Motion Control of a DC Motor through Predistortion and Feedback of the External

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Abstract

The current work presents a simulated open loop DC motor via first operator of the Volterra inverse and also with the feedback of the external load of the motor. An excellent level of control on the angular velocity of the motor output is shown.

Keywords: DC motor, open loop control, Volterra inverse, predistortion.

1. Introduction

The objective of the current work is to implement the open control strategy of predistortion via the first Volterra inverse operator of the angular velocity of a DC motor, considering the effect of the consumed energy due for the work realized against the external load.

The error in a traditional PID, depends on the type of input signal⁽¹⁾. In the case of an input signal with non-uniform variations, there is little control over the permanent error and it is not always possible to control the system response considering disturbances⁽²⁾. This type of control considers that the system is linear and therefore if this system presents any nonlinearity source there is no mechanism to eliminate its effect on the output signal.

On the other hand, it has been proposed in⁽³⁾, a strategy of open loop control by means of the inverse of Volterra. The theoretical error is zero on no matter if the system is linear or continuous nonlinear. It does not matter the type of signal which entered the system. The efficiency of this strategy depends on a good model to represent the system, and in the case of discrete control, also has limitations on the maximum frequency that can be handled⁽⁴⁾. However, this strategy has proven to be very useful in applications for

sensors such as accelerometers⁽⁵⁾ and LVDTs⁽⁶⁾.

Most control methods in servo motors is based on a strategy of PID feedback and a control signal based on its rms value⁽⁷⁾. Here is to do something completely different. It is intended to implement the open loop control known as predistortion, as it was used with the accelerometer and the LVDT. This results in a proportional control output angular velocity through supply voltage in the armature. The angular velocity is seriously affected by the external load to the motor, so that the control should take into account the perturbation (external load) on the system to adjust the voltage necessary to develop the required angular velocity. Proper implementation of the control of open-loop predistortion engine, seems to require feedback of the external load to determine the energy loss of the system in order to adjust the voltage needed.

Next section gives the Simbology to be used along the article. The third section shows motor model to be simulated. The fourth and fifth sections deal with the ARX identification of the simulated model and the inverse Volterra construction. Finally, the sixth section gives the performance of the inverse Volterra when there is a external load, with and without feedback of this load.

2. Simbology

Bm -Viscous damping

Lt - Inductance

Rt -Resistance

kj -Torque constant

kb -Electromotive force constant

Jm - Motor inertia

ζ -Damping ratio

ω_n - Natural frequency

ω - Angular velocity

V- Voltage

f - External load equivalent Voltage

T_L -External

z -Volterra inverse load

H-Operator that represents the motor system

Hr-Operator relating f and M

K-Predistortion operator

W-Inverse Volterra operator

Fig. 1. Diagram of model systems of a DC motor

3. DC Motor Model

The motor is a DC motor modelled as second order system. Figure 1 shows the diagram of the model. The data to be used are in Table 1. From⁽⁸⁾, the modal parameter of the engine is obtained from the following equations,

$$2\zeta\omega_n = \frac{Rt Jm+Bm}{Lt Jm} \quad (1)$$

$$\omega_n = \frac{Rt Jm+kj^2}{Lt Jm} \quad (2)$$

Where the modal parameters are,

$$\omega = 31.31 \text{ rad/s}$$

$$\zeta = 2.4944 \text{ rad/s}$$

Based on these results, the sampling interval is $t = 0.015s$, so the maximum frequency that can be displayed is,

$$\omega_{max} = 209 \text{ rad/s}$$

The Figure 2 shows the comparison between the Function Frequency Response (FRF) obtained from the model compared with the theoretical FRF, both show good agreement.

Table 1 Motor parameters

Parameter	Obtained Value
Rt	17.43 Ω
Lt	113.5 mH.
Kj	0.3605 N m s / rad
Kb	0.3605 V s / rad
Jm	$2.02 \times 10^{-3} \text{ kg m}^2$
Bm	$5.45 \times 10^{-3} \text{ N m s / rad}$

Fig. 2. Comparison thrown FRF between the model and the theoretical

4. Identification By ARX

The identification process for autoregressive models with exogenous outputs (ARX) requires greater data rate per unit of time, the rate of 5×10^{-4} data per second is used. Signal voltage three frequencies (10, 35, 45 rad / s) to identify a model that relates the input voltage to the angular speed of the output shaft of the engine.

The obtained model is then,

$$\omega_i = 1.9246\omega_{i-1} - 0.9248\omega_{i-2} + 3.7793 \times 10^{-4}V_{i-1} \quad (3)$$

the model gives a mean square error (mse) of 0.2%. See Figure 3 where the input voltage is shown and the angular velocity for both simulated and ARX predicted can be seen.

Now, an external load of 0.2 Nm and a frequency of 23 rad / s is added into the system. In Figure 4 the effect of the

external loading is shown. It can be seen that the external load to appreciably affect the angular velocity output.

It is now necessary to find another ARX model whose

Fig. 3. Comparison between the angular velocity obtained from the simulation model with the obtained ARX

input is the load and the output is the kinematic power loss (voltage drop) as a function of the energy used against the load (external load torque of the motor).

The model obtained by keeping the input voltage constant and vary the external load is,

$$f_i = -0.9748f_{i-1} - 0.0218f_{i-2} - 0.0934M_{i-1} \quad (4)$$

where f_i becomes the Voltage to add to the input voltage to compensate for the variation in the angular velocity at the output.

5. The Inverse Volterra For A DC Motor

From⁽⁴⁾, the inverse Volterra obtained from the multiplicative inverse of the z_i transform of the equation (3), the first inverse Volterra is obtained,

$$z_{-i-1} = 10^{-3}\omega_{i-1} + 2.447 \times 10^{-3}\omega_{i-2} \quad (5)$$

With no external load, you can plan the angular velocity versus time you wish to obtain at the output of the

engine. The desired speed is passed through the Volterra preinversa then z_i will become the voltage applied to the motor. Figure 5 shows the comparison between the desired angular velocity and the output by the DC motor simulated.

Fig. 4. Comparison between the angular velocity and external load predicted by the ARX model without external load

By introducing the load the preinversa efficiency is affected by the energy devoted to work against the external load.

6. Predistortion Control With The External Load Feedback On A DC Motor

In Figure 8 you can see the proposed strategy, the external load M is fed back to the input voltage (the output of the preinversa $\mathbf{H}$) to obtain the desired output angular

Fig. 7. Comparison between the desired angular velocity and the obtained to feed the engine with the output of the Volterra preinversa equation (5) including external load

velocity. Feedback is given by equation (4) represented by the H_r operator in the Figure.

Fig. 8. Schematic of the control system

The output is shown Obtained in Figure 9 where you can see there is a noticeable improvement in the performance of the preinversa control.

7. Conclusions

A proposal for control of a DC motor through the first operator of the inverse of Volterra and the feedback from the external load is demonstrated through a simulated DC motor. It was shown as the improved control of the angular velocity of the engine output is noticeable when the inverse

Volterra is added the equivalent voltage held against the external load.

Fig.9: Comparison of the efficiency of the inverse Volterra when the external load is fed

The method proved to be competitive with other servo control especially when it comes to controlling the angular velocity function of the time.

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