Manufacturing Scheduling for Electricity Cost and Peak Demand Reduction in a Smart Grid Scenario

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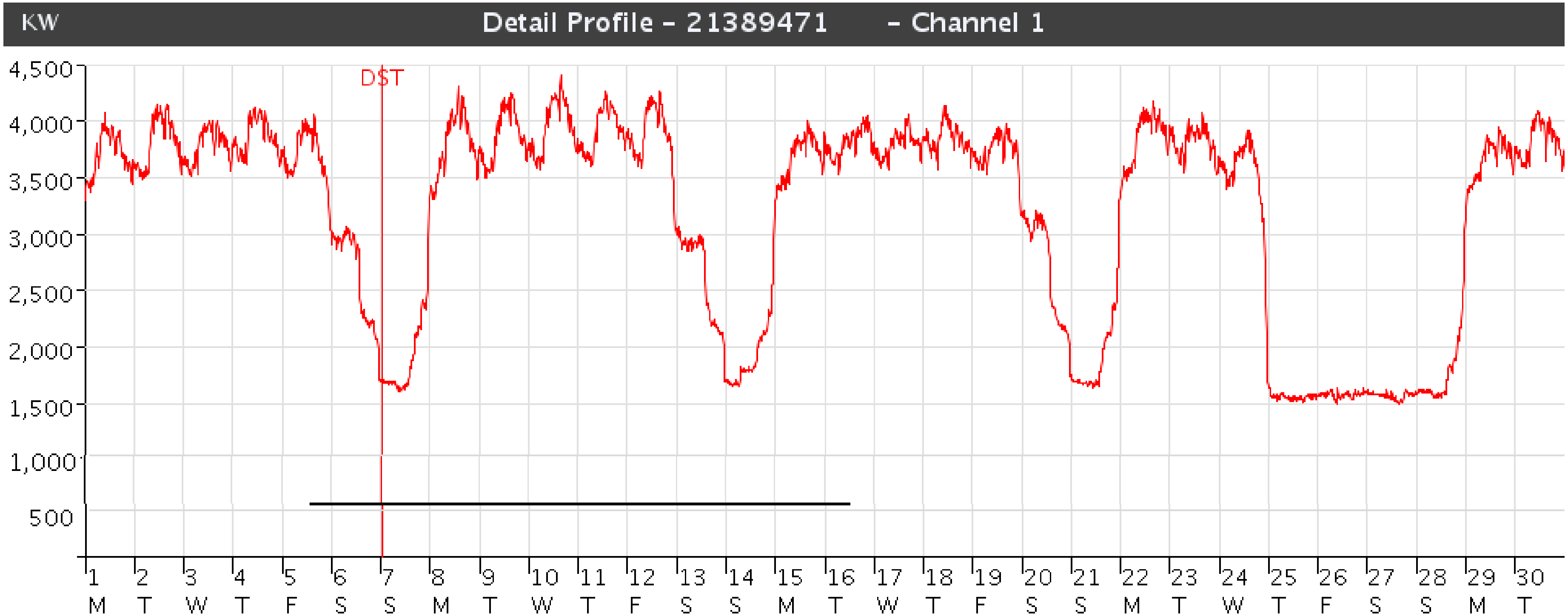

	Industrial Rate Structure		I2 Rate Structure	
Demand Charge	$ 9.00	per kW	$ 17.20	per kW
Electricity Consumption Charge	$ 0.06175	per kWh	$ 0.0384	per kWh
Power Tracker Charge	$ 0.0009	per kWh	$ 0.0009	per kWh

