

# Modeling the Neuro-Fuzzy Control with the Dynamic Model of the Permanent Magnet DC Motor

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*Abstract: Using Fuzzy-Neural network eliminates the need for mathematical modelling and allows easy realization of a solution. With this solution the control quality level of cheaper universal motors will be the same as in the case of more expensive universal motors. Some deficiencies of this motor have been partly eliminated which arise from the fact that this motor type is mainly designed (its windings are wound in such a way) so as to be optimal for a single revolution speed.*

## 1 Introduction

This paper describes the Simulink model of a Fuzzy-Neuro system which controls a permanent magnet DC motor.

An MSP430F149 device is used in this motor control application. It can easily be substituted by any other MSP430 device with required hardware elements available. The MSP430 is sourced by an 8-MHz crystal to provide a high-resolution clock source that is used for both PWM generation and speed measurement.

The universal serial motor is driven with a PWM signal. The MSP430 output signal is then delivered to the to the actual motor driver output stage. To provide feedback for the control loop, an optical encoder is used.

The Simulink model of the system consists of three parts:

- the input signal generators
- the fuzzy-neural controller
- the mathematical model of the motor, the load and the noise.

The input signal generators provide the desired speed for the system. The desired speed is not a constant value, it may have square wave, sine or step trajectory. [1]



The mathematical model of the DC motor is a second order transfer function (MOTOR). This model is in Z terms. The sampling time is 25ms. To evaluate the influence of the fuzzy-neuro block, we put another motor with the same parameters in the system, but without fuzzy-neural controller.

The noise generator models mechanical frictions in the motor, the variations of the voltage source, and the variations of the load. It also models the different characteristics of the DC motor in the different rotating direction. [4]

## 2 The Dynamic Model of the Permanent Magnet DC Motor

The permanent magnet direct current (DC) motors are reliable, easy to maintain and relatively inexpensive. Due to their favourable electrical and mechanical properties, high starting torque, high efficiency, and the ease with which they can be controlled DC motors are used in most servo applications in actuation, robotics, machine tools, and positioning devices.

By reason of precise simulation of a system, it is important to determine the mathematical model of the DC motor.

A very basic dc motor is constructed of two main components: the rotor or armature and the stator. The armature rotates within the framework of the stationary stator. The stator consists of permanent magnets which create a magnetic field. The armature consists of an electromagnet created by a coil wound around an iron core. The armature rotates due to the phenomenon of attracting and opposing forces of the two magnetic fields. A magnetic field is generated by the armature by sending an electrical current through the coil and the polarity is constantly changed by alternating the current through the coil (also known as commutation) causing the armature to rotate.

The goal in the development of the mathematical model is to relate the voltage applied to the armature to the velocity of the motor. Two balance equations can be developed by considering the electrical and mechanical characteristics of the system.

The electrical equation is:

$$V_a - i_a R_a - L_a \frac{d}{dt} i_a - k_v \omega_a = 0 \quad (1)$$

where  $V_a$  is voltage applied on the armature,  $\omega_a$  is the rotational velocity of the armature,  $i_a$  is the armature current,  $L_a$  is the armature inductance and  $R_a$  is the resistance of the armature. The  $k_v$  is the velocity constant determined by the flux density of the permanent magnets, the reluctance of the iron core of the armature, and the number of turns of the armature winding.

The mechanical equation is:

$$k_t i_a - J \frac{d}{dt} \omega_a - B \omega_a - T_L = 0 \quad (2)$$

where  $k_t$  is the torque constant and like the velocity constant is dependent on the flux density of the fixed magnets, the reluctance of the iron core, and the number of turns in the armature winding,  $J$  is the inertia of the rotor and the equivalent mechanical load,  $B$  is the damping coefficient associated with the mechanical rotational system of the machine and finally  $T_L$  is the torque of the mechanical load.

