

Control of an induction machine using Flux® - Portunus coupling.

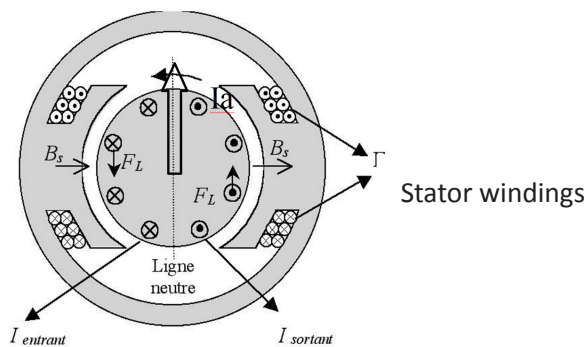
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Everyone will have noticed that the use of induction motors has significantly increased lately. One of the key challenges surrounding electrical machines is their precise control. CEDRAT is meeting the challenge of simulating the control of an induction machine using one of its tools: Portunus - system simulator. The next obvious step to do this as precisely as possible was to create a Flux-Portunus coupling.

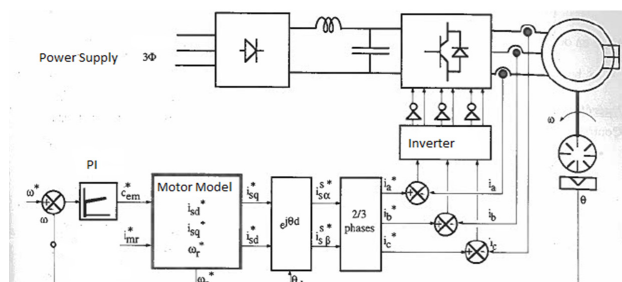
1. Control architecture: Indirect Field-Oriented Control (IFOC)

>> a - What does IFOC involve?

The main aim for a motor is to produce the maximum level of torque at a given speed, and the best machine for this purpose is the Brushed DC electric motor. With it, the current and the flux vector are always in squaring position, delivering a constant level of maximum torque.



The target in the FOC is to mimic this functioning by delivering current to the motor which will enforce a squaring position between the current and the flux vector within the rotor.



Overview of the architecture of an IFOC

>> b - Details of the architecture

- Motor model- key equations

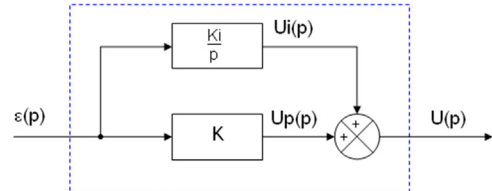
$$I_{sq}^* = p \times \left(\frac{L_r}{M^2} \right) \times \left(\frac{C_{em}^*}{I_{mr}^*} \right)$$

$$I_{sd}^* = I_{mr}^* + tr \times \frac{d I_{mr}^*}{dt}$$

$$\omega = \left(\frac{I_{sq}^*}{I_{sd}^*} \right) \times \frac{1}{Tr}$$

These equations describe the functioning of the motor. They are meant to build I_{sq} and I_{sd} , the current order to obtain the desired current and magnetic field vector.

- PI Controller



This device is pretty limited in terms of steadiness and the settings are done empirically way. Nevertheless, it is easy to build and gives excellent results when the coefficients are well calibrated.

Action	Steadiness	Precision	Speed
Proportionnal	-	+	+
Integrator	-	+++	-

>> c - Benefits and limitations of an IFOC

This method is simple to implement, as only the position of the rotor is needed to generate orders.

Magnetic and torque are treated separately.

An induction machine controlled via an IFOC is technically better than a DC machine with the same output power.

But, in practice, implementation of this command requires a DSP controller for PARK/CLARKE transformations.

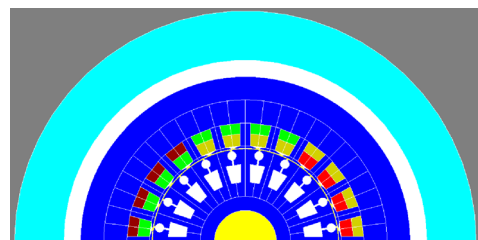
IFOC depends heavily on the machine's electromagnetic parameters.

