Department of Electrical Engineering
Faculty of Engineering
University of Moratuwa

Control Systems

Design Home Assignment-1

March, 2025

Submission deadline: 10th of April, 2025

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Marks allocation:

This home assignment accounts for a 15% of the total module mark.

Deliverables:

You are expected to complete ALL parts of this assignment, write an individual report in typed format, and submit ***exclusively in PDF format as a single file*** *to MOODLE.*

Your report needs to be neat, legible and well-structured. In assessing your assignment working we will be looking for evidences of ***your learning****. The deeper you have discussed the meaning of your results the richer the technical contents of your report and therefore the higher your attainments.*

A mechanical work of simply presenting solutions to the theoretical part and including plots of MATLAB® simulation, if free of error and presented well, would only just meet a satisfactory standard. Your discussions of the obtained results and the way in which these are connected to the theory are the main aspect of the assignment that assessors will be looking for. ***All MATLAB® programmes must be included in an Appendix at the end of the report.***

Your individual report must be submitted in PDF form to MOODLE by due date.

Temperature Control and Energy Performance of a Standalone Air-Conditioning System

Introduction and Background

Air conditioning plays a crucial role in maintaining comfortable indoor temperatures, particularly during hot and humid weather conditions. However, the operational and energy performance of air conditioning systems can vary based on various factors including the temperature control technology and settings, environmental conditions and the location of the outdoor unit.

Assignment Tasks

A school in the downtown Colombo has 36 identical classrooms with the class size of 40 students.

Classroom indoor dimensions: l = 10 m, w = 8 m, h = 4.5 m
Based on data in ASHRAE handbook, the average heat transfer coefficient of the walls and the ceiling were estimated to be $U = 0.13$ kJm^{-2}°C^{-1}min^{-1}

Each classroom has recently installed two on-off type split air-conditioner units of rated (nameplate) cooling capacity of 12000 BTU per hour each. Both air-conditioners were turned on at the same time with 40 students in a classroom and the following readings were recorded.

Indoor temperature (initial), $\theta(0) = 31℃$
Outdoor temperature, $\theta_{outd} = 32℃$
Set temperature, $\theta_r = 20℃$
Final temperature, $\theta(\infty) = 23℃$
Air-conditioner power consumption = 2812 W

Indoor air circulation fan consumes 120 W.

It is found that temperature is usually set at 20℃. School operates in the week days with each day pre-lunch session 08.00—11.00 hrs; lunch 11.00-12.00 hrs; post-lunch 12.00-14.00 hrs. It is 210 days per year on average. All air-conditioners are turned off during the lunch break.
The histogram of temperature distribution in this area in the normal operating time of the day of the school excluding the lunch hours is given in Fig. 1.

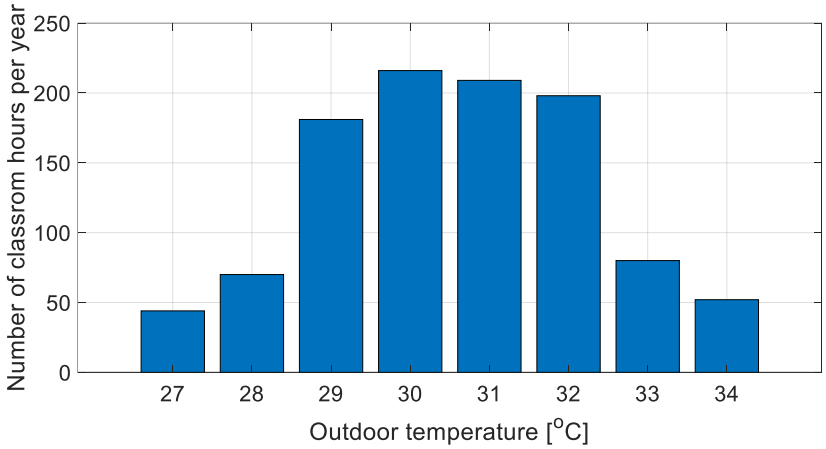

Fig. 1: Temperature distribution histogram

x = [27 28 29 30 31 32 33 34]; y = [44 70 181 216 209 198 80 52]

a) Using a suitable mathematical modeling and simulation study of the system, explain why the air-conditioners worked in the bypass mode under the testing conditions. Estimate the annual energy consumption and the cost of energy (reference: Tariff Plan)
b) Estimate the annual saving if the school implements a policy to make the set temperature exclusively at 26 °C all the time (Hysteresis band width for on-off control, $2\Delta\Theta = 1^{o}C$)
c) Do you recommend inverter type units in place of on-off type for better energy performance? Explain the reasons with the use of the technical background behind your recommendation. Using suitable mathematical formulation, investigate the effectiveness of proportional (PI) and PI control strategies for an inverter-based system
d) Perform computer simulation studies to demonstrate the merits of PI control over P for following scenarios
    i. Set temperature is changed to 25°C while the actual indoor temperature is steady at a higher value and then changed to 26°C ten minutes later
    ii. Outdoor temperature rises steadily from 32°C to 34°C within an hour
e) Redo the energy calculations in b) for inverter type instead of on-off type. Assume inverter type air-conditioner of the same capacity consumes 300-1200 W.

Clearly state the assumptions made.

When completing this work, you should have a number of plots and associating codes. Feel free to add as many if you think it is necessary to clarify your decisions and conclusions. However, plotting the variables on the same graph will facilitate better comparison and save paper.

Do not forget to collate all the MATLAB® codes that you have developed for each part of the simulation into one *m-file* and include this *m-file* at the end of your report in an appendix. The *m-file* should have appropriate comments on the top (the header information) and also additional comments on various lines to make your program easy to follow.

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