KONTROL OTOMATIK LANJUT

Metode Persamaan Ruang Keadaan untuk Desain Sistem Pengendalian (Studi Kasus Sistem Pengendalian Tegangan Pada *Buck Converter*)

Disusun oleh:

Rio Dermawan

NRP. 02311950010003

Dosen Pengajar Mata Kuliah :

Prof. Dr. Ir. Aulia Siti Aisjah, M.T

NIP. 19660116 198903 2 001

PROGRAM STUDI S2 INSTRUMENTASI INDUSTRI

DEPARTEMEN TEKNIK FISIKA

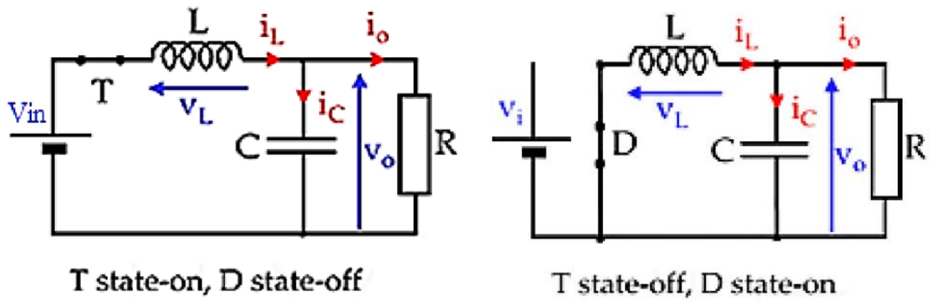
FAKULTAS TEKNOLOGI INDUSTRI

INSTITUT TEKNOLOGI SEPULUH NOPEMBER

2020

Metode Persamaan Ruang Keadaan untuk Desain Sistem Pengendalian

(Studi Kasus Sistem Pengendalian Tegangan Pada *Buck Converter*)



Gambar 1. Rangkaian ekuivalen *buck converter*

Persamaan Sistem

Kondisi saat saklar dalam keadaan tertutup

Hukum Kirchoff Tegangan

$$V_i D = L\frac{di_L}{dt} + i_L r_L + V_o$$

$$i_L = i_C + \frac{V_o}{R}$$

$$V_o = V_C + i_C r_C$$

$$V_o = (i_L - i_C)R$$

Kondisi saat saklar dalam keadaan terbuka

$$C\frac{dV_C}{dt} = i_L - \frac{V_o}{R}$$

$$i_L = C\frac{dV_C}{dt} + \frac{V_o}{R}$$

$$i_L = C\frac{dV_o}{dt} + \frac{V_o}{R}$$

Persamaan diferensial *buck converter*

$$V_i D = L\frac{di_L}{dt} + i_L r_L + V_o$$

$$V_i D = CL\frac{d^2V_o}{dt^2} + \frac{L}{R}\frac{dV_o}{dt} + r_L C\frac{dV_o}{dt} + \frac{r_L}{R}V_o + V_o$$

$$\frac{V_i}{CL}D = \frac{d^2V_o}{dt^2} + \frac{1}{RC}\frac{dV_o}{dt} + \frac{r_L}{L}\frac{dV_o}{dt} + \frac{r_L}{RCL}V_o + \frac{1}{CL}V_o$$

$$\frac{V_i}{CL}D = \frac{d^2V_o}{dt^2} + \left(\frac{1}{RC} + \frac{r_L}{L}\right)\frac{dV_o}{dt} + \left(\frac{r_L}{RCL} + \frac{1}{CL}\right)V_o$$

Persamaan ruang keadaan

$$D = u$$

$$x_1 = y = V_o$$

$$x_2 = \dot{x}_1 = \frac{dV_o}{dt}$$

$$\dot{x}_1 = x_2 = \frac{dV_o}{dt}$$

$$\dot{x}_2 = \ddot{x}_1 = \frac{d^2V_o}{dt^2} = -\left(\frac{r_L}{RCL} + \frac{1}{CL}\right)V_o - \left(\frac{1}{RC} + \frac{r_L}{L}\right)\frac{dV_o}{dt} + \frac{V_i}{CL}D$$

$$\dot{x}_2 = \ddot{x}_1 = \frac{d^2V_o}{dt^2} = -\left(\frac{r_L}{RCL} + \frac{1}{CL}\right)x_1 - \left(\frac{1}{RC} + \frac{r_L}{L}\right)x_2 + \frac{V_i}{CL}D$$

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -\left(\frac{r_L}{RCL} + \frac{1}{CL}\right) & -\left(\frac{1}{RC} + \frac{r_L}{L}\right)\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ \frac{V_i}{CL}\end{bmatrix}u$$

$$y = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

Matriks keterkendalian

$$M = \left[B : AB : \ldots : A^{n-1}B\right]$$

$$M = \left[B : AB\right]$$

$$AB = \begin{bmatrix} 0 & 1 \\ -\left(\dfrac{r_L}{RCL} + \dfrac{1}{CL}\right) & -\left(\dfrac{1}{RC} + \dfrac{r_L}{L}\right) \end{bmatrix} \begin{bmatrix} 0 \\ \dfrac{V_i}{CL} \end{bmatrix}$$

$$AB = \begin{bmatrix} \dfrac{V_i}{CL} \\ -\left(\dfrac{1}{RC} + \dfrac{r_L}{L}\right)\dfrac{V_i}{CL} \end{bmatrix}$$

$$M = \begin{bmatrix} 0 & \dfrac{V_i}{CL} \\ \dfrac{V_i}{CL} & -\left(\dfrac{1}{RC} + \dfrac{r_L}{L}\right)\dfrac{V_i}{CL} \end{bmatrix}$$

Matriks keteramatan

$$N = \left[C^T : A^T C^T : \ldots : \left(A^T\right)^{n-1} C^T\right]$$

$$N = \left[C^T : A^T C^T\right]$$

$$A^T C^T = \begin{bmatrix} 0 & -\left(\dfrac{r_L}{RCL} + \dfrac{1}{CL}\right) \\ 1 & -\left(\dfrac{1}{RC} + \dfrac{r_L}{L}\right) \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$A^T C^T = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$N = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Keterkendalian

Desain regulator dengan penempatan kutup

a. Metode perbandingan langsung

$$|sI - A| = \left| \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ -\left(\dfrac{r_L}{RCL} + \dfrac{1}{CL}\right) & -\left(\dfrac{1}{RC} + \dfrac{r_L}{L}\right) \end{bmatrix} \right|$$

$$s^2 + a_1 s + a_0 = \begin{vmatrix} s & -1 \\ \left(\frac{r_L}{RCL} + \frac{1}{CL}\right) & s + \left(\frac{1}{RC} + \frac{r_L}{L}\right) \end{vmatrix}$$

$$s^2 + a_1 s + a_0 = s^2 + \left(\frac{1}{RC} + \frac{r_L}{L}\right) s + \left(\frac{r_L}{RCL} + \frac{1}{CL}\right)$$

$$a_1 = \left(\frac{1}{RC} + \frac{r_L}{L}\right)$$

$$a_0 = \left(\frac{r_L}{RCL} + \frac{1}{CL}\right)$$