Sample

Problem 6

I. Consider a dynamic plant expressed by a differential equation (i):

$$\frac{dy(t)}{dt} = 2u(t) - 3y(t) \ , \qquad \text{(i)}$$

where $u(t)$ and $y(t)$ are the input and the output of the control system, respectively, and the corresponding Laplace transforms are denoted by $U(s)$ and $Y(s)$. Answer the following questions.

(1) Find the transfer function of the plant: $\mathrm{(s)} = {Y(s)}/{U(s)}$.

(2) Let us design a feedback controller of the plant $C(s)$ in the PI (Proportional and Integral) form as expressed by equation (ii). Draw a block diagram of the feedback control system.

$$U(\mathrm{s}) = C(\mathrm{s})\big(R(s) - Y(s)\big) \ , \quad C(s) = K_P + \frac{K_I}{s} \qquad \text{(ii)}$$

Here, $R(s)$ is the reference value, K_P and K_I are the proportional and integral gains, respectively.

(3) In Question (2), find K_P and K_I to place all the poles of the closed loop system to $\mathrm{s} = -10$.

(4) Assume that the controller gains derived in Question (3) are applied. Find the time response of the output $y(t)$ when the reference value $r(t)$ is a unit step function.

(5) Illustrate Bode diagram of the open loop transfer function $P(s)C(s)$ when the controller gains derived in Question (3) are applied.

(6) Explain how to acquire the information on phase margin from the Bode diagram in Question (5).

II. Consider a single-phase AC power source with an angular frequency ω. The terminal voltage and current are expressed as $V(t) = V_0 \cos \omega t$ and $I(t) = I_0 \cos(\omega t + \varphi)$, respectively. Answer the following questions.

(1) Find the instantaneous output power of this AC power source. From this result, derive the effective values of the current and the voltage, and the power factor.

(2) Based on the results of Question (1), explain the problems of a single-phase AC power supply.

(3) Assume that we construct a symmetrical three-phase AC power source by combining three power sources in Question (1) with the voltage and current phases shifted by ${1}/{3}$ period. Find the instantaneous total power of this three-phase AC power source.

(4) From the above results, explain why symmetrical three-phase AC is widely used in the electrical power systems.