# Optimization of Servo System's Dynamic Performance Based on Luenberger Observer

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**Abstract: Linear electro-mechanical actuator is used as a core component of large space mechanic and its position is measured by resolver. Velocity of the linear electro-mechanical actuator is calculated by the position data using the simple difference which always caused the phase lag issues. In order to reduce the phase lag, luenberger observer has been designed and analyzed. According to the specific parameters of the servo system and closed loop control structure, luenberger observer for compensation is designed in velocity loop. Simulation model is established by Simulink which showed that the luenberger observer can effectively reduce the phase lag caused by the simple difference of resolver data and improve servo system's dynamic response significantly.**

## 1 Introduction

Position and velocity are usually measured by different kind of sensors in typical servo systems which introducing significant errors, such as noise, deterministic error, and limited response capability. Those factors reduce the servo system's control performance. In addition, sensors and cables are one of the most expensive components in the system, so we try to introduce the observers to augment or replace sensors of the servo control system for solving the existing problems described above. Observer is a control algorithm which combining sensor signals with information from control system as a feedback of control system [1], thus can replace sensor measurement and make system more accurate, cheap and reliable. Usually we can't access to the state variables due to the measurement methods [2], so algorithm used to estimates state variables by measurement output and control input are called observer.

In recent years, due to its good stability and robustness, observers have been widely applied in many fields. France scholar Z.Jabbour [3] has used state observers on PMSM to solve the steady-state problems of slow velocity; Zhang Xuefei [4], scholar of Chinese Academy of Sciences, has introduced the observer on aviation camera pitch angle servo control system, which improved the dynamic characteristics of the system, precision and anti-jamming capacity. Yang Bo [5] of Yanshan University has designed the reduced dimension velocity observer using the measurement error to reconstruct a generalized Hamilton system, which improved the stability of the closed-loop system. This paper focuses on the servo system of linear actuator as a core components of large space mechanical .We introduce Luenberger observer to the servo system and observers can effectively reduce phase lag caused by the resolver and simple difference and improve servo system's dynamic response.

## 2 Luenberger observer model

Luenberger observer is one of the most practical observer forms, which consists of the following five components:

a) Sensor output $Y(s)$

b) Power converter output $P_c(s)$

c) Control plant model $G_{PEst}(s)$

d) Sensor model $G_{SEst}(s)$

e) Compensation observer $G_{CO}(s)$

General form of luenberger observer is shown in Figure 1:

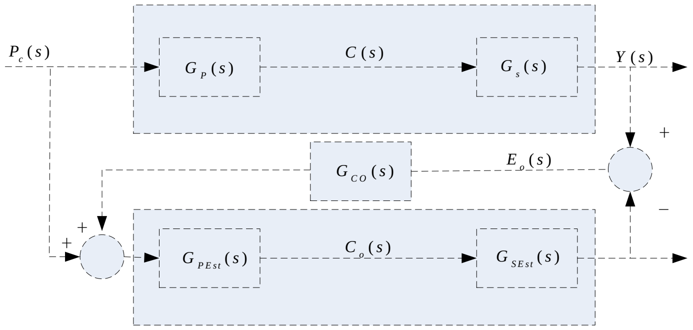



Fig.1 Luenberger observer

Luenberger observer can be represented as a transfer function form, which can express the observer's detailed operation clearly. As shown in Figure 1, transfer function of luenberger observer has two inputs $P_C(s)$ and $Y(s)$ with one output $C_O(s)$. Consider the observer transitive relation between input and output, we ignored the internal sensor measurement error and used the Mason method to establish transfer function of luenberger observer:

$$C_O(s) = \frac{Y(s)G_{CO}(s)G_{PEst}(s) + P_C(s)G_{PEst}(s)}{1+G_{PEst}(s)G_{CO}(s)G_{SEst}(s)} \quad (1)$$

Then we break the transform function into two parts:

$$C_O(s) = Y(s)\frac{G_{CO}(s)G_{PEst}(s)}{1+G_{PEst}(s)G_{CO}(s)G_{SEst}(s)} + P_C(s)\frac{G_{PEst}(s)}{1+G_{PEst}(s)G_{CO}(s)G_{SEst}(s)} \quad (2)$$

The first part can be transfer to a form of low pass filter and the second part can be transfer to a form of high pass filter. Thus, luenberger observer can use two kinds of signal source to get the observer states and use the different filter to make up the output at the best frequency range as shown below:

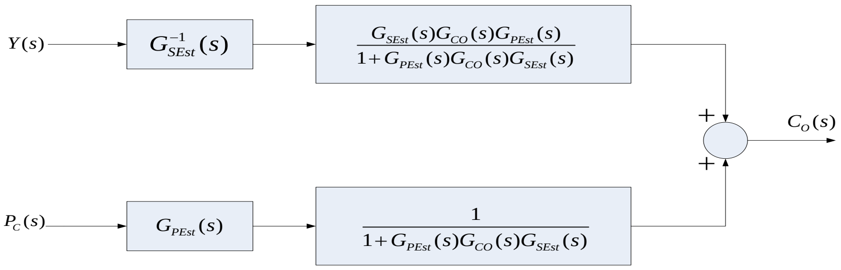



Fig.2 filter form of luenberger observer

## 3 Observer application design

To meet the high performance requirement, servo system of linear electro-mechanical actuator adopts the full closed control loop with currency, velocity and position feedback [6].

