Study on Servo-Control System of Astronomical Telescopes

Li Zhu-lian, Zheng Xiang-ming, Xiong Yao-heng

1. National Astronomical Observatories/Yunnan Observatory, Chinese Academy of Sciences, Kunming 650011,China

Abstract

Based on recent and modern control theories, this paper describes an analysis of the control system compensation function and its application to astronomical telescope servo control requirements. It discusses corresponding compensation networks for modern astronomical telescopes.

Keywords: *Servo System, Compensation Network, SLR/LLR telescope*

Introduction

Most of modern telescopes servo-control systems are computer closed loop control systems which are based on classical control theories and are composed of one or more feedback control loop. Typical feedback control system is shown in Fig.1. In theory, control system designed according to this block diagram might meet the requirements. However, in a concrete project, control system simply designed like this way is not simultaneously satisfied with all the requirements until it is compensated properly.

C(s) represents controlled output, its value is sent back through feedback controller

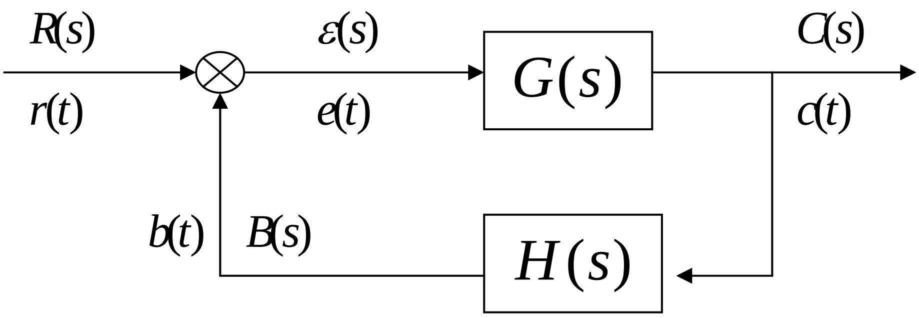

Fig.1 *Typical Feedback Control Loop*

whose transfer function is H(s). Its output B(s) is compared with expected output R(s), i.e. input of whole control system, the error which R(s) substracts B(s) is sent into controller G(s), which adjusts the error to near zero.

Compensation of Control System

In order to carry out expected capability, modifying and adjusting the control system structure is named compensation. In another words, compensation is used to adjust structure for compensating defect of system. PD (Proportion Differential) Compensation Network and PI (Proportion Integral) are often used in modern control system design. Corresponding control loop block diagram is shown as Fig.2. Gc(s) is the transfer function of the compensation network. [1]

PD Compensation Network Function

When compensation network transfer function $G_c(s)$ is:

$$G_c(s) \approx \frac{k}{p} s$$

it is a PD type compensation Network.[2] Fig.3 is its corresponding bode graph, which is magnitude versus phase plot. It could be clearly seen that magnitude gain increases with frequency and phase is greater than zero. This means that PD compensation can offer additional phase for primary system without compensation network.

