A NOVEL NONLINEAR TORQUE AND CURRENT CONTROL OF THE INDUCTION MOTOR COUPLE DC MOTOR

Zulkarnain Lubis
Electrical Engineering Department, Universitas Pembangunan Panca Budi, Indonesia
Corresponding author: lubisdrzulkarnain@gmail.com

ABSTRACT

The stability of control torque tracking problem of the induction motor for Hybrid Electric Vehicle (HEV) applications is addressed. Because the induction motor couple dc motor to increase torque of machines where a high starting torque induction motor with simultaneously reduced starting current. This paper mainly deals with the design of an advanced control law with an observer for a special class of nonlinear systems. These two control strategies are different on the operation principle but their objectives are the same. Torque control of an induction machine based on DTC strategy has been developed and a comprehensive study is present in this research. To perform controller design a torque-flux dynamic model with stator voltage as an input is obtained and separation of the torque and flux regulation is achieved. The performance of proposad method has been demonstrated by simulations performed using a versatile simulation package, Matlab/Simulink. Several numerical simulations have been carried out in a steady state and transient operation on a speed control mode.

Keywords: Current Control, Dc Motor, Induction Motor**,** Torque Control

INTRODUCTION

The automotive industry is increasingly seeking cleaner and more energy-efficient vehicles. The Hybrid Electric Vehicle (HEV) is one of solutions that assures lower gas emissions while saving energy usage[1,2]. An HEV vehicle usually has two sources of traction; a combustion engine and an electric motor.

In an all-electric vehicle (EV) there is no internal combustion engine (ICE), but all other components exist including batteries with excessive power. EVs and HEVs are studied by numerous authors in the past, one comprehensive study is that of Chan [3]. For many years, induction machine have provided the most common form of electromechanical drive for industrial, commercial and domestic applications that can operate at essentially constant speed[4,5]. The DTC controller consists of two hysteresis comparator (flux and torque) to select the switching voltage vector in order to maintain flux and torque between upper and lower limit[6].

In this paper, we redesign the observer based on a control law in order to ensure the global stability of the process-observer-controller system. Two different sub-controllers independently control the engine and the motor. Both sub-controllers receive their commands from the supervisory controller. an induction couple dc motor for direct torque and flux regulation of IM is described. The scheme does not use a transformation to the rotor flux related frame and it provides asymptotic tracking of the torque and flux commands. In the speed sensorless mode of operation the scheme shows robustness to the rotor time constant variation that could improve electric drive efficiency as compared to the commonly used IFO scheme. The controller design is based on a torque-flux dynamic model that has torque, flux magnitude and one auxiliary signal as state variables and the stator voltage as the inputs.

LITERATURE REVIEW

A hybrid electrical vehicle (HEV) may consist of an internal combustion engine (ICE), electric motor (EM), electric generator (EG), power electronic circuits, advanced electronic control units (ECU), a complex mechanical transmission and a battery bank[7,8].

Fig.1 shows the structure of drive assembly of a hybrid electric car. There are 3 electrical machines, generator and starter (M/G), starter and the main motor (M), in the figure. G/M is an integrated started and generator (ISG) which connects with the internal combustion engine (ICE) using a couple . The starter is a standby one. The M, which is subject of this paper, is called main motor. It connects with the wheels through the final gear. Main motor is a three phase asynchronous Motor. The battery pack is a 288V, 10Ah NiH one.

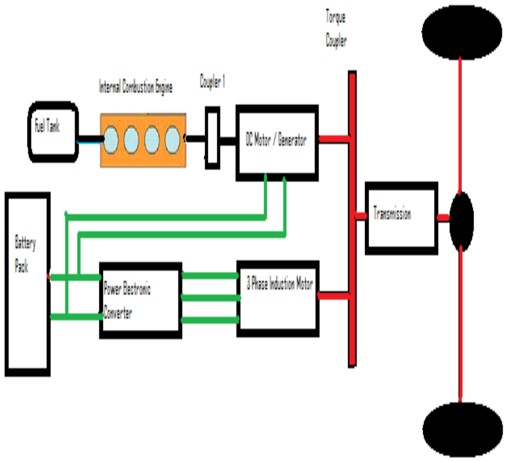


Figure 1. Power assembly diagram of HEV

The first step in vehicle performance modelling is to write an equation for the electric force. This is the force transmitted to the ground through the drive wheels, and propelling the vehicle forward. This force must overcome the road load and accelerate the vehicle as shown in Fig.2.

