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EXTREMUM SEEKING PID AUTOTUNER FOR ELECTRICAL SERVO DRIVES

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1 INTRODUCTION

This paper deals with automatic tuning algorithm of PID controller for electrical servo drives. Servo drives are widely used (not only) in motion control applications. Usually the motion control system consists of two parts. The first part is a trajectory generator which computes the planned path of the actuator in time. The second part is a feedback controller which ensures the correct tracking of the reference trajectory. For the proper function of the closed loop, parameters of the tracking controller needs to be tuned precisely. Manual tuning of controller parameters is a very slow and difficult process. Usually there is no precise system model and there are various nonlinearities contained in the system - for example stiction, gear clearance or saturated input signals. There exist no general reliable design method which can be used in most cases. Most of major manufacturers offer an auto-tuning function in their servo inverters, but it often fails.

In this approach there is used a so called extremum seeking algorithm to tune the controller parameters automatically. For the control of servo drive there was used a common cascade structure of the controllers (PI controller for drive speed and P controller for drive position).

2 EXTREMUM SEEKING ALGORITHM

The extremum seeking method was discovered in 1950's and it was used in adaptive control.In 2000's there were new applications - real time optimization (Krstic 2001) and PID controller parameter tuning (Krstic 2006).

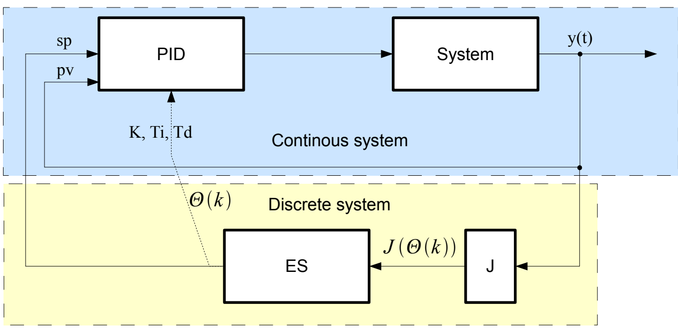

Fig. 1: Scheme of extremum seeking PID autotuner

Structure of PID autotuner is displayed in figure 1, discrete version of extremum seeking algorithm is used. The tuning algorithm performs experiments with different

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parameter values and examines the behavior of the closed loop. It seeks a parameter set which minimizes the cost function.

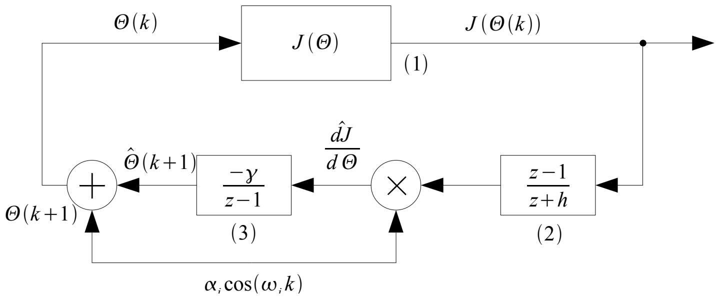

Fig. 2: Extremum seeking algorithm

The functionality of the extremum seeking algorithm is demonstrated in figure 2. In each step, the controller parameters which were computed in previous iteration (or an initial condition) are used to perform an experiment (unit step or constant error) with the system. The computed value of a cost function is led to a high-pass filter (2), which removes the dc component of the signal. The signal needs to be demodulated by multiplication with the perturbation signal. The new values of the controller parameters are obtained by applying a correction in the negative direction of the gradient estimated in the integrator block (3) and by adding a sinusoidal perturbation.

$$\begin{aligned} \xi(k) &= -h\xi(k-1) + J(\Theta(k-1)) \\ \hat{\Theta}_i(k+1) &= \hat{\Theta}_i(k) - \gamma_i \alpha_i \cos(\omega_i k)[J(\Theta(k)) - (1+h)\xi(k)] \\ \Theta_i(k+1) &= \hat{\Theta}_i(k+1) + \alpha_i \cos(\omega_i (k+1)) \end{aligned} \tag{1}$$

Equation 1 shows the implementation of discrete-time extremum seeking algorithm. Where γ_i is adaptation gain, α_i perturbation amplitude, ω_i modulation frequency; $\omega_i = a^i \pi$, $0 < a < 1$ and h is discrete highpass filter parameter , $0 < h < 1$.

3 CONCLUSION

This paper presents a method for automatic tuning of a servo drive controller. Optimal controller parameters for the velocity and position loop are tuned by the extremum seeking algorithm. This method performs a set of experiments with the closed loop and examines its performance by a chosen cost function. Using a gradient-based approach, optimal parameter set is found. The algorithm needs some initial values of the parameters. These are obtained by generalized moments tuning algorithm. Extremum seeking autotuner was tested on a real device. Performance of tuned controller was very good but there are several problems which have to be solved before using in practice. The biggest problem is a quite difficult adjusting of the extremum seeking algorithm itself. Once these problems will be solved, extremum seeking autotuner should outperform most of commonly used electrical servo drives autotuners.

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