Advanced Control Systems
Lab 4 and 5 Report Marking Guide

- A maximum of three students are allowed per group. The groups must be fixed between Labs 4-5 and all group members must attend the same lab session.
- Due to the work required to complete the lab, students who do not attend a lab with their group will not receive a mark for the report. Your attendance will be recorded.
- Labs 4-5 will be combined into a single report worth 15% of your ACS grade. Please submit the report on Canvas. Only one submission is required per group. **[Total Report Marks: 235]**
- Present the results and diagrams clearly with annotations for complicated features. Graphs should be plotted in MATLAB and should include the legend, title, x-axis and y-axis labels. Moreover, the pictures in the report should be clear to read i.e. of good resolution.
- Address the questions in the order as they appear in this document, and in your reports, clearly indicate the section that you are answering.
- Finally, please ensure that the content included in your report is your own intellectual property. Any occurrence of significant plagiarism may result in loss of partial/full credit.

Overall production quality of the report **[15 marks]**

Lab 4:

0.1.1: Park-Clarke Transformation

1. What is the meaning of a balanced three-phase load? How does it help in reducing the number of current sensors? **[2 marks]**
2. What are the input and output variables to Park-Clarke Current transform block? **[3 marks]**
3. Show the screenshot of block diagram and code of the PCCurrent block? **[7 marks]**
4. Explain the working of PCCurrent block? **[4 marks]**
5. How is 'theta' (input to the PCCurrent block) measured and supplied to the PCCurrent block? **[3 marks]**

0.1.2: Inverse Park-Clarke Transformation

1. What is the role of Inverse Park-Clarke Voltage transformation? **[3 marks]**
2. What are the input and output variables to Inverse Park-Clarke Voltage transform block? **[3 marks]**
3. Show the screenshot of block diagram and code of the IPCVoltage block? **[7 marks]**
4. Explain the working of IPCVoltage block? **[4 marks]**

0.2: Simulation Model for PMSM

1. Show the complete block diagram of your *PMSMModel.slx* file. **[10 marks]**
2. Explain the working of this block diagram? **[8 marks]**
3. Does this block diagram characterize an open-loop or closed-loop system? **[2 marks]**
4. Identify the input and output variables of the system shown in *PMSMModel.slx*? **[4 marks]**

5. What is the role of Zero-Order Hold blocks in this block diagram? **[2 marks]**
6. Identify the load disturbance in this block diagram. **[3 marks]**
7. Why is the <Rotor angle thetam (rad/s)> multiplied with "p" before feeding it to the IPCVoltage and PCCurrent blocks? **[3 marks]**
8. Show the code of m-file generated for defining parameters in Lab 04? **[7 marks]**

Lab 5:

Model of PMSM

1. What control structure is being used for the angular speed control of PMSM? **[4 marks]**
2. Show the mathematical model of PMSM and identify input and output variables in the model? **[7 marks]**

Task-1: Current Controller Design

1. Write down the transfer functions $G_1(s)$ and $G_2(s)$? **[6 marks]**
2. Are $G_1(s)$ and $G_2(s)$ open-loop or closed-loop transfer functions? **[3 marks]**
3. Identify the input and output of $G_1(s)$ and $G_2(s)$ transfer function block? **[4 marks]**
4. What are the poles and zeros of $G_1(s)$ and $G_2(s)$? **[4 marks]**
5. Is PI controller a suitable controller for step reference tracking for $G_1(s)$ and $G_2(s)$; why/why not? **[4 marks]**
6. Can we design a PID controller for $G_1(s)$; why/why not? **[2 marks]**
7. How does γ_1 impact the bandwidth of the current PI controllers? **[2 marks]**
8. Write down the <u>process</u> of control design for $G_1(s)$ and $G_2(s)$? (You can attach a screenshot of your handwritten notes.) **[10 marks]**
9. Write down the closed-loop poles of i_d and i_q control loops? **[6 marks]**
10. Apply final value theorem to prove that the closed-loop system for $G_2(s)$ can track a step reference of $i_q^* = 10A$ (i.e. $I_q^*(s) = 10/s$) with zero steady-state error. [Hint: $Y(s) = I_q(s)$ and $R(s) = I_q^*(s)$] **[10 marks]**
11. Show the m-file code with PI parameter equations for $G_1(s)$ and $G_2(s)$? **[6 marks]**

Task-2: Speed/Velocity Controller Design

1. Write down the transfer functions $G_3(s)$? **[3 marks]**
2. Identify the input and output of $G_3(s)$ transfer function? **[3 marks]**
3. What are the poles and zeros of $G_3(s)$? **[3 marks]**
4. How does γ_2 impact the bandwidth of the speed PI controller? **[2 marks]**
5. Write down the <u>process</u> of control design for outer (speed) control loop? (You can attach a screenshot of your handwritten notes.) **[12 marks]**
6. Apply final value theorem to prove that the closed-loop system of speed control loop can reject step output disturbance of $d_o(t) = 20$ rad/s (i.e. $D_o(s) = 20/s$). **[10 marks]**
7. Would the speed control loop be able to track a sinusoidal speed reference without steady state error; why/why not? **[4 marks]**
8. Show the m-file code for PI parameter equations for $G_3(s)$? **[6 marks]**

Task-3: Simulation of Closed Loop Control of Speed/Velocity

1. Show the complete block diagram of closed-loop system with all the PI controllers? **[10 marks]**
2. What is the role of load torque “TL” in the closed-loop simulation? **[2 marks]**
3. Show the graphs : i_d *and* i_d* on one graph, and ω_e and ω_e* on another graph for each of the following cases:
   a. $\gamma_1 = \gamma_2 = 0.8$
   b. $\gamma_1 = 0.8$, $\gamma_2 = 0.93$
   c. $\gamma_1 = 0.93$, $\gamma_2 = 0.8$
   d. $\gamma_1 = \gamma_2 = 0.93$

   State your observations. **[10 marks]**
4. Plot sum of squared errors for ω_e in all four cases? Which case is best and why? **[7 marks]**
5. Observe and comment on the noise rejection capability of all cases by adding a suitable measurement noise in the speed measurement. Describe in terms of speed controller bandwidth. Provide insight without showing graphs. **[5 marks]**