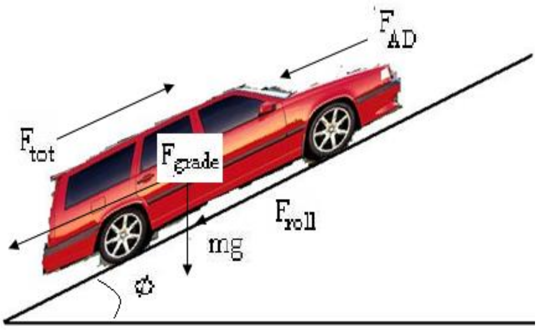


Figure 2. Basic of Forces on a Vehicle

The rolling resistance is primarily due to the friction of the vehicle tires on the road and can be written as:

$$f_{roll} = f_r \, Mg \, , (1)$$

where M is the vehicle mass, f , is the rolling resistance coefficient and g is gravity acceleration .

The aerodynamic drag is due to the friction of the body of vehicle moving through the air. The formula for this component is as in the following .Dynamic modelling and simulation of an induction motor with

$$f_{AD} = \frac{1}{2}\xi C_D AV^2 \quad (2)$$

The gravity force due to the slope of the road can be expressed by:

$$f_{grade} = Mg.\sin\alpha \quad (3)$$

Where α is the grade angle.

In addition to the forces shown in Fig.3, another one is needed to provide the linear acceleration of the vehicle given by:

$$f_{acc} = M\alpha = M\frac{dV}{dt} \quad (4)$$

The propulsion system must now overcome the road loads and accelerate the vehicle by the tractive force, F_{tot} , as follows :

$$F_{tot} = f_{roll} + f_{AD} + f_{garde} + f_{acc} \quad (5)$$

Whells and axels convert F_{tot} and the speed of vehicle to torque and angular speed requirements for differential as follow :

$$T_{whell} = F_{tot}\, r_{wheel}\ ,\ \omega_{wheel} = V/\, r_{wheel} \quad (6)$$

Where T_{whell}, r_{wheel} and ω_{wheel} are the tractive torque, the radius, and the angular velocity at the wheels, respectively.

The angular torque velocity and torque of the wheels are converted to motor rpm and motor torque requirements using the gears ratio at differential and gearbox as follows :

$$\omega_{m} = G_{fd}\, G_{gb}\ \omega_{wheel}\ ,\ T_m = T_{whell} / G_{fd}\, G_{gb} \quad (7)$$

Where G_{fd} and G_{gb} are respectively differential and gear box gears ratios.

METHODS

Controllers couple IM and DCM

The coupling of these two components can be in parallel or in series. In the parallel configuration, both the IM and the DC electric motor contribute to the traction force that moves the vehicle. Power is split between them according to a control strategy, which is usually implemented by a supervisory controller. Two different sub-controllers independently control the IM and the DC motor. Both sub-controllers receive their commands from the supervisory controller. Among these commands are the two torque requests required from both sub-systems as shown in Fig.3.

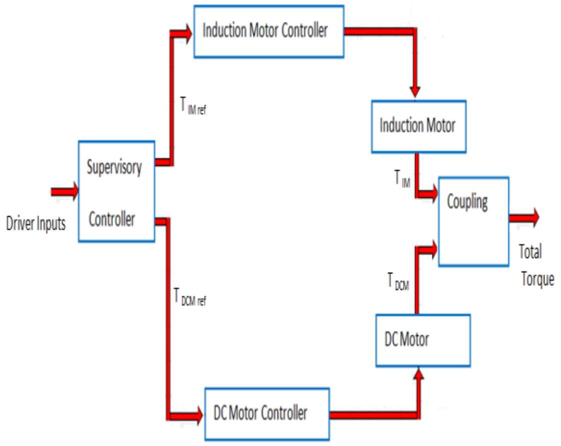


Figure 3. Controllers IM and DCM in a typical HEV application

Controller Simulation Model

To study the performance of the developed Transient torque and current model, a closed loop torque control of the drive is simulated using Matlab/Simulink simulation package. Fig.4 shows the simulation block diagram[9]. The drive cycle gives the required vehicle speed then the torque and speed requested from the electric motor. The current drawn from IM power supply shows the battery performance. The dynamic behaviour of the IM in the DCM+IM drive cycle. Power assembly diagram of HEV Normal Condition the ECE drive cycle. IM torque and average torque, power assembly diagram of HEV in Hybrid Electric. The block diagram of the simulink model is shown in Fig.5.