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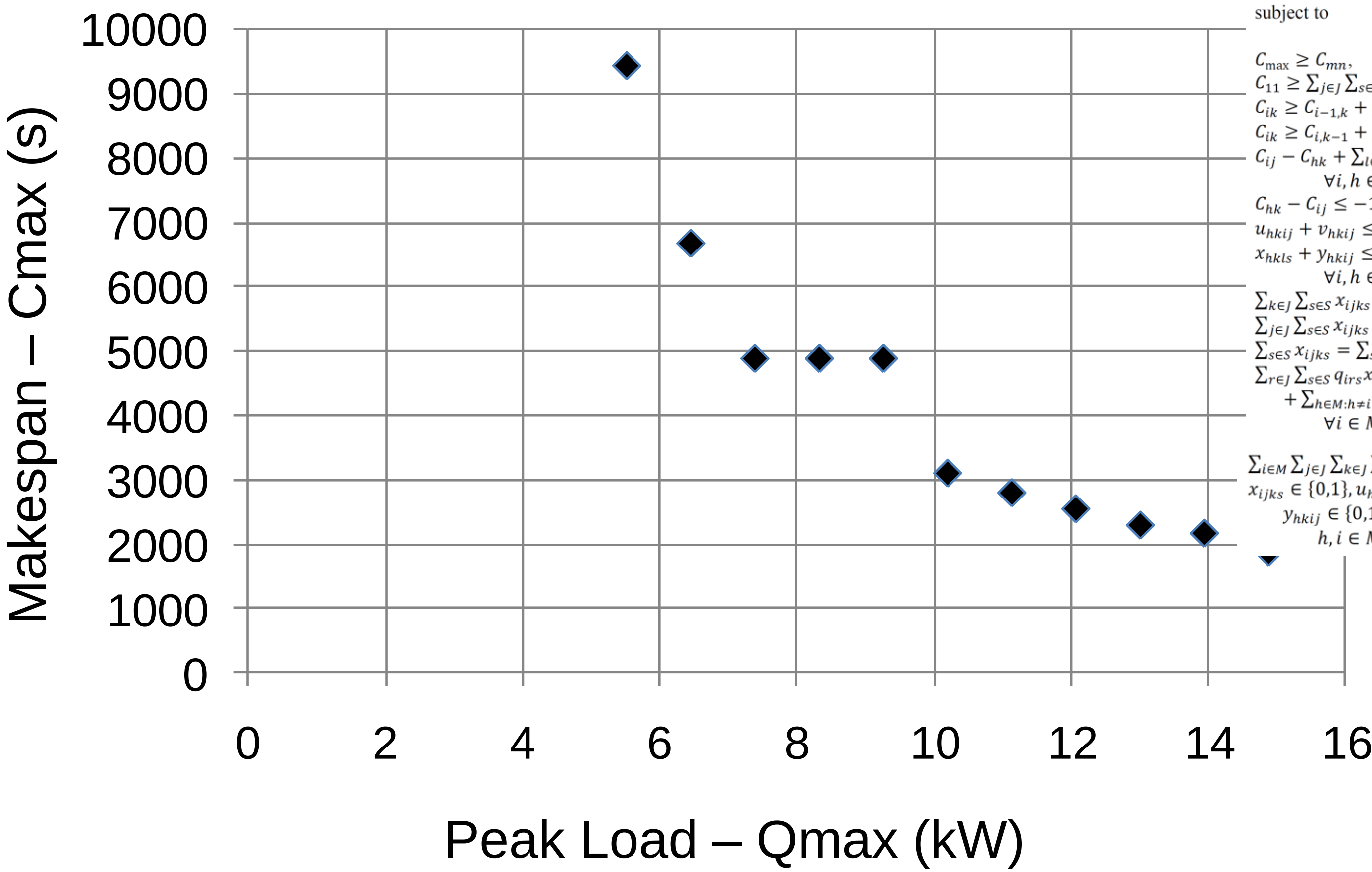
Flow shop scheduling-2 machine case



$$\text{minimize } C_{\max}$$
$$\text{minimize } P_{\max}$$
$$\text{minimize } G_{\max}$$

