Martin Djup
Elias Allar

Controlling a new and better variant of the DC motor

This article is a popular scientific summary of the master thesis *Sensorless Control of Brushless DC Motor in Hydraulic Application,* (2015) which was written and conducted by the two students Martin Djup and Elias Allar from the Department of Automatic Control at the Faculty of Engineering at Lund University.

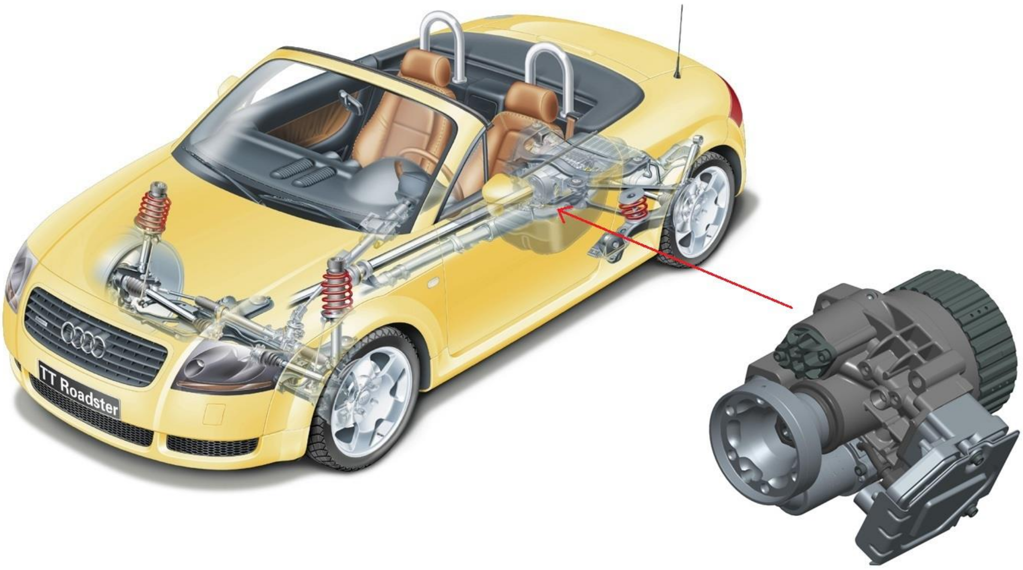

Figure 1. The Haldex coupling from BorgWarner TorqTransfer Systems AB. It is used to give vehicles intelligent all-wheel drive.

In today's society ordinary DC motors can be found in many places and applications such as tools, toys, appliances, electric vehicles, elevators and hoists. You can almost say that if an application can move on its own, and doesn't have a combustion engine, then there is a high probability that there is a DC motor involved. Since the DC motor can be very small or very large, they work well in a wide variety of applications.

The DC motor uses a so called commutator in order to spin. The use of a commutator demands that the rotor (the moving part of the motor) and the stator (the part of the motor that is kept still) are in contact with each other so that an electric current can pass between them. This will of course give a lot of wear and tear to the motor, especially since it often runs at high speeds for extended periods of time. This means that there is a risk that the DC motor might be wearied down before the application it is used in is. In applications with long lifetimes, it might therefore be good to use an alternative without a commutator .

A natural alternative to the ordinary DC motor is the brushless DC motor (BLDC for short). Just as the name implies the BLDC is an electrical motor that does not use brushes, which means that is doesn't use a commutator. So the advantage of the BLDC compared to the DC motor is that there is no direct contact between the rotor and stator of the motor, which means that it is expressed to a lot less wear and tear. Due to this fact, the BLDC has grown on the market in recent years even though it is a lot harder to control its speed.

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One application that today uses an ordinary DC motor, but to which its developers has looked into the possibilities of using a BLDC instead, is the Haldex coupling from BorgWarner TorqTransfer Systems AB. The Haldex coupling provides intelligent all-wheel drive for vehicles, and the DC motor in it controls the hydraulic pressure that the coupling uses to move the torque to the desired wheels. The performance of the electrical motor is therefore very crucial as it has to have e short response time and be able to run at high speeds. This of course puts a lot of demands on the development of control techniques for a BLDC, if such a motor is to be implemented.

At least two control techniques has been tested on BLDC’s at BorgWarner when the possibilities of using a BLDC has been studied. The one which most of the focus probably has been laid on is the so called field-oriented control (FOC for short). The FOC technique is a very mathematical control method as it uses voltage vectors to produce the optimal input current vector to the motor which will make it run as optimal as possible. The other proposed method is called six-step commutation which is one of the simplest ways to control a BLDC. The method simply follows and produces a pattern of six input current vectors to the BLDC which are used as inputs over and over again. And if the motor is to run backwards, it simply runs the pattern backwards.

Both control methods looks promising, but the thing that makes the control tasks hard is that there can be no sensors in the Haldex coupling. Sensors would be used to sense the speed of the motor, and what angle the rotor has. Both of these quantities are needed by the control methods, which means that the speed and angle has to be estimated in some way instead of being sensed. The FOC controller that is tested for the Haldex coupling uses a so called sliding mode observer to do the estimations. The sliding mode observer has a lot of mathematical theory behind it, but the main idea behind it is to use the input voltages and input currents to the BLDC, and from them determine what angle the rotor has to have in order to give such input currents as the measured ones with the measured input voltages. The speed is then simply obtained from how fast the angle estimation changes. In the six-step commutation method, there is always one input phase which is idle. This means that the currently idle phase can be used to measure the voltage that is induced in the windings of that input phase. This induced voltage contains information about the rotor angle, which can be extracted to the controller. The speed is (just as for the FOC) calculated as the change of angle estimation.

Both of these methods seems applicable to the Haldex coupling if it is to use a BLDC, but only the future can tell which of the two control techniques will be used in the coupling. In any case, you may soon be driving a vehicle that has a sensorless BLDC in its coupling, which will be controlled by either FOC or six-step commutation.