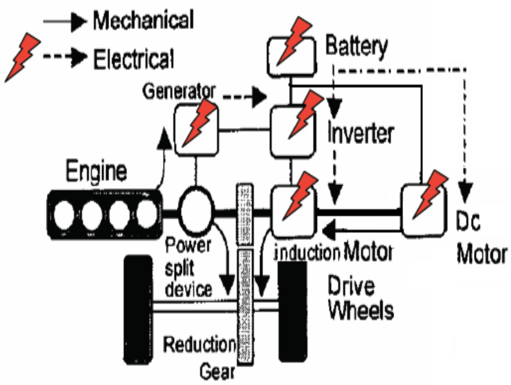


Figure 4. Simulation block diagram for stability control

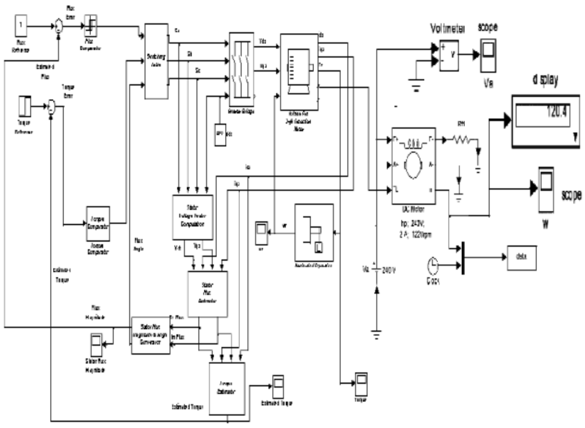


Figure 5. Developed model of transient torque and current control of induction machine

RESULTS AND DISCUSSION

Experimental Results

Results is explained by the pact that, in experimental test (as shown in fig.6) were observed a strong influence of motor inductance in coupler to dc motor, more precisely, in the power system, however in the simulation such influence was not considered, and also non-linearity and additional losses as shown in fig.7&8.

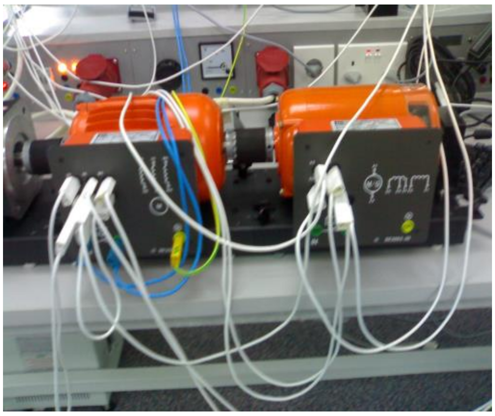


Figure 6. Wiring of Induction Motor Couple DC Motor

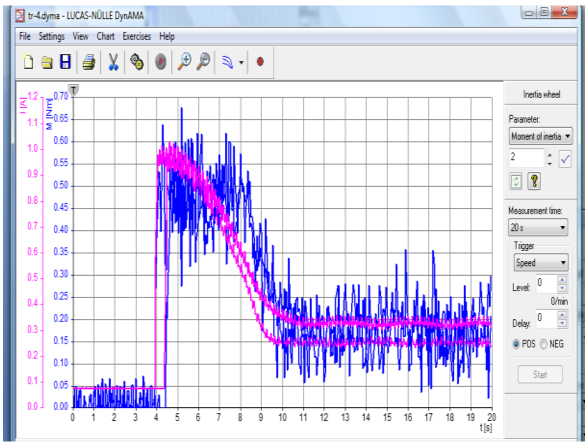
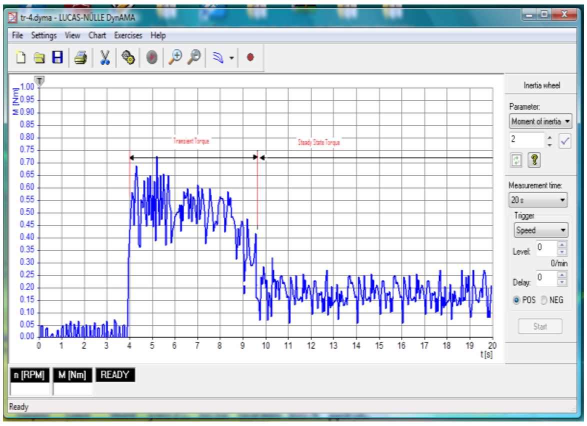
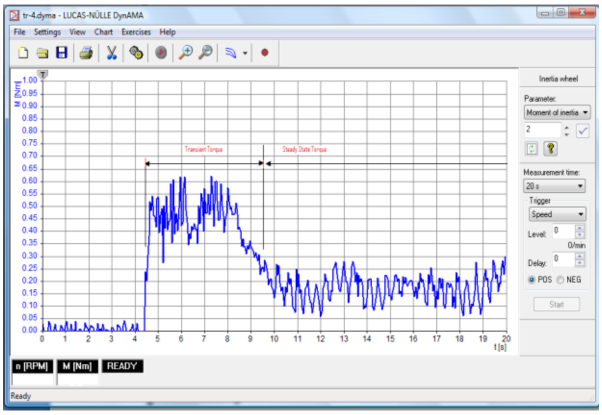