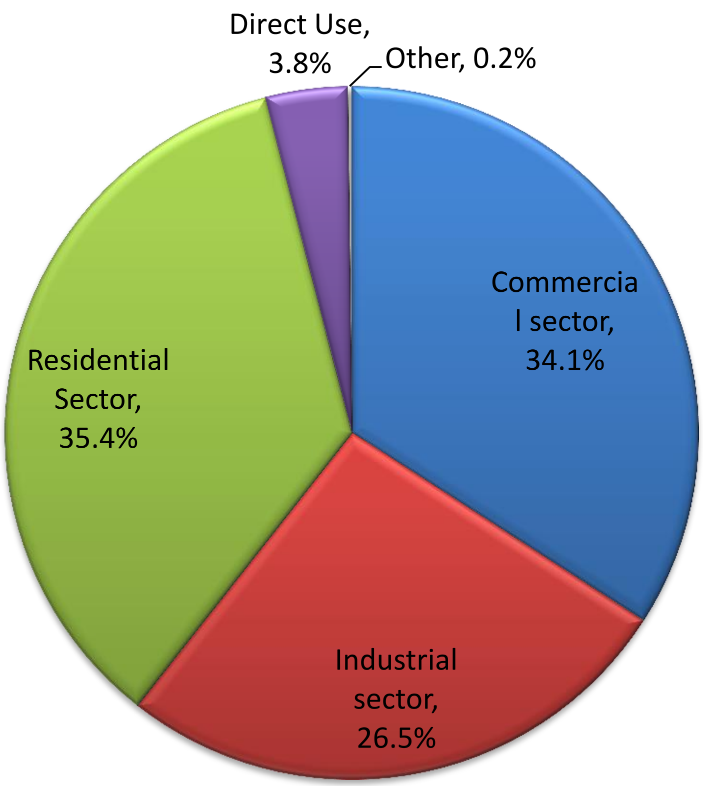
subject to

$$C_{\max} \geq C_{mn}, \quad (1)$$
$$C_{11} \geq \sum_{j\in J}\sum_{s\in S} p_{1js}x_{1jks} \;\; \forall j \in J, \quad (2)$$
$$C_{ik} \geq C_{i-1,k} + \sum_{j\in J}\sum_{s\in S} p_{ijs}x_{ijks} \;\; \forall i \in M \setminus \{1\}; k \in J, \quad (3)$$
$$C_{ik} \geq C_{i,k-1} + \sum_{j\in J}\sum_{s\in S} p_{ijs}x_{ijks} \;\; \forall i \in M \setminus \{1\}; k \in J, \quad (4)$$
$$C_{ij} - C_{hk} + \sum_{l\in J}\sum_{s\in S} p_{hls}x_{hkls} \leq K u_{hkij} \;\; \forall i,h \in M;\; j,k \in J, \quad (5)$$
$$C_{hk} - C_{ij} \leq -1 + K v_{hkij} \;\; \forall i,h \in M;\; j,k \in J, \quad (6)$$
$$u_{hkij} + v_{hkij} \leq 1 + y_{hkij} \;\; \forall i,h \in M;\; j,k \in J, \quad (7)$$
$$x_{hkls} + y_{hkij} \leq 1 + z_{hlksij} \;\; \forall i,h \in M;\; j,k,l \in J;\; s \in S, \quad (8)$$
$$\sum_{k\in J}\sum_{s\in S} x_{ijks} = 1 \;\; \forall i \in M; j \in J, \quad (9)$$
$$\sum_{j\in J}\sum_{s\in S} x_{ijks} = 1 \;\; \forall i \in M; k \in J, \quad (10)$$
$$\sum_{s\in S} x_{ijks} = \sum_{s\in S} x_{hjks} \;\; \forall i,h \in M; j,k \in J, \quad (11)$$
$$\sum_{r\in J}\sum_{s\in S} q_{irs}x_{irjs} + \sum_{h\in M: h\neq i}\sum_{l\in J}\sum_{k\in J}\sum_{s\in S} q_{hls}z_{hlksij} \leq P_{\max} \;\; \forall i \in M; j \in J, \quad (12)$$
$$\sum_{i\in M}\sum_{j\in J}\sum_{k\in J}\sum_{s\in S} \varepsilon q_{ijs}\, p_{ijs}x_{ijks} \leq G_{\max}, \quad (13)$$
$$x_{ijks} \in \{0,1\}, u_{hkij} \in \{0,1\}, v_{hkij} \in \{0,1\}, y_{hkij} \in \{0,1\}, z_{hlksij} \in \{0,1\} \;\; h,i \in M; j,l,k \in J; s \in S. \quad (14)$$