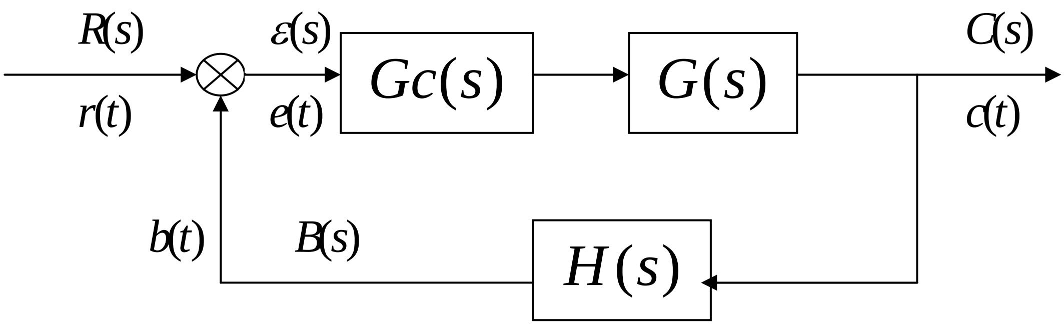

Fig.2 *Feedback Control Loop with Compensation*

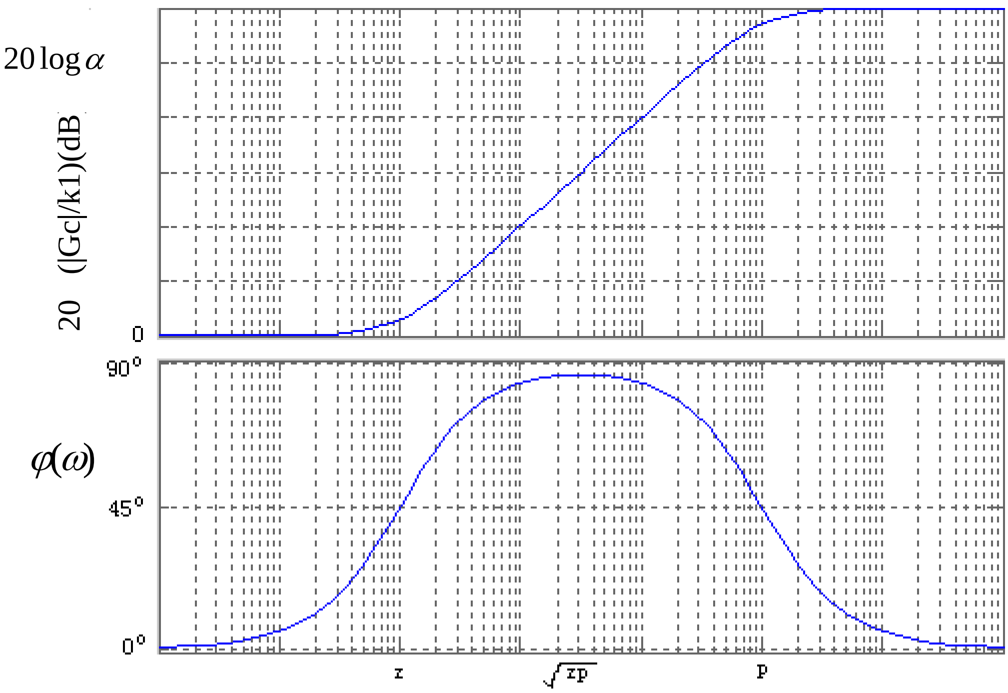

Fig.3 *The Bode Graph of PD Compensation*

Therefore, to make system response more quickly and strengthen system stability is the function of PD compensation.

PI Compensation Network Function

When compensation network transfer function $G_c(s)$ is :

$$G_c(s) \approx \frac{k}{ps}$$

it is a PI type compensation Network.[2] Fig.4 is its corresponding bode graph, which is magnitude versus phase plot. It is obvious that magnitude gain descends with frequency and phase is negative. This shows that PI compensation can offer delay phase for primary system without compensation network. So, the function of PI compensation is to improve system accuracy of stability. To sum up, PD compensation may be used to improve instantaneous response and PI can be used to meliorate stable response.

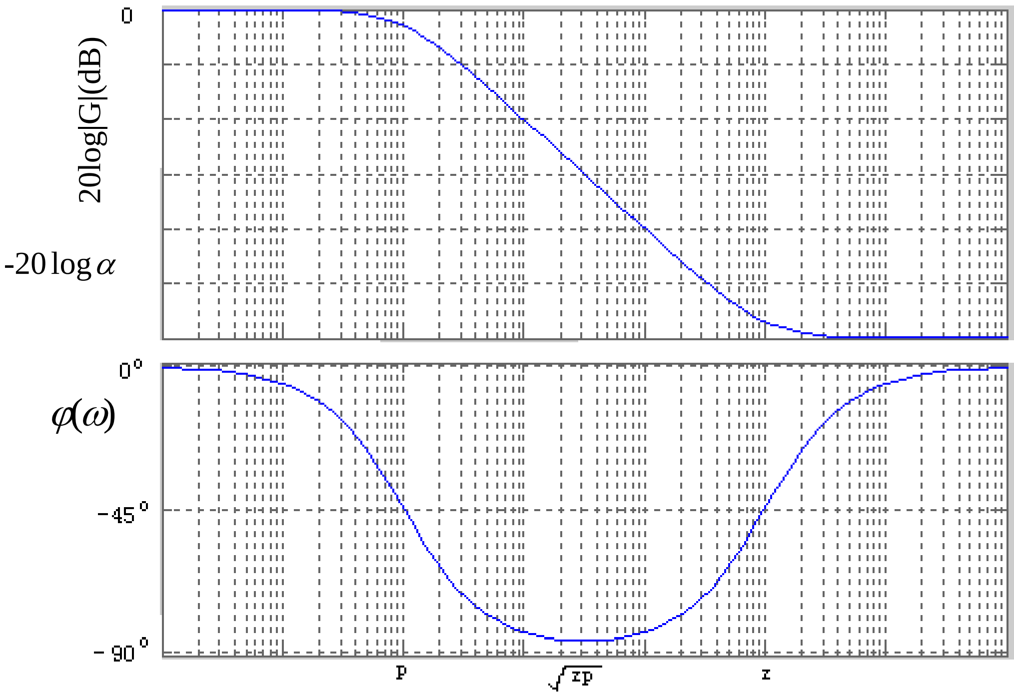

Fig.4 *The Bode Graph of PI Compensation*

Compensation Network Design for Telescope Servo System

According to characters of the compensation network which were analysed above, we could design a proper servo control system for any astronomical telescope.

If a telescope is required to track quick motion celestial bodies, such as satellites near the Earth, we would design the control system compensation network as PD compensation, or PI compensation would be better to observe slow motion celestial bodies for a telescope.

Of course, when a telescope is not require to track quick motion celestial bodies but slow motion bodies, to combine advantages of PI and PD could gain the expected performance or we could directly design the control system compensation network as PID compensation.

Discussion

Though PID compensation network could attain better capability, its disadvantage is that needs more devices and increases design cost. Therefore, if a telescope need track both quick and slow bodies, in order to save resource, we'd better select PD compensation network, then through software methods to compensate the accuracy of stability.

References

[1] Richard C., Dorf, Robert H and Bishop. Modern Control System (eighth edition). Translation by Xie Hong-wei, Zou Feng-xing and Zhang Ming. Beijing Higher Education Press.

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