Figure 7. Torque, Current in Starting Transient and Steady Stated



a)



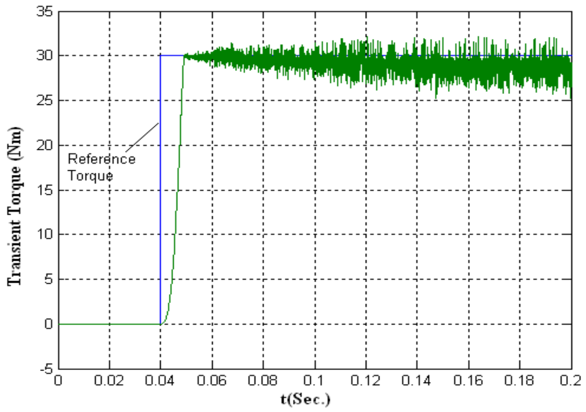
b)

Figure 8. Transient torque a) Torque of Induction Motor couple dc motor b) Torque of Induction Motor

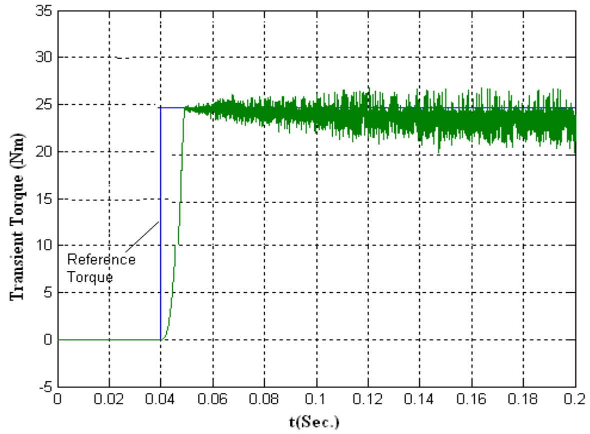
Simulation Results

Start-up with wheel Load: Torque control dynamic performance of developed IM Couple DCM model is evaluated by applying a step input of amplitude 30 Nm after 0.4 ms to torque reference while the stator flux reference is maintained at 1 Wb. The width of the hysteresis band is adjusted to □0.01 Wb for the flux comparator and □0.01 Nm for the torque comparator. Maximum step size of 0.1 ms is used in this simulation. The estimated electromagnetic torque remains at zero at period before 0.4 ms, so the rotor does not rotate. At t=0.4 ms, a step of 30 Nm is

A Fig.9(a&b) results comparison – The transient torque Three phase Induction Motor couple DC Motor and only Three phase Induction Motor (simulation). From Fig. 11(a&b) are transient torque of induction motor couple dc motor and only induction motor , the estimated electromagnetic torque remains at zero at period before 0.4 ms, so the rotor does not rotate. At t=0.4 ms, a step of 30 Nm is applied to the torque reference and the electromagnetic torque immediately increases to reach the demand torque. This causes the rotor to accelerate at a rate dictated by the rotor inertia.

