Notes Week 48

Dependence Diagram:

A dependency graph is a data structure formed by a directed graph that describes the dependency of an entity in the system on the other entities of the same system. The underlying structure of a dependency graph is a directed graph where each node points to the node on which it depends.

In our project we will be looking at the score/reward function variable interdependence.

Episode Based Score/Reward Function

The reward function as given is:

$$Score_{Control} = 0.3 \cdot Score_{Control}^{Comfort} + 0.1 \cdot Score_{Control}^{Emissions} + 0.3 \cdot Score_{Control}^{Grid} + 0.3 \cdot Score_{Cont}^{Resi} \tag{1}$$

where:

$$Score_{Control}^{Comfort} = U, \tag{2}$$

$$Score_{Control}^{Emissions} = G, \tag{3}$$

$$Score_{Control}^{Grid} = \overline{R, L, P_d, P_n}, \tag{4}$$

$$Score_{Control}^{Resilience} = \overline{M, S}, \tag{5}$$

where these 4 scores are made up of 8 key performance indicators (KPIs): carbon emissions (G), discomfort (U), ramping (R), 1 - load factor (L), daily peak (P_d), all-time peak (P_n) 1 - thermal resilience (M), and normalized unserved energy (S).

The grid control and resilience control scores are averages over their KPIs.

The KPIs are calculated as follows:

G: Carbon emissions -> the emissions from imported electricity:

$$G = \sum_{i=0}^{b-1} g^i_{control} \div \sum_{i=0}^{b-1} g^i_{baseline}, \tag{6}$$

where:

$$g = \sum_{t=0}^{n-1} max(0, e_t \cdot B_t), \tag{7}$$

where:
e_t = building level net electricity consumption,
B_t = Emission rate.

U: Unmet hours -> proportion of time steps when a building is occupied and indoor temperature falls outside a comfort band

$$U = \sum_{i=0}^{b-1} u^i_{control} \div b, \tag{8}$$

where:

$$u = a \div o, \tag{9}$$

where:

$$a = \sum_{t=0}^{n-1} \begin{cases} 1, \text{ if } |T_t - T_t^{setpoint}| > T^{band} \text{ and } O_t > 0 \\ 0, \text{ else} \end{cases}, \tag{10}$$

where:

$$o = \sum_{t=0}^{n-1} \begin{cases} 1, \text{ if } O_t > 0 \\ 0, \text{ else} \end{cases}, \tag{11}$$

where:
T_t = Indoor dry-bulb temperature (oC),
$T_t^{setpoint}$ = Indoor dry-bulb temperature setpoint (oC) (Desired temperature for thermal comfort),
T^{band} = Indoor dry-bulb temperature comfort band (±$T^{setpoint}$),
O_t = Occupant count,
b = Total number of buildings.

R: Ramping -> Smoothness of the district's consumption profile where low R means there is gradual increase in consumption even after self-generation is unavailable in the evening and early morning. High R means abrupt change in grid load that may lead to unscheduled strain on grid infrastructure and blackouts caused by supply deficit.

$$R = r_{control} \div r_{baseline}, \tag{12}$$

where:

$$r = \sum_{t=0}^{n-1} |E_t - E_{t-1}|, \tag{13}$$

where:
E = Neighborhood-level net electricity consumption (kWh)

L: 1 - Load factor -> Average ratio of daily average and peak consumption. Load factor is the efficiency of electricity consumption and is bounded between 0 (very inefficient) and 1 (highly efficient) thus, the goal is to maximize the load factor or minimize (1 − load factor).

$$L = l_{control} \div l_{baseline}, \tag{14}$$

where:

$$l = \left(\sum_{d=0}^{n \div h} 1 - \frac{(\sum_{t=d \cdot h}^{d \cdot h + h - 1} E_t) \div h}{max(E_{d \cdot h}, ..., E_{d \cdot h + h - 1})} \right) \div \left(\frac{n}{h} \right), \tag{15}$$

where:
E = Neighborhood-level net electricity consumption
n = Total number of time steps
d = Day
h = Hours per day

P_d: Daily peak -> Average, maximum consumption at any time step per day.

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$$P_d = p_{d_{control}} \div p_{d_{baseline}}, \tag{16}$$

where:

$$p_d = \left(\sum_{d=0}^{n \div h} max(E_{d \cdot h}, ..., E_{d \cdot h + h - 1}) \right) \div \left(\frac{n}{h} \right), \tag{17}$$

where:

E = Neighborhood-level net electricity consumption,
n = Total number of time steps,
d = Day,
h = Hours per day.

