UTS Cyber Physical System

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UTS CPS_Muhammad Arif Wijayanto.ipynb

1. **Analisis KCL/KVL:** Menurunkan persamaan tegangan untuk loop primer dan sekunder.

1. KCL & KVL Analysis

Persamaan Rangkaian:

- Primary Loop:

$$V_1 = I_1(R_1 + sL_T) + sMI_2$$

- Secondary Loop:

$$0 = I_2(R_2 + R_B + sL_R) + sMI_1$$

[2]
```python
import sympy as sp

# Definisi simbol
R1, R2, RB, LT, LR, K, M, s = sp.symbols('R1 R2 RB LT LR K M s')
I1, I2, V1 = sp.symbols('I1 I2 V1')

# Mutual inductance
M_expr = K * sp.sqrt(LT * LR)

# Persamaan KVL
eq1 = V1 - I1*(R1 + s*LT) - s*M_expr*I2
eq2 = -I2*(R2 + RB + s*LR) - s*M_expr*I1

sol = sp.solve([eq1, eq2], [I1, I2])
I1_expr = sol[I1]
I2_expr = sol[I2]

# Transfer function
Vout = I2_expr * RB
H = Vout / V1
```

Analisis KCL/KVL

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2. **State-Space:** Memodelkan sistem dalam bentuk matriks untuk simulasi dinamik.

2. State Space Model

Matriks State-Space:

$$\mathbf{A} = \frac{1}{L_T L_R - M^2} \begin{bmatrix} -L_R R_1 & M(R_2 + R_B) \\ M R_1 & -L_T(R_2 + R_B) \end{bmatrix},$$
$$\mathbf{B} = \frac{1}{L_T L_R - M^2} \begin{bmatrix} L_R \\ -M \end{bmatrix},$$
$$\mathbf{C} = [0 \quad R_B], \quad \mathbf{D} = 0$$

```
[3] det = LT*LR - M_expr**2
    A = sp.Matrix([
        [-LR*R1/det, M_expr*(R2 + RB)/det],
        [M_expr*R1/det, -LT*(R2 + RB)/det]
    ])
    B = sp.Matrix([LR/det, -M_expr/det])
    C = sp.Matrix([[0, RB]])
    D = sp.Matrix([0])
```

State-Space

```
det = LT*LR - M_expr**2
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B = sp.Matrix([LR/det, -M_expr/det])
C = sp.Matrix([[0, RB]])
D = sp.Matrix([0])
```

3. **Transfer Function:** Menghasilkan fungsi alih untuk analisis frekuensi.

3. Transfer Function

- Fungsi Alih Simbolik:

$$H(s) = \frac{-sMR_B}{(R_2 + R_B + sL_R)(R_1 + sL_T) + s^2 M^2}$$

- Substitusi Nilai Numerik:

$$R_1 = 1.2\,\Omega, \quad R_2 = 1.6\,\Omega, \quad R_B = 1\,\mathrm{k}\Omega,$$
$$L_T = 63.46\,\mu\mathrm{H}, \quad L_R = 29.2\,\mu\mathrm{H}, \quad K = 0.6$$

```
component_values = {
    R1: 1.2,
    R2: 1.6,
    RB: 1e3,
    LT: 63.46e-6,
    LR: 29.2e-6,
    K: 0.6
}
H_numeric = H.subs(component_values).simplify()
```

Transfer Function

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    R1: 1.2,
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4. **Respon Frekuensi:** Menunjukkan pengaruh variasi K pada bandwidth dan gain.

4. Respon Frekuensi

- Evaluasi pada Domain Frekuensi:

$$H(j\omega) = H(s)|_{s=j\omega}$$

```
import numpy as np
import matplotlib.pyplot as plt
import sympy as sp

# Definisi simbol dan substitusi nilai komponen (kecuali K)
R1, R2, RB, LT, LR, K, s = sp.symbols('R1 R2 RB LT LR K s')
component_values = {
    R1: 1.2,
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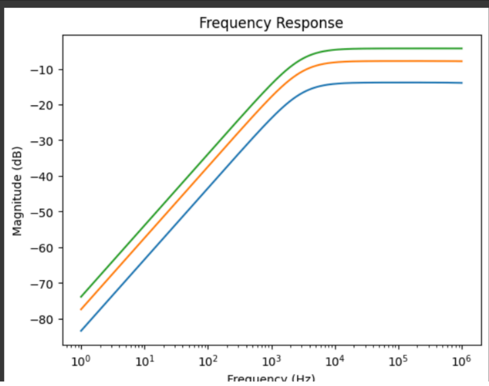
    LT: 63.46e-6,
    LR: 29.2e-6
}
H_numeric = H.subs(component_values).simplify()  # K masih simbol

# Fungsi transfer dengan parameter s dan K
H_func = sp.lambdify((s, K), H_numeric, 'numpy')

# Evaluasi untuk K berbeda
omega = np.logspace(0, 6, 2000)  # Frekuensi dalam Hz
K_values = [0.3, 0.6, 0.9]
```

```
plt.figure()
for K_val in K_values:
    s_vals = 1j * 2 * np.pi * omega  # Konversi Hz ke rad/s
    H_eval = H_func(s_vals, K_val)    # Evaluasi dengan s dan K
    plt.semilogx(omega, 20 * np.log10(np.abs(H_eval)))

plt.title('Frequency Response')
plt.xlabel('Frequency (Hz)')
plt.ylabel('Magnitude (dB)')
plt.show()
```



