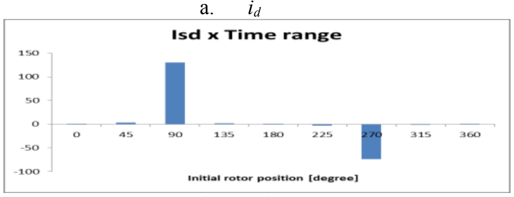
b. $\theta_{r0} = 90^0$

Figure 5. The response of i_q when the vehicle runs on a flat road

Fig. 6.a shows the overshoot changes in i_d values to different starting positions. Fig. 6.b shows the changes in the i_d value multiplied by the time. Fig. 7.a shows the overshoot changes in the i_q value to different starting positions, whereas Fig. 7.b shows the change in the i_q value multiplied by the time.

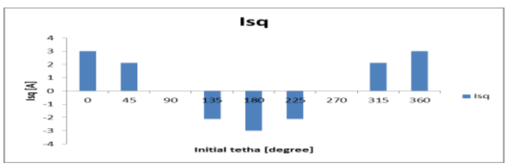


a. i_d

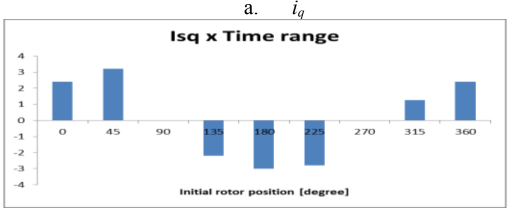


b. i_d x time range

Figure 6. The condition of i_d versus initial position on a flat road conditions.



a. i_q



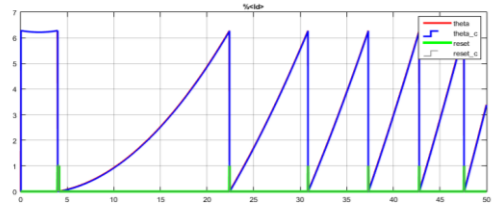
b. i_q x time range

Figure 7. The condition of $i_q$versus initial position on a flat road conditions.

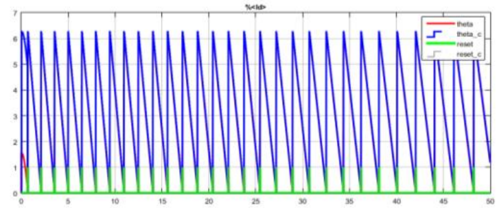
Fig. 6 and 7 show that both the current i_d and i_q at different starting positions have different values. From Fig.6.b and 7.b, it appears that the worst response occurs when the rotor's initial position is 90^0 and 270^0. This shows that initial position synchronization on PMSM is very important.

B. Testing on an Uphill Road

Testing on an uphill road is done with is applied a load T_L = 0.16 N.m. Fig. 8.a shows the reset process with an initial position of 0^0. It appears that the position of the rotor and the output position of the controller from the start are the same. Fig. 8.b shows the reset process with an initial position of 90^0. It appears that the start is at the rotor position of 90^0 or 1.57 radians while the controller output position (θ_c) is at position 360^0 (6.28 radians). When at position 0^0, it is reset so that it is at position 0^0. After reset, both positions are the same.



a. $\theta_{r0} = 0^0$

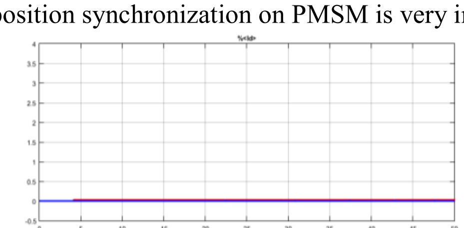


b. $\theta_{r0} = 90^0$

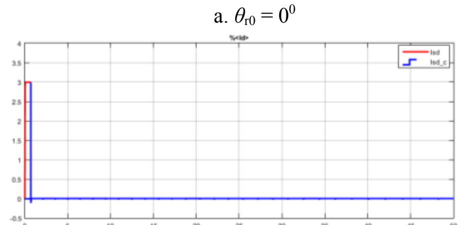
Figure 8. Reset process under load conditions = 0.16 N.m.

As happens when the motor is moving on a flat road, this condition also affects the i_d and i_q values. Fig. 9.a shows the i_d values when the starting position is the same. Fig. 9.b shows the i_d values when the starting position is different. The problem also occurs when the initial position of the rotor differs from the controller's output position. It appears that the i_d current overshoots to 3 A. After a reset, the i_d value returns to set point (0 A). Fig.10 shows the i_q value when the motor runs on an uphill road. When the initial position of the rotor differs from the controller's output position, the i_q current drops to 0 A. After a reset, the i_q value returns to set point (3 A). Fig. 9 and 10 show that initial position synchronization on PMSM is very important.

Fig. 11.a shows the overshoot changes in i_d values to different starting positions. Fig. 11.b shows the changes in the i_d value multiplied by the time. Fig. 12.a shows the overshoot changes in the i_q value to different starting positions, whereas Fig. 12.b shows the change in the i_q value multiplied by the time. It appears that both the current i_d and i_q at different starting positions have different values. Fig.11.b and 12.b show that the worst response occurs when the rotor's initial position is 90^0 and 270^0. This shows that initial position synchronization on PMSM is very important.