P_n : All-time peak -> Maximum consumption at any time step.

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$$P_n = p_{n_{control}} \div p_{n_{baseline}}, \tag{18}$$

where:

$$p_n = max(E_0, ..., E_n), \tag{19}$$

where:
E = Neighborhood-level net electricity consumption,
n = Total number of time steps.

M: 1 - thermal resilience -> Same as unmet hours (thermal comfort) U but only considers time steps when there is power outage.

$$M = \sum_{i=0}^{b-1} m^i_{control} \div b, \tag{20}$$

where:

$$m = a \div o, \tag{21}$$

where:

$$a = \sum_{t=0}^{n-1} \begin{cases} 1, \text{ if } |T_t - T_t^{setpoint}| > T^{band} \text{ and } O_t > 0 \text{ and } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{22}$$

where:

$$a = \sum_{t=0}^{n-1} \begin{cases} 1, \text{ if } O_t > 0 \text{ and } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{23}$$

where:
T_t = Indoor dry-bulb temperature (oC),
$T_t^{setpoint}$ = Indoor dry-bulb temperature setpoint,(oC) (Desired temperature for thermal comfort),
T^{band} = Indoor dry-bulb temperature comfort band (±$T^{setpoint}$),
O_t = Occupant count,
F = Power outage signal (Yes/No),
b = Total number of buildings.

S: Normalized unserved energy -> Proportion of unmet demand due to supply shortage e.g. power outage.

$$S = \sum_{i=0}^{b-1} s_{control}^{i} \div b, \tag{24}$$

where:

$$s = s^{served} \div s^{expected}, \tag{25}$$

where:

$$s^{served} = \sum_{t=0}^{n-1} \begin{cases} q_n^{served}, \text{ if } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{26}$$

$$s^{expected} = \sum_{t=0}^{n-1} \begin{cases} q_n^{expected}, \text{ if } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{27}$$

where:
q = Building-level cooling, domestic hot water and non-shiftable load energy demand (kWh),
n = Total number of time steps,
b = Total number of buildings.

Step-Reward Conversion

We convert the cummulative episode-wise score function to a step-wise reward function.

The reward function as given is:

$$Score_{Control} = 0.3 \cdot Score_{Control}^{Comfort} + 0.1 \cdot Score_{Control}^{Emissions} + 0.3 \cdot Score_{Control}^{Grid} + 0.3 \cdot Score_{Cont}^{Resi} \tag{28}$$

We convert it to:

$$Reward_t = 0.3 \cdot Comfort_t + 0.1 \cdot Emissions_t + 0.3 \cdot Grid_t + 0.3 \cdot Resilience_t \tag{29}$$

where:

$$Comfort_t = U_t, \tag{30}$$

$$Emissions_t = G_t, \tag{31}$$

$$Grid_t = \overline{R_t, L_t, Pd_t, Pn_t}, \tag{32}$$

$$Resilience_t = \overline{M_t, S_t}, \tag{33}$$

where these 4 reward components are made up of 8 key performance indicators (KPIs): carbon emissions (G), discomfort (U), ramping (R), 1 - load factor (L), daily peak (Pd), all-time peak (Pn) 1 - thermal resilience (M), and normalized unserved energy (S).

The grid and resilience reward components are averages over their KPIs.

The KPIs are calculated as follows:

G: Carbon emissions -> the emissions from imported electricity:

$$G_t = \sum_{i=0}^{b-1} g_t^i \div \sum_{i=0}^{b-1} g_{baseline_t}^i, \tag{34}$$

where:

$$g_t = max(0, e_t \cdot B_t), \tag{35}$$

where:
e_t = building level net electricity consumption,
B_t = Emission rate.

U: Unmet hours -> proportion of time steps when a building is occupied and indoor temperature falls outside a comfort band

$$U_t = \left(\sum_{i=0}^{b-1} u_t^i \right) \div b, \tag{36}$$

where:

$$u_t = a_t \div o_t, \tag{37}$$

where:

$$a_t = \begin{cases} 1, \text{ if } |T_t - T_t^{setpoint}| > T^{band} \text{ and } O_t > 0 \\ 0, \text{ else} \end{cases}, \tag{38}$$

where:

$$o_t = \begin{cases} 1, \text{ if } O_t > 0 \\ 0, \text{ else} \end{cases}, \tag{39}$$

where:
T_t = Indoor dry-bulb temperature (oC),
$T_t^{setpoint}$ = Indoor dry-bulb temperature setpoint (oC) (Desired temperature for thermal comfort),
T^{band} = Indoor dry-bulb temperature comfort band ($\pm T^{setpoint}$),
O_t = Occupant count,
b = Total number of buildings.