Servo system's electromagnetic torque $T_E$ equals to feedback current $I_F$ multiplied by the torque constant $K_T$; and the feedback current $I_F$ multiplied by the torque constant estimated value $K_{TEst}$ estimated the value of electromagnetic torque $T_{EEst}$. Rotating resolver transformer model based on the Luenberger observer is shown in Figure 3.

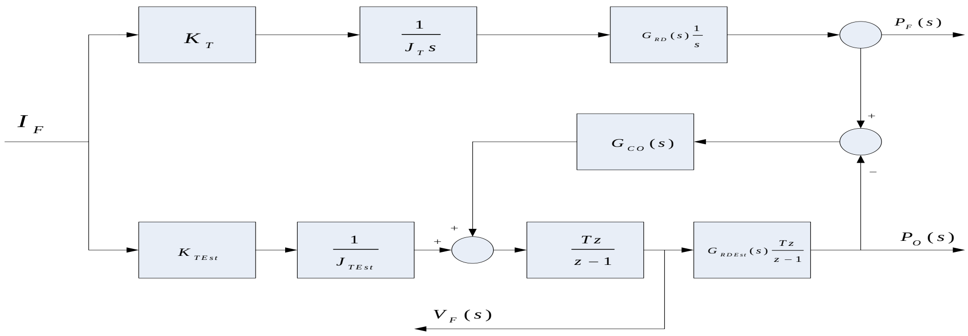



Fig.3 velocity by observer output

PID-$D^2$ structure is used to compensation luenberger observer, where $D^2$ is the second-order differential. We use the differential to add the phase lead which improve the stability allowance, increase the observer gains and dynamic response of the servo system. Form 1/s is replaced by which is equivalent to the number $\frac{Tz}{z-1}$ in your observation circuit, so the entity system remains same with the model system.

## 4 Simulation results and analysis

Feedback loops based on the Luenberger observer model is established by Simulink as shown in Figure 4.

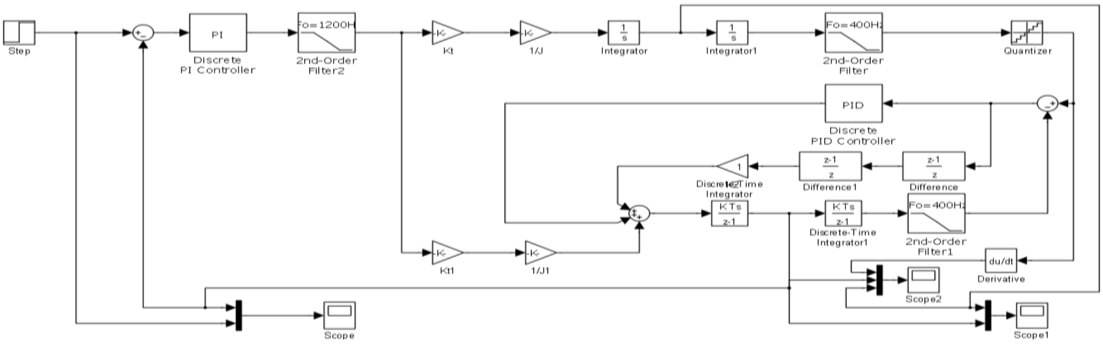
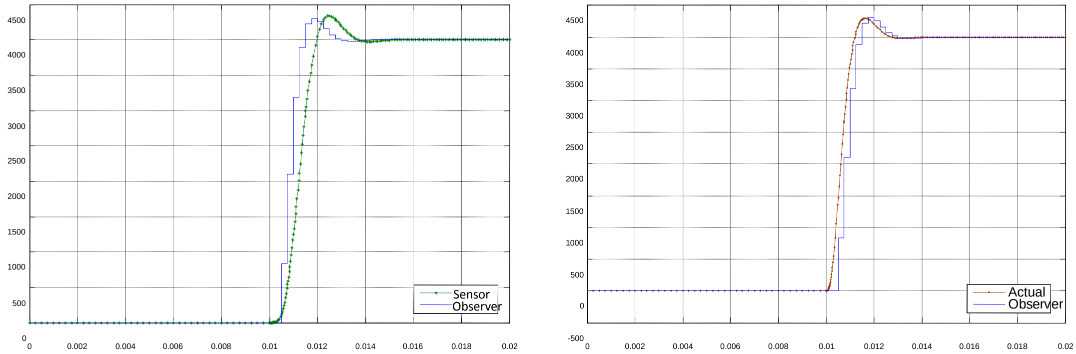



Fig.4 Simulation model

As shown in Figure 4, speed step instructions through the speed controller ASR into current loop. ASR speed regulator is made up by the PI controller. Current loop is a two poles low pass filter model with a constant bandwidth setting to 1200Hz, damping ratio setting to 0.707 and R-D converter bandwidth setting to 400Hz.




(A)Observer and sensor output (B) Observer and actual output

Fig.5 Velocity comparison

As shown in Figure 5, input step signal is 4000rpm. The observer velocity output and sensor velocity output is shown in Figure 5A. The observer velocity output and actual velocity output is shown in Figure 5B. From Figure above, the velocity loop step response based on the Luenberger observer has smaller phase delay. Besides, the observing output velocity curve tracks the actual speed compared to the sensor output curve has a smaller following error and servo system has a better dynamic performance.

## 5 Conclusions

Through introducing luenberger observer in the velocity loop of closed-loop structure, observer information and control system information has been synthesized. What's more, results getting from the luenberger observer are used to the control system. By Simulink software, simulation model is established according to the actual parameters of the servo system. Simulation results show that the Luenberger observer can effectively reduce phase-lag caused by the resolver and simple difference and improved servo system's dynamic response effectively.

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