Sensorless control of induction motors

Mari Lord, Lund institute of technology

With good ideas and appropriate research it is possible to improve the technology that we already have around us. A small detail, like being able to remove a component from a machine can increase the reliability and the robustness and at the same time give the machine a more competitive price. Three qualities that decide the success of a motor on the market.

The most common machine that we see around us today is the so called asynchronous machine, also known as induction motor. It is used both in high power and low power applications and is therefore suitable for a large spectrum of industrial applications. It has basically become this popular because of its cheap and simple construction and we see the induction motors in laundry machines and food processors as well as in electric cars.

The induction motor consists of an electromechanical system in which it is necessary to control various parameters, such as for example currents, voltages and the speed. The most common way of doing this is by using a method called vector control. This method depends, among other things, on the knowledge of the actual rotor speed, and a speed sensor is required in order to measure this speed. The speed sensor is placed on the rotor shaft of the machine (see *Figure 1*) and reduces, as mentioned in the beginning, the robustness and the reliability of the machine.

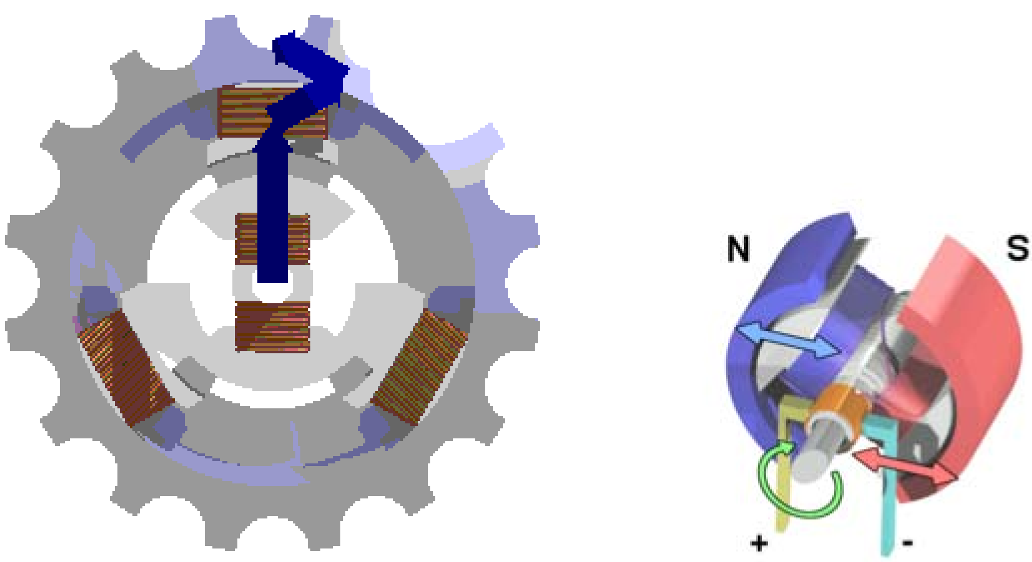

Figure 1 Two examples of the induction motor. The inner part is the rotor and the outer one is called stator.

Produce and maintain the speed sensors in a good condition is also costly and we will here look at one of many methods that can make it possible to construct induction motors without speed sensors. Thus, to be able to do so it is necessary to find a way to calculate or estimate the speed of the motor at every moment.

Sensorless control

Consequently, this has opened a new interesting area for research and during the last few years a variety of different solutions has reached the market. Neural networks, artificial intelligence and sensorless control are names that might sound familiar. The last one is a method that consists, as indicated by the name, of different ways of controlling the induction motor without using a speed sensor. Even though the induction motor is cheap and simple in its construction, this is not the case when it comes to its mathematics. The machine is represented by a nonlinear model with unknown variables and external inputs, which with its complexity makes sensorless control a challenging theoretical problem.

A solution with filters?

One of the results of all the research that has been made within this area is a doctoral thesis written by Jaime Antonio Gonzalez Castellanos. In this thesis the author presents a solution of sensorless control where he uses a combination of two filters to estimate the rotor speed. The well known Kalman filter, here in its extended version, is used together with a quadratic filter which is constructed in order to estimate the so called noise covariance matrices. These matrices are necessary for the calculations in the Kalman filter.

The Kalman filter is known to be an efficient and robust speed estimator. Its performance is a complicated story but its purpose is to compute an optimal estimate. To be able to do so the filter needs certain information. It needs basic knowledge of the parameters of the system and it needs the values of the matrices mentioned above - the noise covariance matrices.

This is where the second filter, the quadratic filter, comes into the picture. It is built up based on the first filter, the Kalman filter, and has one simple mission - to achieve optimal values of the unknown noise covariance matrices and return these to the Kalman filter.

Simulating the idea

The algorithms of the two filters were written as a code in a program called Matlab to see how they worked together. Later this code was implemented in the simulation tool Simulink. In this simulation tool it is possible to let the Matlab code act together with the actual induction motor (see *Figure 2*).