Respon Frekuensi

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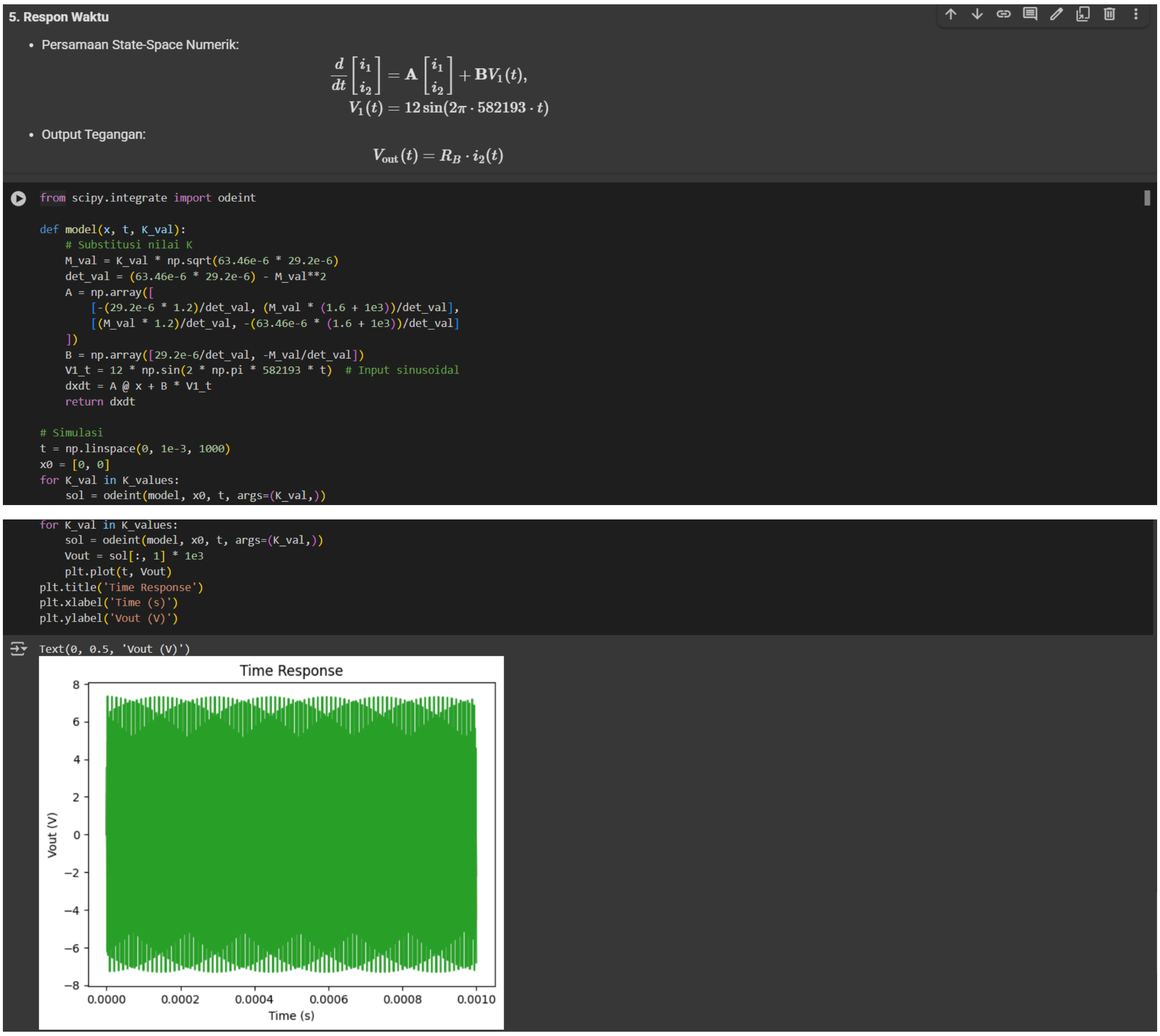
```

5. **Respon Waktu:** Simulasi transient untuk melihat respons sistem terhadap input sinus.



Respon Waktu

```python
from scipy.integrate import odeint

def model(x, t, K_val):
    # Substitusi nilai K
    M_val = K_val * np.sqrt(63.46e-6 * 29.2e-6)
    det_val = (63.46e-6 * 29.2e-6) - M_val**2
```

```
    A = np.array([
        [-(29.2e-6 * 1.2)/det_val, (M_val * (1.6 + 1e3))/det_val],
        [(M_val * 1.2)/det_val, -(63.46e-6 * (1.6 + 1e3))/det_val]
    ])
    B = np.array([29.2e-6/det_val, -M_val/det_val])
    V1_t = 12 * np.sin(2 * np.pi * 582193 * t)  # Input sinusoidal
    dxdt = A @ x + B * V1_t
    return dxdt

# Simulasi
t = np.linspace(0, 1e-3, 1000)
x0 = [0, 0]
for K_val in K_values:
    sol = odeint(model, x0, t, args=(K_val,))
    Vout = sol[:, 1] * 1e3
    plt.plot(t, Vout)
plt.title('Time Response')
plt.xlabel('Time (s)')
plt.ylabel('Vout (V)')
```