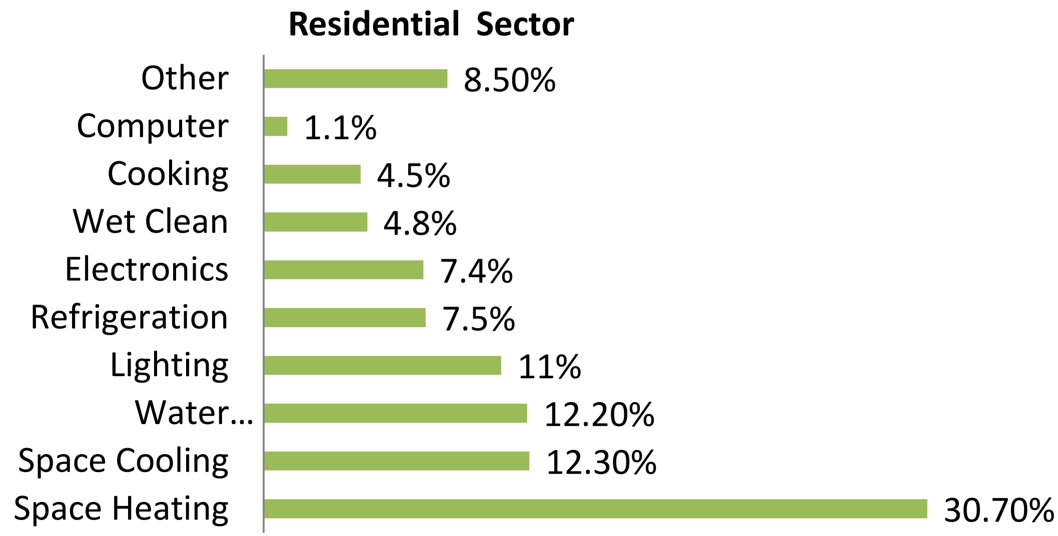
Smart grid brings both challenge and opportunity to manufacturing scheduling

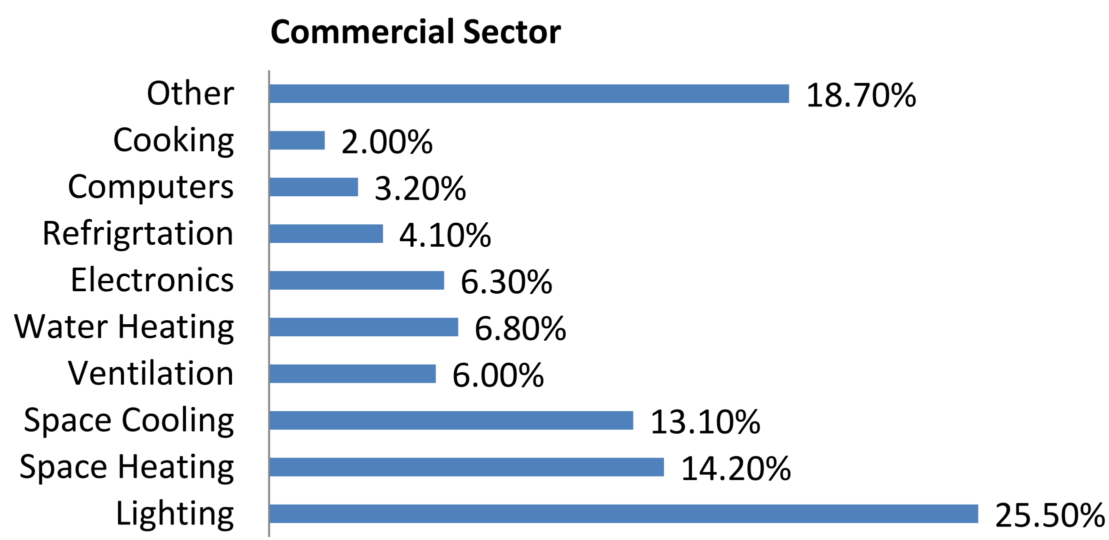
- We are building an integrated model (using GridLAB-D) consisting of residential, commercial, and industrial end users and investigate how manufacturing activities can be scheduled to take advantages of a smart grid.
- The goal is to minimize electricity charge for manufacturing without reducing production, while having manufacturing facilities contribute to the reduction of power grid peak demand.