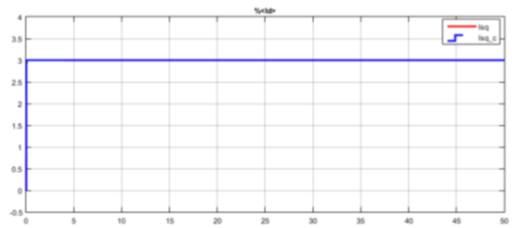


a. $\theta_{r0} = 0^0$

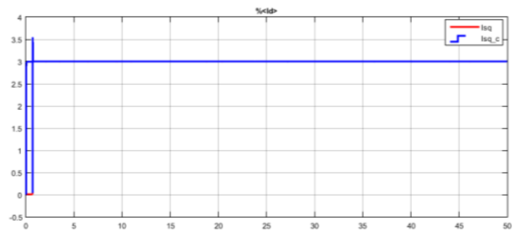


b. $\theta_{r0} = 90^0$

Figure 9. The response of i_d when the vehicle runs on an uphill road

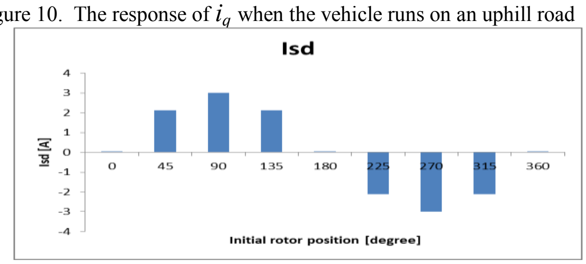


$\theta_{r0} = 0^0$

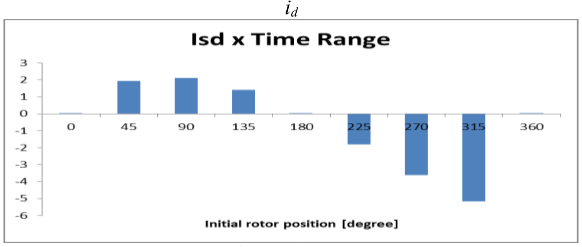


$\theta_{r0} = 90^0$

Figure 10. The response of i_q when the vehicle runs on an uphill road

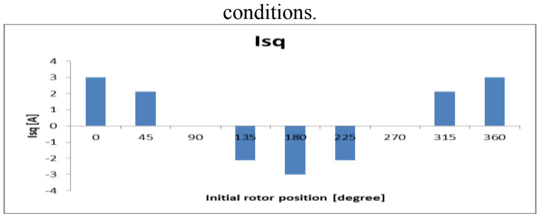


i_d

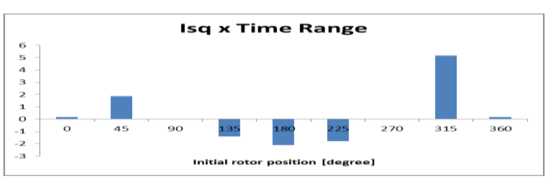


b. i_d x time range

Figure 11. The condition of i_d versus initial position on an uphill road conditions.



a. i_q



b. i_q x time range

Figure 12. The condition of i_d versus initial position on an uphill road

VI. Conclusion

From the above analysis, it appears that PMSM motors used as vehicles still have problems, both when runs on a flat road and an uphill road. This issue is very important to be solved. In addition to detecting the initial position of the rotor, so that the current i_d and i_q correspond to the set point value, the rotor is rotated first to get the zero crossing. At zero crossing, the controller output position is reset to equal the rotor position. At this point, the i_d and i_q value return to the set point value.

Acknowledgment

This research is funded by Universitas Indonesia research grant of the *Publikasi International Terindeks untuk Tugas Akhir Mahasiswa* UI (PITTA) 2018.

References

[1] E. Edge. (2000). *Synchronous Motor Starting Review*.

[2] P. Vas, *Sensorless vector and direct torque control*: Oxford University Press, USA, 1998.

[3] F. Semiconductor, "Sensorless PMSM vector control with a sliding mode observer for compressors using MC56F8013," *Document Number,* 2008.

[4] B. W. Harini, A. Subiantoro, and F. Yusivar, "Study of speed sensorless permanent magnet synchronous motor (PMSM) control problem due to braking during steady state condition," in *Quality in Research (QiR): International Symposium on Electrical and Computer Engineering, 2017 15th International Conference on*, 2017, pp. 184-189.

[5] D.-H. Jung and I.-J. Ha, "An efficient method for identifying the initial position of a PMSM with an incremental encoder," *IEEE Transactions on Industrial electronics,* vol. 45, pp. 682-685, 1998.

[6] W. Lei, "Study on initial rotor position identification of permanent magnet synchronous motor based on high frequency signal injection," in *Informatics in Control, Automation and Robotics (CAR), 2010 2nd International Asia Conference on*, 2010, pp. 397-401.

[7] A. S. Mohamed, M. S. Zaky, A. Z. El Din, and H. A. Yasin, "Comparative study of sensorless control methods of PMSM drives," *Innovative Systems Design and Engineering,* vol. 2, pp. 44-67, 2011.

[8] A. S. Mohamed, M. S. Zaky, A. Z. El Din, and H. A. Yasin, "Comparative study of sensorless control methods of PMSM drives," *Innovative Systems Design and Engineering,* vol. 2, pp. 2222-1727, 2011.

CERTIFICATE OF PRESENTATION

Bernadeta Wuri Harini

Universitas Indonesia

Paper Title: Effect of Initial Rotor Position on Rotor Flux Oriented Speed Permanent Magnet Synchronous Motor Control using Incremental Encoder

For your excellent oral presentation at the conference and your significant contribution to the success of 2nd International Conference on Green Energy (ICOGE 2018), Kuala Lumpur, Malaysia, August 12-14, 2018.

Paper ID: OGE18-107

Certificate Number: 18A01744

Session Chair

Green Energy ★ International Conference ICOGE

Conference Committee
ICOGE 2018