

CUMCM-2026 Problem C

Power Regulation Strategies for Microgrid and External Grid

Microgrids are small-scale generation and consumption systems that have developed rapidly to support the local consumption of distributed energy sources, such as photovoltaic (PV) power generation, and to mitigate grid-connection challenges. For economic considerations, non-isolated microgrids can charge their energy storage devices when the electricity price on the external grid is lower or when distributed energy sources generate surplus electricity and discharge the stored electricity when the external grid electricity price is higher.

The objective of regulating microgrid and external grid is to use data, such as the residential load, PV power generation output, and current stored energy of the energy storage device, to provide as precise as possible estimates of the quantity of electricity purchased by the microgrid and the charging-discharging capacity of the energy storage device, thereby ensuring that the electricity supplied by the microgrid can meet the residential load while minimizing the electricity purchase cost.

Problem 1 If the daily electricity price and residential load remain unchanged, the predictions of daily PV power generation are provided. The load of electricity provided by the microgrid cannot be less than the residential load, and the energy storage capacity of the storage device should be the same at 00:00 and 24:00. Please provide the daily planned electricity purchasing strategy at 0:00 every day.

Using the data in Attachment 1 and Appendix 1, please give the detail planned electricity purchasing strategy for the current day at 0:00. In the paper, please provide the electricity purchased quantities (unit: kWh) at specified start time periods, all-day electricity purchase quantity (unit: kWh), and cost (unit: RMB) in the format of Table 1, the charging-discharging capacities (unit: kWh) of the energy storage device during the specified time periods, and the stored energy at 0:00 and 24:00 in the format of Table 2. Save the complete strategy to the file result1.xlsx (the template file is provided in Attachment 5).

Table 1 Quantities of electricity purchased by microgrid at specified time periods and the total quantity and cost of electricity purchased

Time period	Electricity purchase quantity	Time period	Electricity purchase quantity	Time period	Electricity purchase quantity
10:00-10:10		12:00-12:10		14:00-14:10	
16:00-16:10		18:00-18:10		20:00-20:10	
All-day electricity purchase quantity			All-day electricity purchase cost		

Table 2 Charging-discharging capacity of energy storage device during the specified time period, as well as the stored energy at 0:00 and 24:00

Time period	Charging capacity	Discharging capacity	Time period	Charging capacity	Discharging capacity
0:00-4:00			4:00-8:00		
8:00-12:00			12:00-16:00		
16:00-20:00			20:00-24:00		
Stored energy at 0:00			Stored energy at 24:00		

Problem 2 If the daily electricity price is fixed, while the residential load and PV generation vary over time. The load of electricity provided by the microgrid cannot be less than the residential load. If it falls below the load, emergency electricity can be purchased from the external grid, with the electricity price being 5 times the price at the trading time. Except for the cost of emergency electricity purchase, the electricity purchase costs during other periods are calculated based on the planned electricity purchase quantities. Please provide the daily planned electricity purchasing strategy at 0:00 every day.

Using the electricity price in Attachment 1 and the data in Attachment 2, please formulate the daily electricity purchasing strategy at 0:00 every day. In the paper, please provide the results for the specified dates in Table 3 in the format of Tables 1 and 2 and provide the emergency electricity purchase periods and corresponding purchase quantities in the format of Table 3. Save the complete strategy to the file result2.xlsx (the template file is provided in Attachment 5).

Table 3 Emergency electricity purchase periods and corresponding purchase quantities on specified dates

2025.3.20		2025.6.21		2025.9.23		2025.12.21	
Purchase period	Electricity purchase quantity	Purchase period	Electricity purchase quantity	Purchase period	Electricity purchase quantity	Purchase period	Electricity purchase quantity

Problem 3 Hourly predictions of PV power generation for the next 24 hours are available at 0:00, 6:00, 12:00, and 18:00 every day. Based on the prediction at 0:00, a planned electricity purchasing strategy for the current day can be formulated, and an adjusted electricity purchasing strategy can be developed based on the predictions at other prediction times. If the adjusted electricity purchasing quantity is less than the planned quantity, the shortfall should be paid at 50% of the electricity price at the trading time. If the adjusted electricity purchase quantity exceeds the planned quantity, the price for the excess quantity should be 1.5 times the electricity price at the trading time. The total electricity purchase cost comprises the planned electricity purchase cost, emergency electricity purchase cost, and cost associated with the adjusted electricity purchase quantity. Under the above conditions, please establish a mathematical model for the daily electricity purchasing strategy.