R: Ramping -> Smoothness of the district's consumption profile where low R means there is gradual increase in consumption even after self-generation is unavailable in the evening and early morning. High R means abrupt change in grid load that may lead to unscheduled strain on grid infrastructure and blackouts caused by supply deficit.

$$R = r_t \div r_t^{baseline}, \tag{40}$$

where:

$$r_t = |E_t - E_{t-1}|, \tag{41}$$

where:
E = Neighborhood-level net electricity consumption (kWh)

L: 1 - Load factor -> Average ratio of daily average and peak consumption. Load factor is the efficiency of electricity consumption and is bounded between 0 (very inefficient) and 1 (highly efficient) thus, the goal is to maximize the load factor or minimize (1 − load factor).
-> Ratio of daily average and peak consumption. Load factor is the efficiency of electricity consumption and is bounded between 0 (very inefficient) and 1 (highly efficient) thus, the goal is to maximize the load factor or minimize (1 − load factor).

$$L = l_t \div l_t^{baseline}, \tag{42}$$

where **DUBBLE CHECK**:

$$l = \left(\sum_{d=0}^{n \div h} 1 - \frac{(\sum_{t=d \cdot h}^{d \cdot h + h - 1} E_t) \div h}{max(E_{d \cdot h}, ..., E_{d \cdot h + h - 1})} \right) \div \left(\frac{n}{h} \right), \tag{43}$$

TO ->

$$l_t = 1 - \frac{(\sum_{i=t-h}^{t} E_i) \div h}{max(E_{t-h}, E_{t-h+1} ..., E_t)} \tag{44}$$

where:
E = Neighborhood-level net electricity consumption
n = Total number of time steps
d = Day
h = Hours per day
t = Current time step

Pd: Daily peak -> maximum consumption at any time step of this day.

$$Pd = pd_t \div pd_t^{baseline}, \tag{45}$$

where **DOUBLE CHECK:**:

$$p_d = \left(\sum_{d=0}^{n \div h} max(E_{d \cdot h}, ..., E_{d \cdot h+h-1}) \right) \div \left(\frac{n}{h} \right), \tag{46}$$

TO ->

$$pd_t = max(E_{t-h}, E_{t-h+1}..., E_t), \tag{47}$$

where:
E = Neighborhood-level net electricity consumption,
n = Total number of time steps,
d = Day,
h = Hours per day.
t = Current timestep

P_n : All-time peak -> Maximum consumption at any time step.

How will this be incoorporated step-wise?

$$Pn = p_n \div p_n^{baseline}, \tag{48}$$

To?:

-> Current consumption

$$P_t = p_t \div p_t^{baseline}, \tag{49}$$

$$P_t = E_t, \tag{50}$$

where:
E = Neighborhood-level net electricity consumption,

n = Total number of time steps.
t = Current time step

M: 1 - thermal resilience -> Same as unmet hours (thermal comfort) U but only considers time steps when there is power outage.

$$M_t = \left(\sum_{i=0}^{b-1} m_t^i\right) \div b, \tag{51}$$

where:

$$m_t = a_t \div o_t, \tag{52}$$

where:

$$a_t = \begin{cases} 1, \text{ if } |T_t - T_t^{setpoint}| > T^{band} \text{ and } O_t > 0 \text{ and } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{53}$$

where:

$$o_t = \begin{cases} 1, \text{ if } O_t > 0 \text{ and } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{54}$$

where:
T_t = Indoor dry-bulb temperature (oC),
$T_t^{setpoint}$ = Indoor dry-bulb temperature setpoint,(oC) (Desired temperature for thermal comfort),
T^{band} = Indoor dry-bulb temperature comfort band ($\pm T^{setpoint}$),
O_t = Occupant count,
F = Power outage signal (Yes/No),
b = Total number of buildings.

S: Normalized unserved energy -> Proportion of unmet demand due to supply shortage e.g. power outage.

$$S_t = \left(\sum_{i=0}^{b-1} s_t^i \right) \div b, \tag{55}$$

where:

$$s_t = s_t^{served} \div s_t^{expected}, \tag{56}$$

where:

$$s_t^{served} = \begin{cases} q_t^{served}, \text{ if } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{57}$$

$$s_t^{expected} = \begin{cases} q_t^{expected}, \text{ if } F_t > 0 \\ 0, \text{ else} \end{cases}, \tag{58}$$

where:

F = Power outage signal (Yes/No),

q = Building-level cooling, domestic hot water and non-shiftable load energy demand (kWh),

n = Total number of time steps,

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