CIVL5533
Energy-Efficient Building Systems

ASSIGNMENT 2
(20% of final mark)

Semester 2, 2022
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General information

SUBMISSION DEADLINE

11:59pm on Wednesday 26 October (electronic submission in Canvas)

LATE SUBMISSION

See Unit of Study Outline

SUBMISSION OF FILES

All questions parts specified in this assignment need to be addressed and answered in a pdf file to be uploaded in Canvas, except question part 4 of Question 1 that needs to be answered in a video file.

Based on this, required submission files consist of:

- pdf file for question parts 1.1, 1.2, 1.3, 2.1, 2.2, and 2.3.
- mp4 file for question part 1.4 (with total duration of the video between 3-5 min).
- All files used in the solution process need to be included in the submission

General information (cont'd)

GENERAL COMMENTS

- Make sure to carefully read and answer all question parts of this assignment.
- Make sure to provide a detailed description and explanation of all steps of your thinking process and calculations when answering each question part.
- All answers to questions should be provided in A4 size format and should be uploaded in Canvas as one pdf file.
- If a question does not provide the values of the variables required to calculate the solution, make sure to select appropriate values for these variables based on your engineering judgment. Make sure to point out when such assumptions are introduced.
- Make sure that you highlight any necessary assumption/s introduced in your solution that might be required to perform the calculations.
- In the submission of the assignment make sure to attach all files that you have used in the calculations, e.g. Excel or Matlab files.

General information (cont'd)

SIGN CONVENTION

- Sign conventions should be clearly stated at the beginning of your answers and should be consistent with those recommended in this unit of study or stated in the question.

NOTES

- Updates and support information for this assignment might be provided in separate files that will be available in the 'Assignment 2' section of the Canvas 'Modules' or in the section of assignment 2 in the Canvas 'Assignments' section.

MARK ALLOCATION

- Question 1: 11/20
- Question 2: 9/20

Question 1

Consider a smart building integrated with a photovoltaic (PV) solar panel. The configuration of the PV solar panel is described in Table 1 in the "model data.pdf" file available in your group 'Supporting Files for Assignment 2' Canvas section. The building is equipped with Internet-of-Things and automation facilities so that some equipment in the building can be automatically scheduled and controlled.

Consider a 12-hour scheduling period (from 8am to 8pm) that is divided into 72 time slots. The duration of each time slot is equal to 10 minutes. The time slots can be indexed as t_1, t_2,…,t_{72}.

The solar radiation data over the 72 time slots is provided in a separate excel file (the "RES_data.xlsx" file) that can be downloaded from the 'Assignment 2' Canvas section.

Question 1 (cont'd)

The building is charged by combined energy tariffs: a real-time energy price (RTP) tariff and a demand charge (DC) tariff.

The RTP tariff applies varying energy rates on a hourly basis. The RTP tariff rates are found in Table 2 in the "model data.pdf" file.

In each time slot, only the negative net-energy is charged by the energy tariffs. This implies that if the building's energy consumption of a particular time slot can be fully served by the on-site solar power, the energy cost in that time slot is 0.

Question 1 (cont'd)

In addition to the energy cost charged with the RTP on the negative net-energy, the building can also be charged with the DC tariff due to its peak negative net-power. The charge of the DC tariff is determined based on the difference between the building's peak negative net-power (P') and a threshold value (P^{lim}) with a rate of ρ_{dc} ($/kW):

$$C_{dc} = \begin{cases} \rho_{dc} \times \left(P' - P^{lim}\right) & if\, P' > P^{lim}\text{kW} \\ 0 & if\, P' \leq P^{lim}\text{kW} \end{cases}$$

The building's total energy cost (C) over the 72 time slots (12 hours) is the sum of the costs charged by the RTP (C_{rtp}) and DC (C_{dc}) tariffs:

$$C = C_{rtp} + C_{dc}$$

The values of P^{lim} and ρ_{dc} are provided in Table 3 in the "model data.pdf" file.

Question 1 (cont'd)

Multiple time-shiftable equipments are assumed to be installed in the building. The configuration of the time-shiftable equipments is shown in Table 4 in the "model data.pdf" file.

When there is no scheduling, each equipment operates over a fixed period (the 3rd column in the table). The operation time of each equipment is also schedulable, but the operation can only be scheduled within the allowable operation time range (AOTR).