The block diagram for the system can be developed from these two differential equations. Taking the Laplace transform of each equation gives:

$$s i_a(s) - i_a(0) = -\frac{R_a}{L_a} i_a(s) - \frac{k_v}{L_a} \omega_a(s) + \frac{1}{L_a} V_a(s) \quad (3)$$

$$s \omega_a(s) - \omega(0) = \frac{k_t}{J} i_a(s) - \frac{B}{J} \omega_a(s) - \frac{1}{J} T_L(s)$$

If perturbations around some steady state value are considered, the initial conditions go to zero and all the variables become some change around a reference state, and the equations can be expressed as follows:

$$i_a(s) = \frac{-k_v \omega_a(s) - V_a(s)}{L_a s + R_a} \quad (4)$$

$$\omega(s) = \frac{-k_t i_a(s) - T_L(s)}{J s + B}$$

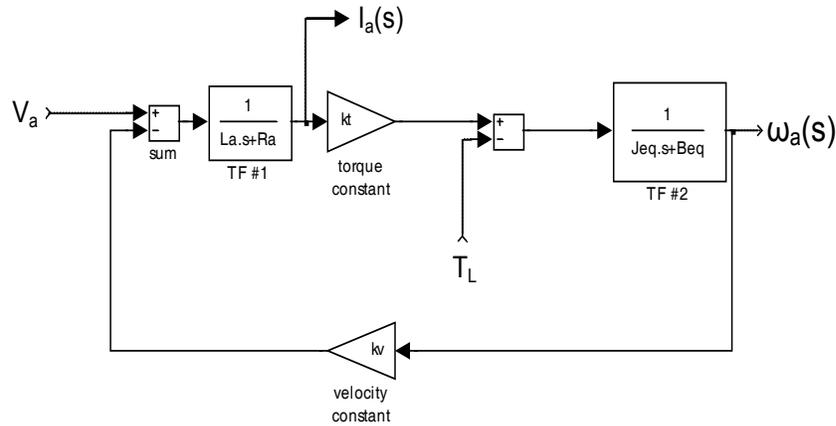


Figure 2  
Second order Simulink model of a DC motor in S terms

The first equation describes the electrical part of the motor (TF#1) and the second equation describes the mechanical characteristics (TF#2). The block diagram obtained from these equations for a permanent magnet dc motor is shown in Figure 2.

In the case of digital control this model must be transformed into Z model. In Z model of the dc motor the sampling time must be taken into consideration.

In our system a dc motor was used from Pacific Scientific, for which was given the following parameters:  $V_a$ ,  $i_a$ ,  $k_v$ ,  $k_t$  and  $B$ .  $J$  and  $L_a$  were not given, so they are determined experimentally.

To determine the armature inductance we must start from the electrical equation of the motor (equation (1)). By locking the rotor we will reduce the back EMF to zero. Now we have to find the transient response of the resulting armature circuit. By putting a resistor ( $R_s$ ) in series with the motor we can then measure the voltage drop across the resistor to graphically obtain the time constant. Once the time constant is found from the next equation can be solved for the motor's inductance:

$$\tau = \frac{L_a}{R_a + R_s} \quad (5)$$

To determine the motor's moment of inertia ( $J$ ) we must start from the mechanical equation of the motor (equation (2)). The moment of inertia and the friction coefficient ( $B$ ) establish the angular velocity decay rate once current to the motor has been cut. The next equation links  $J$  and  $B$  to the time constant of the velocity decay since the  $T_m = k_t i_a = 0$ , and  $T_L = 0$ :

$$\tau = \frac{J}{B} \quad (6)$$

In both case we used digital scope, to determine the time constant. In the second case we used tachometer to measure the angular velocity.

Fuzzy-Neural system output, if the expected rps signal is square, with a first order motor model (earlier DC motor model), shown in Figure 3.

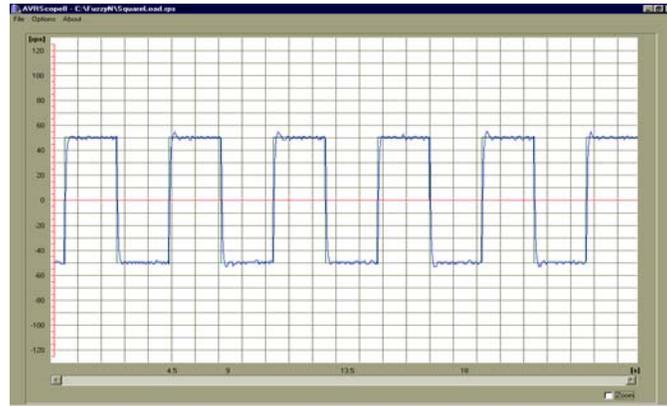


Figure 3  
Fuzzy-Neural system output

### Conclusions

In this paper demonstrated a Simulink model of a fuzzy-neuro system with a DC motor. A second order mathematical model of the DC motor was developed. Explained the experimental determination of some important parameter of that kind of motor.

### References

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