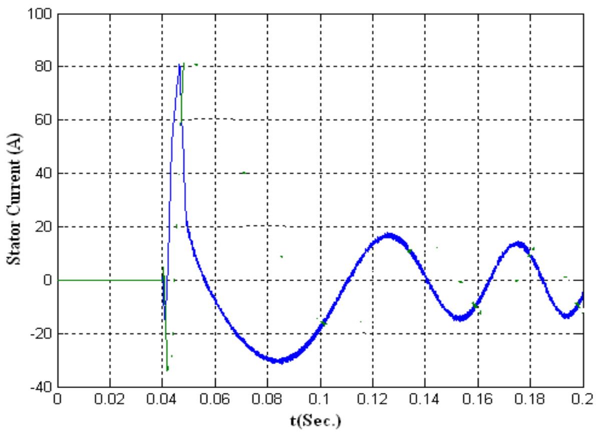


a)

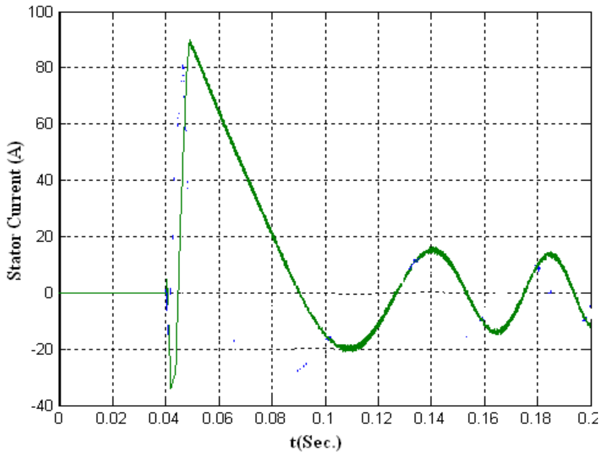


b)

Figure 9. Transient torque a) Torque of Induction Motor couple dc motor b) Torque of Induction Motor



a)



b)

Figure 10. Three phase Induction motor in transient current (Ampere) a) Induction Motor couple dc motor b) Only Induction Motor

Fig.10 Results comparison The transient current Three phase Induction Motor couple DC Motor and only Three phase Induction Motor (simulation).

CONCLUSION

In this paper, the couple of the two electric motors with input-output state feedback controller combined with adaptive backstepping observer and batteries of a typical series hybrid EV is investigated and simulated by Matlab/Simulink, has been presented and the performance and ability of control strategy is investigated. Transient simulation tools have been developed for the design and analysis of electric and hybrid electric vehicles. Simulation results have also been shown the IM and IM + DCM, in transient torque and current in graph fig.7&8. Experiment Laboratory results have also been shown the IM and IM + DCM, transient torque and current in graph fig. (9.a,b) &(10.a,b) for result simulation .

REFERENCES

[1] C. C. CHAN, “The State of Art of Electric and Hybrid Vehicles”, Proceedings of IEEE, vol. 90, no. 2, Feb. 2012.

[2] C. GOKCE, “Modeling and Simulation of a Series Parallel Hybrid Electrical Vehicle”, Master Thesis, Institute of Science and Technology, Istanbul Technical University, Istanbul 2015.

[3] T. Markel, A. Brooker, T. Hendricks, V. Johnson, K. Kelly, B. Kramer, M. O' Keefe, S. Sprik, K. Wipke: ADVISOR: A Systems Analysis Tool for Advanced Vehicle Modelling, ELSEVIER Journal of Power Sources 110, (2012), pp. 255-266.

[4] H.F. Abdul Wahab and H. Sanusi “Simulink Model of Direct Torque Control of Induction Machine” American Journal of Applied Sciences 5 (8): 1083-1090, 2008 ISSN 1546-9239. 2018 Science Publications.

[5] Stephen Yurkovich “Nonlinear Torque Control of the Induction Motor in Hybrid Electric Vehicle Applications”,American Control Conference ,June 8-10, 2015. Portland, OR, USA

[6] RomeOrtega, Nildta Uarabanov, Gerarda Escabar Valderrama. “Direct torque control of induction motors:stability analysis and performance improvement,” IEEE Trans. on Auto. Control, Vol. 46 (8), 2021, pp. 1209-1221.

[7] R. Yazdanpanah, A. Farrokh Payam: Direct Torque Control of An Induction Motor Drive Based on Input-Output Feedback Linearization Using Adaptive Backstepping Flux Observer, Proc. 2016 AIESP Conf., Madeira, Portugal.

[8] S. Sadeghi, J. Milimonfared, M. Mirsalim, M. Jalalifar: Dynamic Modeling and Simulation of a Switched Reluctance Motor in Electric Vehicle, in Proc., 2016 ICIEA Conf.

[9] C. GOKCE, O. USTUN, M. YILMAZ, R. N. TUNCAY, “Modelling and Simulation of Series Parallel Hybrid Electrical Vehicle”, ELECO’05, Int. Conference on Electrical and Computer Engineering, Bursa, 2015.