The building is also subjected to a non-shiftable power demand component. This means that, at a particular time slot, the building's total power demand is the sum of the non-shiftable power demand and the power consumed by the shiftable equipment that are scheduled to operate at that particular time slot. The non-schedulable power demand data is provided in Table 5 in the "model data.pdf" file.

Question 1 (cont'd)

Questions

(1) Determine and plot the solar power output profile over the 12 hours.

(2) Determine the energy cost, net-energy and negative net-energy of the building over the 12 hours in the case without load scheduling.

(3) Consider the case with load scheduling. Use the differential evolution (DE) algorithm to optimize the operation time of the time-shiftable equipment, with the objective of minimizing the total energy cost of the building over the 12 hours.

Modelling:

In the assignment submission:

(i) clearly specify the decision variables (together with their value boundaries and data types), objective function, and constraint(s) of the optimization; and

(ii) clearly describe your constraint handling logic (if applicable).

Question 1 (cont'd)

Computation: The population size (*N*) and maximum generation time (*G*) are taken as 6 and 7, respectively. The parameters *F* and *Cr* and the random numbers used in each generation are provided in the "DE parameters.xlsx" file available in the 'Supporting Files for Assignment 2' Canvas section. For random parameters, please use the data in the worksheets labelled with "Generation" followed by integers.

The updating process of the population and the recorded best individual in each generation need to be clearly provided and described in the assignment submission.

Based on the identified optimal schedules of the time shiftable equipment after all generations, determine the total energy cost and negative net-energy of the buildings with the optimal equipment schedules over the period considered. Compare these results with those obtained in question part (2), and discuss their similarities and differences.

Question 1 (cont'd)

(4) Reconsider the DE-based load scheduling problem. This time revise the AOTR of the equipment and use the same parameters in the "DE parameters.xlsx" file to repeat the computation process. The revised AOTR information can be found in Table 6 in the "model data.pdf" file.

Based on the identified optimal schedules of the time shiftable equipment after all generations, determine the total energy cost and negative net-energy of the buildings with the optimal equipment schedules over the entire period considered with the revised equipment AOTR. Compare these results with those obtained in question parts (2) and (3). Clearly discuss similarities and differences in these results.

The updating process of the population and the recorded best individual in each generation are required to be described and included in the assignment submission.

Question 2

Reconsider the building analysed in Question 1. This time consider the building is equipped with a PV solar panel and a wind turbine. The settings of the solar panel and solar radiation are identical to those of Question 1. The wind speeds over the entire period considered are provided in the "RES_data.xlsx" file. Information on the configuration of the wind turbine is specified in Table 1 in the "model data.pdf" file. The air density (ρ) is set to be 1.3 kg/m^3.

In this question we consider all equipment introduced in Question 1 and we add 1 more power-adjustable equipment called "EQ_new". This equipment' operation time is fixed, but its power consumption can be continuously adjusted within a specific range, as shown in the "Power range" column in Table 7 in the "model data.pdf" file. Its total energy consumption over its operation period MUST be equal to a fixed value (the fixed value is specified in the "Energy consumption" column in Table 7).

Question 2

In addition to the constraints adopted in Question 1, two additional constraints need to be considered to reflect the operational requirements of the equipment. The constraint description is provided in Table 8 in the "model data.pdf" file.

Question 2 (cont'd)

Questions

(1) Determine and plot the wind power output profile over the entire period.

(2) Determine the negative net-energy of the building over the entire period in the case without load scheduling.

(3) Use the differential evolution (DE) algorithm to optimize the operation time of the equipment specified in Question 1 and the power consumption of EQ_new, with the objective of minimizing the total negative net-energy of the building over the entire period. Determine the reduction of negative net-energy of the building obtained in comparison to the optimized results determined in question part (2).

Note: since in this Question the objective function is not the building's energy cost, the energy tariff data in Question 1 does not need to be used.

Question 2 (cont'd)

Modelling: In the assignment submission:

(i) clearly specify the decision variables (together with their value boundaries and data types), objective function, and constraint(s) of the optimization; and

(ii) clearly describe your constraint handling logic.

Computation: The population size (N) and maximum generation time (G) are equal to 6 and 7, respectively. The parameters F, Cr and the random parameters used in each generation are provided in the "DE parameters.xlsx" file. For random parameters, please use the data in the worksheets labelled with "Generation" followed by integers. The updating process of the population and the recorded best individual in each generation are required to be included and discussed in the assignment submission.