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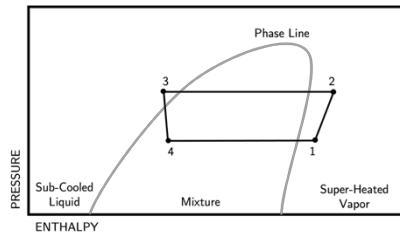
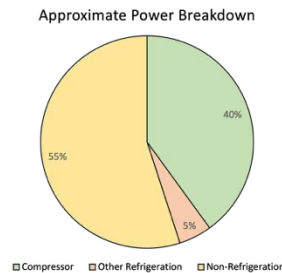
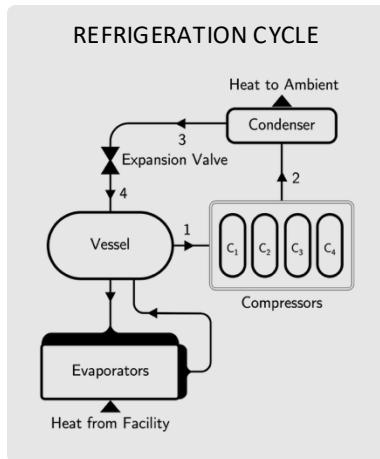
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INTRODUCTION

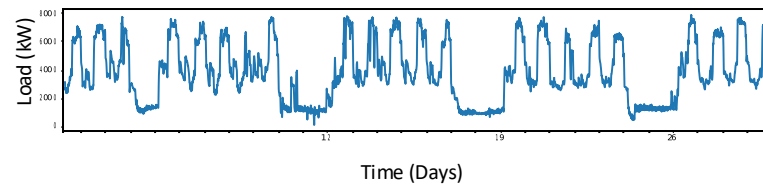
- Industrial refrigeration accounts for more than 8% of total energy usage in the U.S.
- They are prevalent in food processing, plastics, electronics, chemical processing, etc.
- Legacy control techniques are usually implemented: physical operation, manual PID tuning, inherited setpoints



Given knowledge of incoming heat, what is the optimal sequencing policy for the compressors to minimize energy usage?

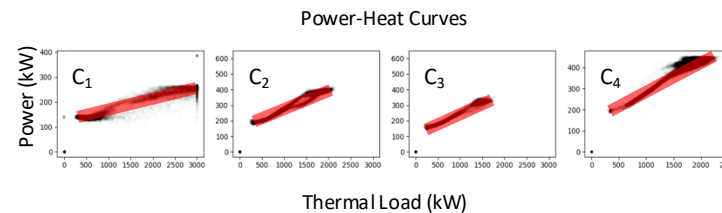
MODEL

Incoming heat : $\{q_{in}^t \in \mathbb{R}^+\}_{1 \leq t \leq T}$

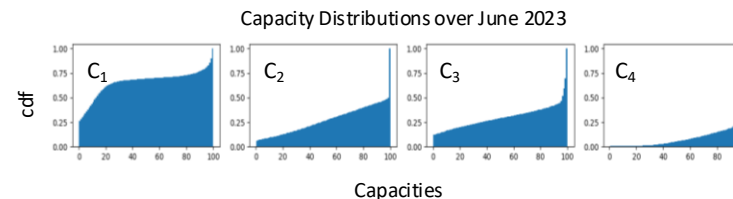


Compressors: $\mathcal{C} = \{c_1, c_2, c_3, \dots\}$

Power-Heat Curves: $P_c : Q_c \rightarrow \mathbb{R}^+, Q_c \in 0 \cup [q^-, q^+]$
(affine)



Not optimal to operate in partial capacity – is this being currently done?



Opportunities for Compressor Sequencing!

OPTIMIZATION & RESULTS

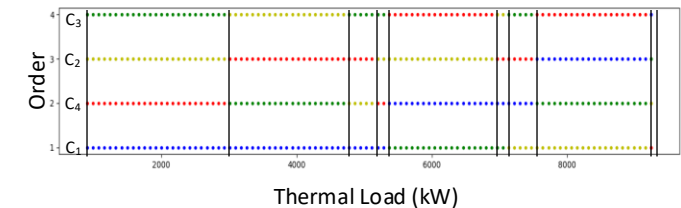
Static sequencing problem

$$J^*(q^{in}) = \min_{q_c \in Q_c} \sum_{c \in \mathcal{C}} P_c(q_c)$$

$$\text{s.t. } \sum_{c \in \mathcal{C}} q_c \geq q^{in}$$

Optimal Solution is achievable with water filling algorithm with **correct** sequence!

Optimal Compressor Sequence for Thermal Load



Dynamic sequencing problem

$$J^*(q^{in}) = \min_{q^{sh}, \{q_c\}} \frac{1}{T} \sum_{k=0}^T \sum_{c \in \mathcal{C}} P_c(q_c(k))$$

$$\text{s.t. } q_c(k) \in Q_c \text{ for all } c \in \mathcal{C}, k \in [0, T],$$

$$\sum_{k=0}^{\tau} q^{sh}(k) \geq \sum_{k=0}^{\tau} q^{in}(k) \text{ for all } \tau \in [0, T],$$

$$\sum_{c \in \mathcal{C}} q_c(k) \geq q^{sh}(k) \text{ for all } k \in [0, T].$$

Water filling with fixed order!

Methodology	Average Power
Worst Fixed Order	856.7 kW
Best Fixed Order	562.3 kW
Compressor Sequencing (C.S)	551.0 kW
Online C.S with Load Shifting	444.3 kW
C.S with Load Shifting	443.5 kW

Load Shifting helps significantly!