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UTILIZATION OF A VIRTUAL SIMULATOR FOR BODE FREQUENCY DIAGRAMS

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ABSTRACT:
The paper presents the use of a virtual simulator implemented trough Scilab-Scicos program to appreciate the stability of some technical processes with help of the frequency characteristic, Bode diagrams.

KEYWORDS:
Frequency diagram (Bode), virtual simulator, transfer function

1. INTRODUCTION

The design of automatic control system requires before their practical application, a verification, that can be done well done through computer simulation, based on the frequency diagrams (Bode plots). After this operation the controller type can be chosen that will assure an optimal function of the automatic control system in closed loop.

2. FREQUENCY CHARACTERISTICS (BODE PLOTS) OF THE TRANSFER FUNCTION

The main idea consists in using the frequency characteristics (Bode plots) of the transfer function in open loop to estimate the answer in closed loop obtained through adding a controller to the system that has to modify, in the wanted direction, the obtained answer in open loop.

Defined open the frequency logarithm characteristics, the Nyquist criteria allows to appreciate the stability of the closed system, when the frequency logarithm characteristics are known (amplitude – pulsation, respectively phase – pulsation) for the open system $H_d(s)$.

The transfer function of the open system is:

$$H_D(s)=H_d(s)H_r(s) \quad (1)$$

where $H_d(s)$ is the transfer function of the direct way and $H_r(s)$ is the feedback transfer function (figure 1).

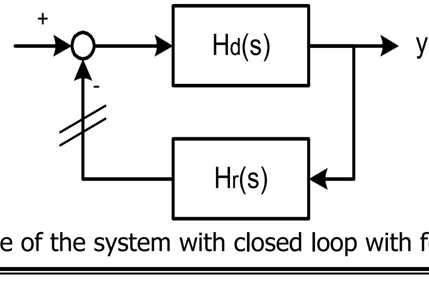

Fig.1 Block scheme of the system with closed loop with feedback interrupting

Based on the Bode plots of the open loop process, figure 1, we define:

- Phase reserve or limit

$$R_{\phi} = 180^{0} + \varphi_{H_d(j\omega)} \tag{2}$$

that is a orientated segment starting from -180^0 to the logarithmic frequency characteristic

- reserve or amplitude limit

$$R_H = \left|H_D(j\omega)\right|_{dB} \tag{3}$$

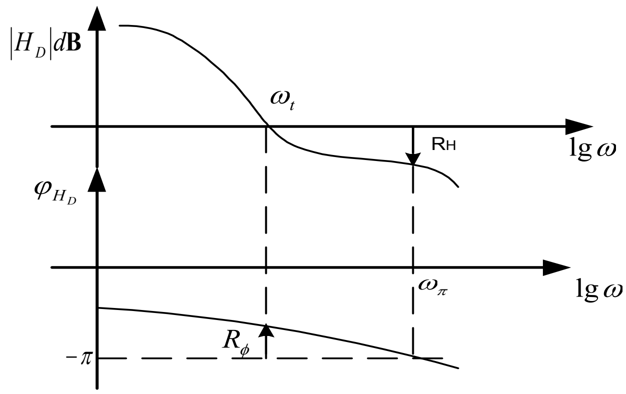

Fig.2. Bode plots for the open loop system

The stability condition of a closed loop system is that the phase limit (reserve) R_ϕ has to be strict positive (R_ϕ >0). These criteria are frequently used in practice and can be applied for system with that time, too. So, for the module limit (reserve) as 'good' values are accepted R_H = 11 – 12 [dB] and for the phase limit values between $R_\phi > 40^0$ and $R_\phi < 60^0$ when the dynamic proprieties of the system are good.

3. THE USE OF THE VIRTUAL BODE SIMULATOR

We'll consider a technical process, referring to the rotation speed control of a DC motor, based on the frequency diagrams (Bode plots). Knowing the nominal parameter of the DC motor:

- moment of inertia of the rotor (J) = 0.01 kg.m^2 /s^2
- electromotive force constant (K=Ke=Kt) = 0.01 Nm/Amp
- damping ratio of the mechanical system (b) = 0.1 Nms
- electric inductance (L) = 0.5 H
- electric resistance (R) = 1 Ω

and the DC motor transfer function

$$H = \frac{K}{(Js + b)\cdot(Ls + R) + K^2} \tag{4}$$

using the Scilab programming software, a free MatLab clone, the phase, amplitude – frequency are represented, as shown in figure 3.