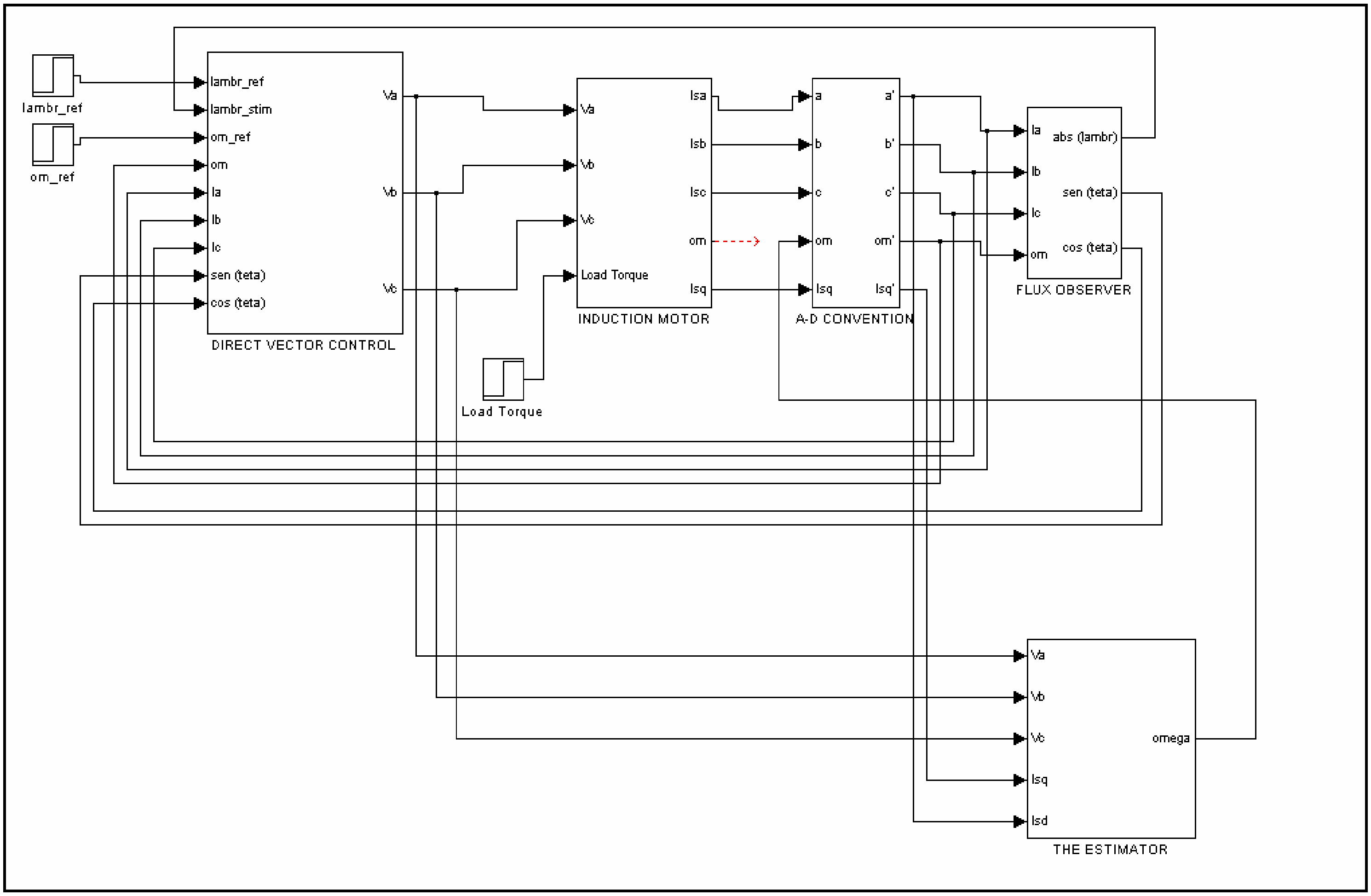

Figure 2 The integrated model in Simulink. The filters are represented by the box called "The estimator" while the induction motor with vector control consists of the rest of the blocks.

The estimation of the rotor speed was made in a way similar to the method used in the doctoral thesis mentioned above. But then, in order to take that research one step further, the goal was to make the whole system work as a completely closed system. Or in other words; replacing the measured rotor speed “om” with the filter estimated “omega”.

Accordingly, the interesting parameter in this setup is the rotor speed which is named in the figure by “omega”. Simulations were made in Simulink in order to study its behavior and compare this with the desired reference value, “om_ref”.

A complicated system

Unfortunately the results were not as good as one could hope for. The beginning seemed promising but after a short while the estimated rotor speed, “omega”, started to grow towards infinity. This is a typical sign of instability and probably depends on the complexity of the system. The algorithms contain a lot of complicated and large calculations which makes it difficult to control the performance of the filters.

But, all this work is well worth its effort! There are a lot of things that are interesting to continue working on, not only with the program presented here but also with alternative solutions in order to realize and develop this idea. Perhaps it is possible for example to use another set of filters that has a more simple construction. Or rewrite the formulas in this solution in order to avoid the more complicated calculations.

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