CONACYT PROCIENCIA PROGRAMA PARAGUAYO PARA EL DESARROLLO DE LA CIENCIA Y TECNOLOGÍA
Fiuna Facultad de Ingeniería
GOBIERNO NACIONAL Construyendo el futuro hoy

A Speed-Sensorless Predictive Current Control of Multiphase Induction Machines Using a Kalman Filter for Rotor Current Estimator

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Programa de Incentivos Para la Formación de Docentes Investigadores - Convocatoria 2015

ABSTRACT

In electrical drive applications based on induction machines, such as the propulsion drive of an electric vehicle, the rotor current cannot be measured, so it must be estimated. This work describes the rotor current estimation through reduced order estimator known as Kalman filter to apply a sensorless speed control of dual three-phase induction machines by using an inner loop of model-based predictive control. Finally, simulation results are provided to show the efficiency of the proposed sensorless speed control algorithm, thus concluding that the system can operate properly without the speed sensor.

INTRODUCTION

In the last decade, the interest in multiphase machines has risen due to intrinsic features such as lower torque ripple, power splitting or better fault tolerance than three-phase machines. Recent research works and developments support the prospect of future more widespread applications of multiphase machines. In recent times, some of the applications of multiphase machines are being studied, such as electric vehicles (EV) and railway traction, all-electric ships, more-electric aircraft, and wind power generation systems. EV is a road vehicle which involves an electric propulsion system. With this broad definition in mind, EVs may include battery electric vehicles, hybrid electric vehicles and fuelcell electric vehicles.

For controlling the variables of dual three-phase induction machines (DTPIM), the most used methods are the direct torque control (DTC) and the vector control using an inner loop current control.

This work considers the sensorless speed control of DTPIM for EVs by using an inner loop of model predictive control (MPC), to predict the effects of future control actions on the state variables. In order to achieve this goal, the proposed algorithm uses reduced order estimators based on a Kalman filter (KF) to estimate the rotor current. Thereafter the rotor current estimated is used to determine an estimate of the speed of the machine. The performance of the proposed control technique in a DTPIM drive is studied for varying load operations and varying speeds.

MATERIALS AND METHODS

A MATLAB/Simulink simulation environment has been designed for the voltage source inverter fed DTPIM, and simulations have been performed to show the efficiency of the proposed predictive speed control technique.

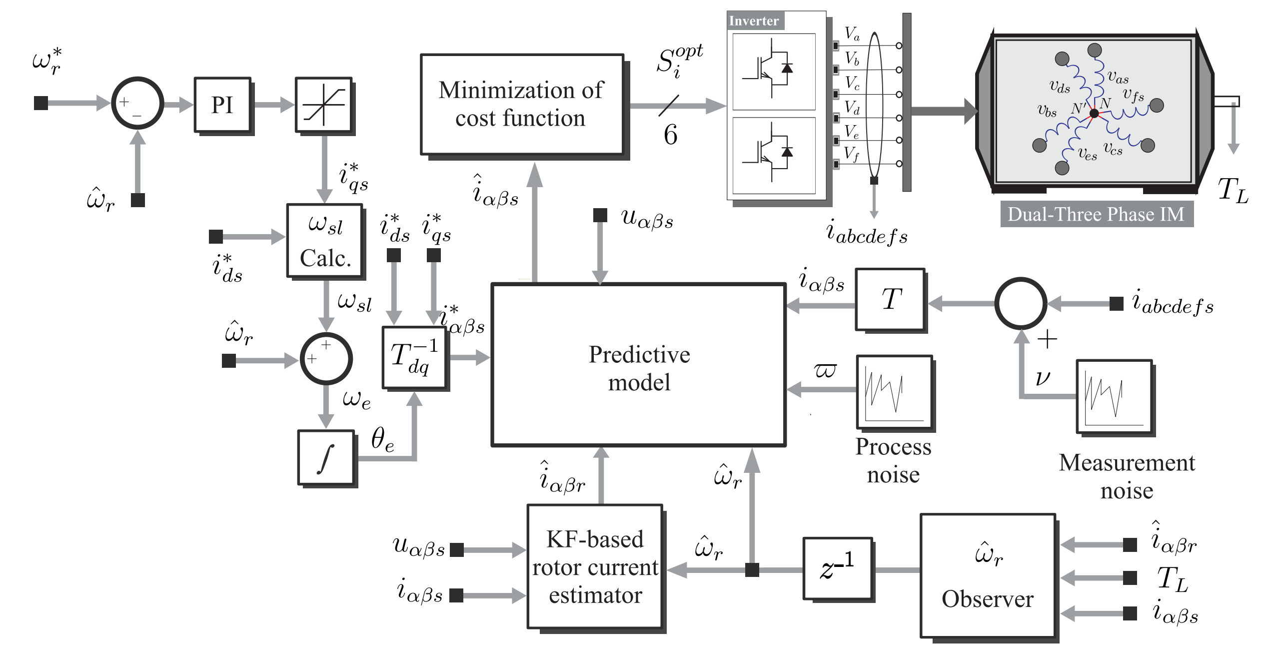

Fig. 1. Proposed speed sensorless control technique for the DTPIM.