From the Bode plot above, we see that the phase margin can be greater than about 60 degrees if the frequency is less than 10 rad/sec. That for, the system needs a supplementary gain to realize a phase margin of about 60 degrees. To have a gain of 1 at 10 rad/sec it's imposing to multiply the transfer function numerator by 70. With this modification, h=h*70, the program is run again and the obtained result represents the Bode plots with proportional controller in open loop, figure 4.

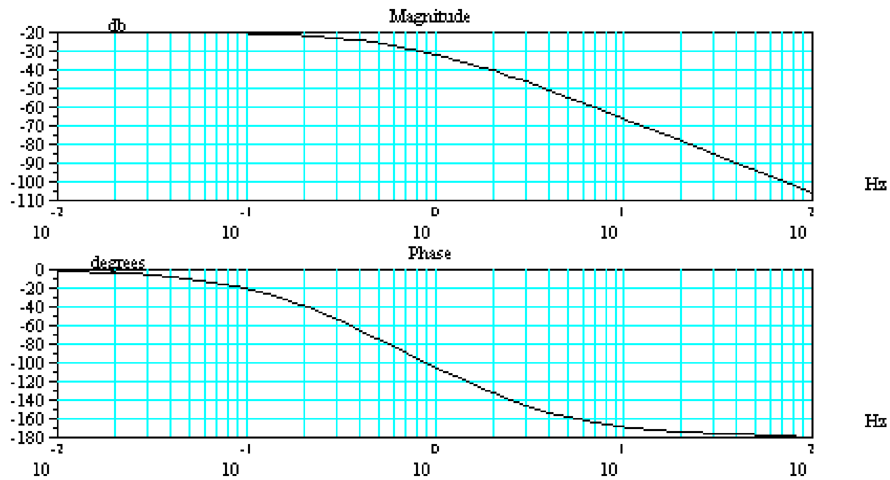

Fig.3. The amplitude – phase evolution depending to the frequency domain

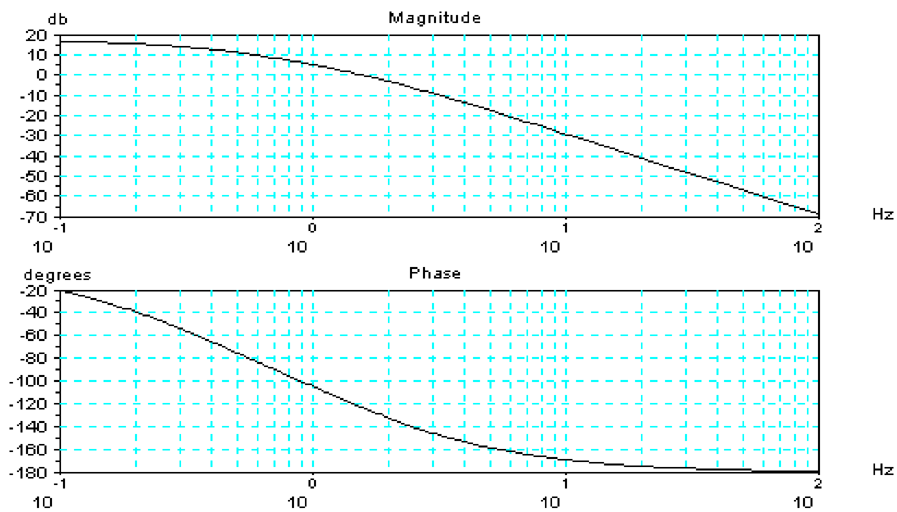

Fig.4. Bode plots for the system with proportional controller in open loop

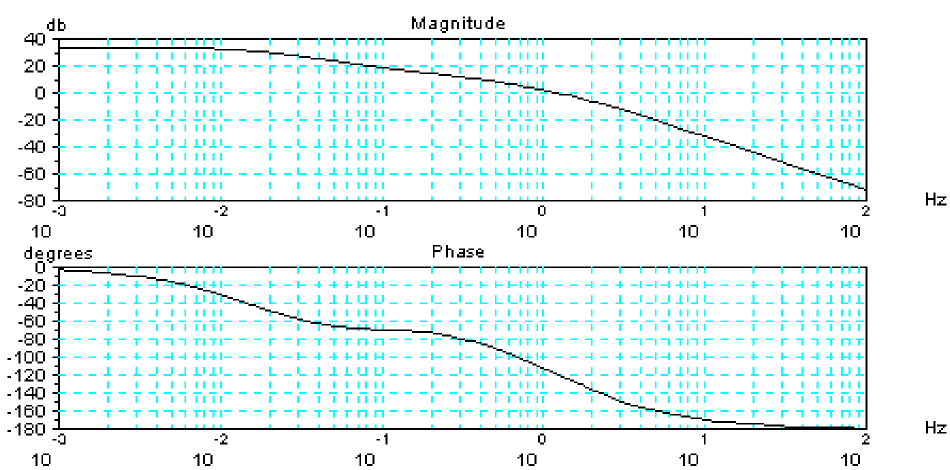

Fig.5. Frequency response in open loop with lag controller

From the diagram above we see that the phase margin is now quite large; under this condition the system transfer function with proportional controller can be definitive. To obtain a better performance for the system, a lag controller we'll be added. The transfer function in open loop is:

$$H_d(s) = \frac{K * K_P}{JLs^2 + (JR + Lb)s + (bR + K^2)} \cdot \frac{s+1}{s+0.1} \tag{5}$$

that leaves to the Bode plots, simulated in figure 5.

It can be observed that the obtained phase limit corresponds and the steady-state error is predicted to be about 1/40dB or 1%, as desired in practice.