Using the data of electricity price in Attachment 1, residential load and actual PV power

generation in Attachment 2, and PV power generation prediction in Attachment 3, please formulate the daily planned electricity purchasing strategy at 0:00 every day and the adjusted electricity purchasing strategies at other forecast times. In the paper, please provide the results for the specified dates in Table 3 in the format of Tables 1–3. Save the complete strategies to the file result3.xlsx (the template file is provided in Attachment 5). Please analyze whether it is necessary to introduce forecasts for other time points to formulate adjusted electricity purchasing strategies.

Problem 4 In practice, the electricity price in the external grid varies in real time. Based on the fluctuating electricity price, please establish a mathematical model for the daily electricity purchasing strategy.

Using the data of residential load and actual PV power generation in Attachment 2, PV power generation prediction in Attachment 3, and electricity price in Attachment 4, please recalculate Problem 2 and Problem 3 under the fluctuating electricity price. Please provide the corresponding results in the paper, and save the complete power regulation strategies in the file result4-2.xlsx (corresponding to Problem 2) and result4-3.xlsx (corresponding to Problem 3) (the template files are provided in Attachment 5).

Appendix 1 Parameters of Energy Storage Device

The energy storage device has a maximum capacity of 12000 kWh and a maximum charging-discharging power of 5000 kW. At the start of operation, the stored energy was 6000 kWh. To prevent overcharging or over-discharging, the stored energy must remain between 1200 and 10800 kWh during subsequent charging and discharging processes. The charging-discharging efficiency of the energy storage device is 90%.

Appendix 2 Description of Attachments

Attachment 1 provides the electricity price (unit: RMB/kWh), residential load (unit: kW), and forecasted PV power generation (unit: kW) at different times for a given day. In the table, "0:00+1" denotes 0:00 on the following day, which corresponds to 24:00 on the current day (the same applies below).

Attachment 2 provides the residential load power (unit: kW) and actual PV power generation (unit: kW) at different times from 2025.1.1 to 2025.12.31.

Attachment 3 provides hourly predictions of PV power generation (unit: kW) for the next 24 hours at 0:00, 6:00, 12:00, and 18:00 every day from 2025.1.1 to 2025.12.31.

Attachment 4 provides fluctuating electricity prices (unit: RMB/kWh) at different times from 2025.1.1 to 2025.12.31.

Attachment 5 is a folder containing the template files for the result files, where

“result1.xlsx” is the template file for the result file of Problem 1.

The sheet “Planned electricity purchase” saves the electricity purchase quantities (unit: kWh) at 10-min intervals from 0:00 to 24:00.

The sheet “Charging-discharging capacity” saves the charging and discharging capacities of the energy storage device (unit: kWh) for the specified time period and the stored energy (unit: kWh) at 0:00 and 24:00.

“result2.xlsx” is the template file for the result file for Problem 2.

The sheet “Planned electricity purchase” saves the planned electricity purchase quantities (unit: kWh) at 10-min intervals from 0:00 to 24:00 each day from 2025.2.1 to 2025.12.31.

The sheet “Charging-discharging capacity” saves the charging and discharging capacity (unit: kWh) of the energy storage device for the corresponding dates and time periods, as well as the stored energy (unit: kWh) at 0:00 and 24:00.

The sheet “Emergency electricity purchase” saves the emergency electricity purchase time periods and quantities (unit: kWh) from 2025.2.1 to 2025.12.31. The filling method is presented in Table 4.

Table 4 Example of filling in emergency electricity purchase

Date	Purchase Period	Electricity purchase quantity
2025/3/1	13:00-13:30	100
	14:40-15:50	400
	16:10-16:30	50

“result3. xlsx” is the template file for the results of Problem 3.

The sheet “Planned electricity purchase” saves the planned electricity purchase quantities (unit: kWh) for each day from 2025.2.1 to 2025.12.31, based on the forecasts at 0:00.

The sheet “Adjusted electricity purchase” saves the adjusted electricity purchase quantities (unit: kWh) based on other predictions.

The sheet “Charging-discharging capacity” saves the charging and discharging capacities (unit: kWh) of the energy storage device for the corresponding dates and time periods, as well as the stored energy (unit: kWh) at 0:00 and 24:00.

The “Emergency electricity purchase” sheet saves the emergency electricity purchase time periods and corresponding purchase quantities (unit: kWh) for the corresponding dates.

“result4-2.xlsx” and “result4-3.xlsx” are the template files of the result files for Problem 4.

All results for Problem 2 under fluctuating electricity prices are saved in “result4-2.xlsx”, and all results for Problem 3 under fluctuating electricity prices are saved in “result4-3.xlsx”.