RESULTS

Fig. 2 shows the results for a multi-step speed reference. The subscripts $(\alpha\text{-}\beta)$ represent quantities in the stationary frame reference of the stator currents. The estimated speed is fedback into the closed loop for speed regulation and a PI controller is used in the speed regulation loop. Furthermore, it can be seen from this graph (as zoom), the change in the phases of the stator currents, caused by the reversal of the direction of rotation of the machine.

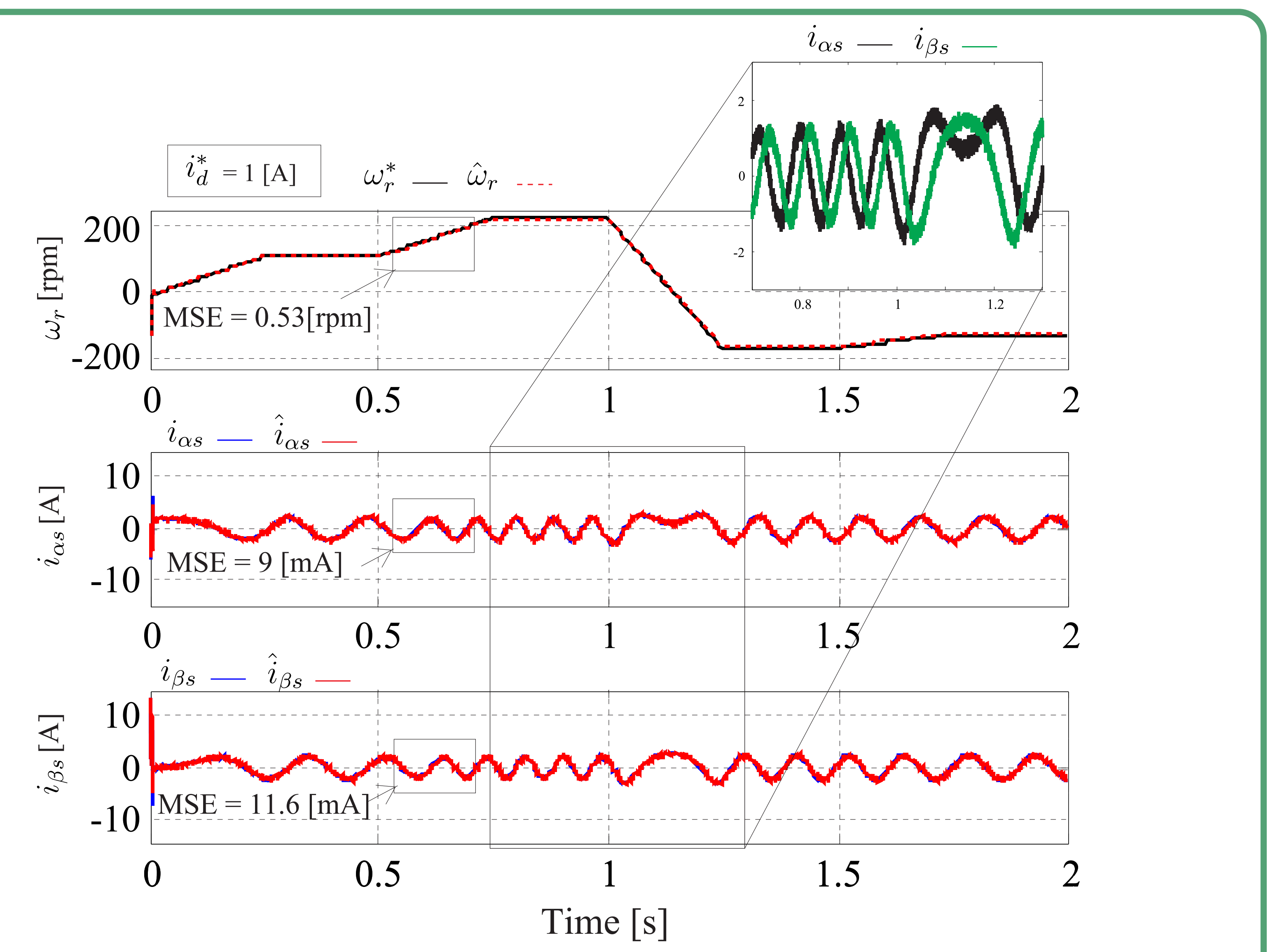

Fig. 2. Simulation results for a multi-step speed references application.

CONCLUSION

In this work, the propulsion drive of EVs based in a sensorless speed control scheme of a DTPIM using an inner loop based on the MPC control is proposed. The MPC is designed through a state-space representation, where the rotor and stator current are the state variables. The rotor current is estimated using a KF. The method avoids the use of a speed sensor and has proven to be efficient even when considering that the machine is operating under varying speeds and load regimes.

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ACKNOWLEDGMENT

The authors would like to thank to the Paraguayan Government for the economical support provided by means of a CONACYT grant project 14-INV-101 and program support training teachers-researchers, PROCIENCIA with reference code 14-POS-031 (call 2015).