2. Flux-Portunus coupling stakes

The most interesting aspect of the bridge between Flux® and Portunus is simulation precision. Indeed with Flux®, the finite elements deliver the closest model of the motor compared to the real machine. The control built into Portunus is applied to the most realistic model of the motor.

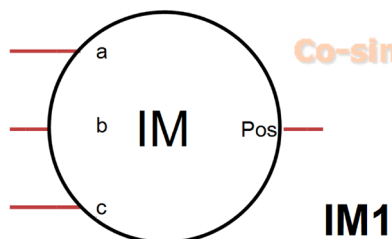
>> a - Design specifications and requirements

The motor considered in this case is an induction machine from the technical paper tutorial. We want to command the speed of the machine at no-load rate.



Power	Phase	Frequency	Enc. Stator	Bars Rotor	Pole pair	Inertia
8 KW	3	50 Hz	24	20	1	0.034

(continued on page 9)



Rs	Rr	Lfs	Lm	P	J
1.54 Ω	1.44 Ω	10 mH	332 mH	1	0.034 Kg.m ²

>> b - Transformations Block

Portunus Library already includes blocks for PARK/CLARKE transformations.

- Inverse PARK/CLARKE transformation: from a (d,q) system from an (a,b,c) system.



- Inverse PARK transformation: From a (d,q) system to an (a,β) system



3. Simulation strategy

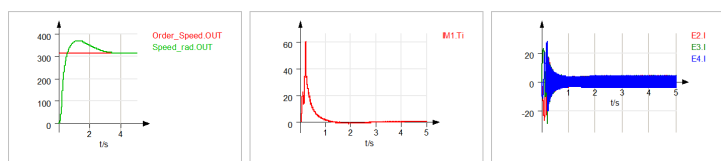
Before coupling Flux® to Portunus, we first need to have an idea of the PI controller parameters. So, preliminary simulations are run with an analytic model of the machine taken from the Portunus library. This step is very quick and easy for setting PI parameters.

Once the PI parameters are known, the coupling can begin.

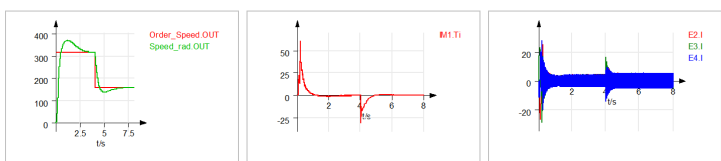
>> a - Portunus simulation- PI settings

Speed order	Current order	Voltage	P gain	I gain
3000 rpm	5 A	400 V	0.1	0.1

Single speed order



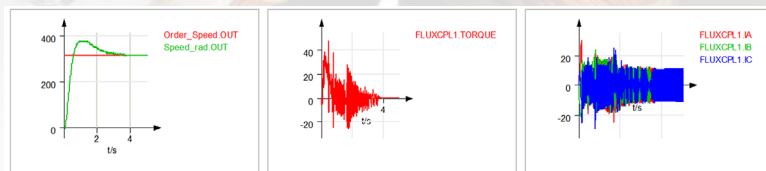
Variable speed order



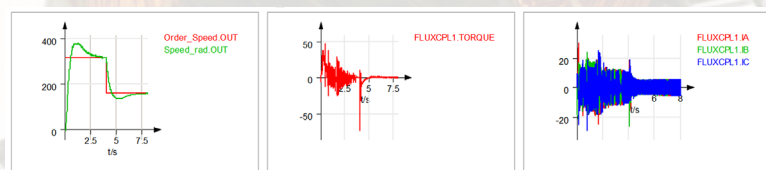
>> b - Flux – Portunus coupling

Then, the analytic model of the motor is replaced by a Flux® communicator.

Single speed order



Variable speed order



4. Conclusion

Thanks to coupling, we can get an idea of the behaviour of the machine in its environment. It becomes clear that analytic and finite element results are very close. However, FE curves show speed and torque fluctuations very precisely, like on an actual machine.

On the other hand, Portunus is to be praised for its well-stocked library and the accuracy of its results, even for an analytic tool. And calculation time is very quick, less than 10 minutes for the Portunus simulation and around 3 hours for the coupling simulation.