To confirm the optimal system parameters, the steady state error, settling time and overshot, we want to obtain the step response for the closed loop system. That for, we calculate the closed loop transfer function of the system, based on equation (6):

$$H(s) = \frac{H_D(s)}{1 + H_D(s)} \tag{6}$$

where $H_D(s)$ is the transfer function of the open loop system, with lag and proportional controller. Using the relation (5) and (6), the transfer function in closed loop will be calculated and given by equation (7); the step response in figure 6.

$$H(s) = \frac{KK_P s + zKK_P}{JLs^3 + (JR + bL + pJL)s^2 + (bR + K^2 + pJR + pLb + KK_P)s + p(bR + K^2) + zKK_P} \tag{7}$$

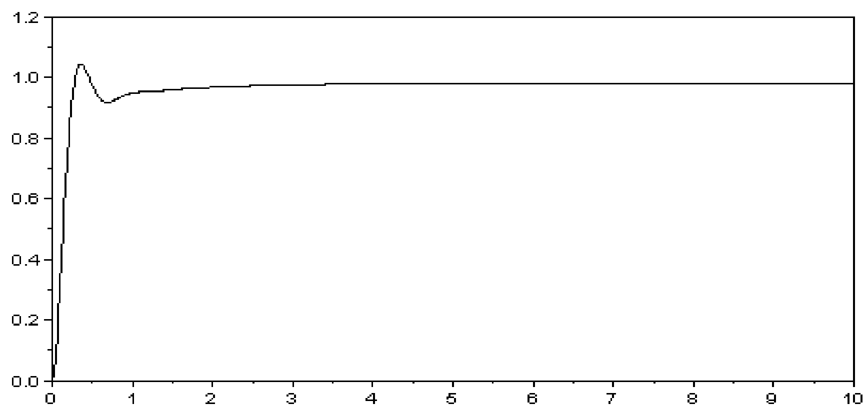

Fig.6. Step response with a lag and proportional controller for close loop

The plot above shows that the step response meets the practical design requirements. The steady-state error is less than 1%, the overshoot is about 5%, and the settling time is about 2 seconds.

4. CONCLUSION

The designing of automatic control systems with high performances, based on the frequency response method, respectively the Bode diagrams, simplified and efficiencies the problem trough the use of the Scilab - Scicos virtual simulator. This allows analyzes of a great number of variants, in a short time and obtain an optimal solution for the implemented system.

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