ELECTRICITY END-USES



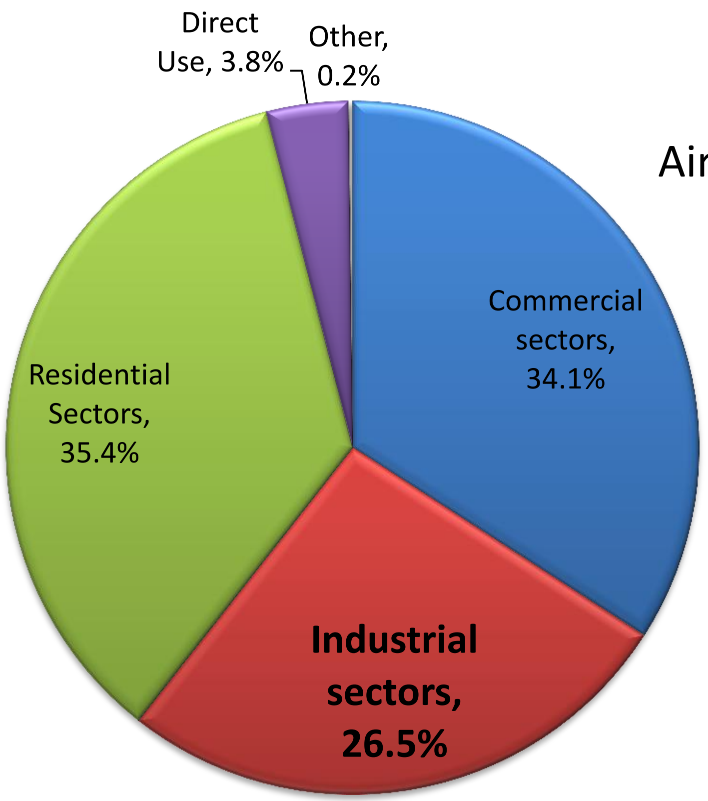
Industrial facilities have very different profile



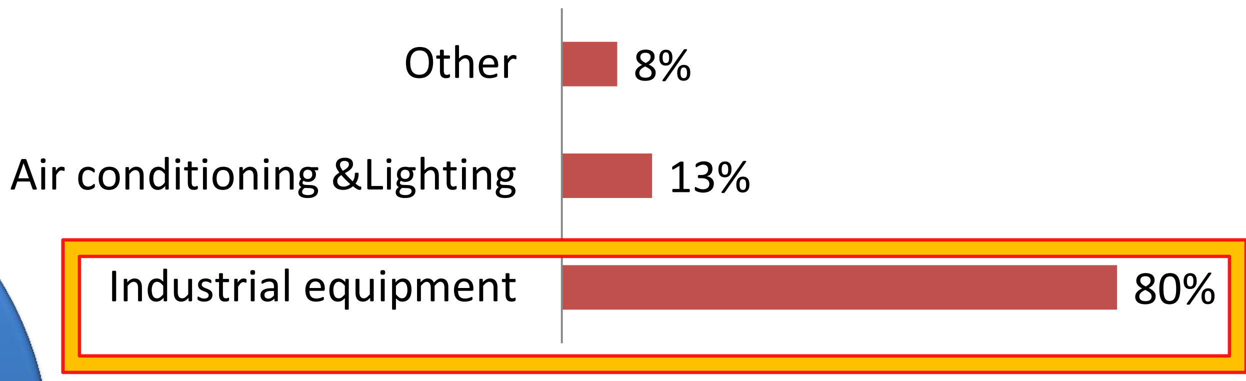


[Source: U.S. Department of Energy]

ELECTRICITY END-USES



Industrial Energy End-Use Splits



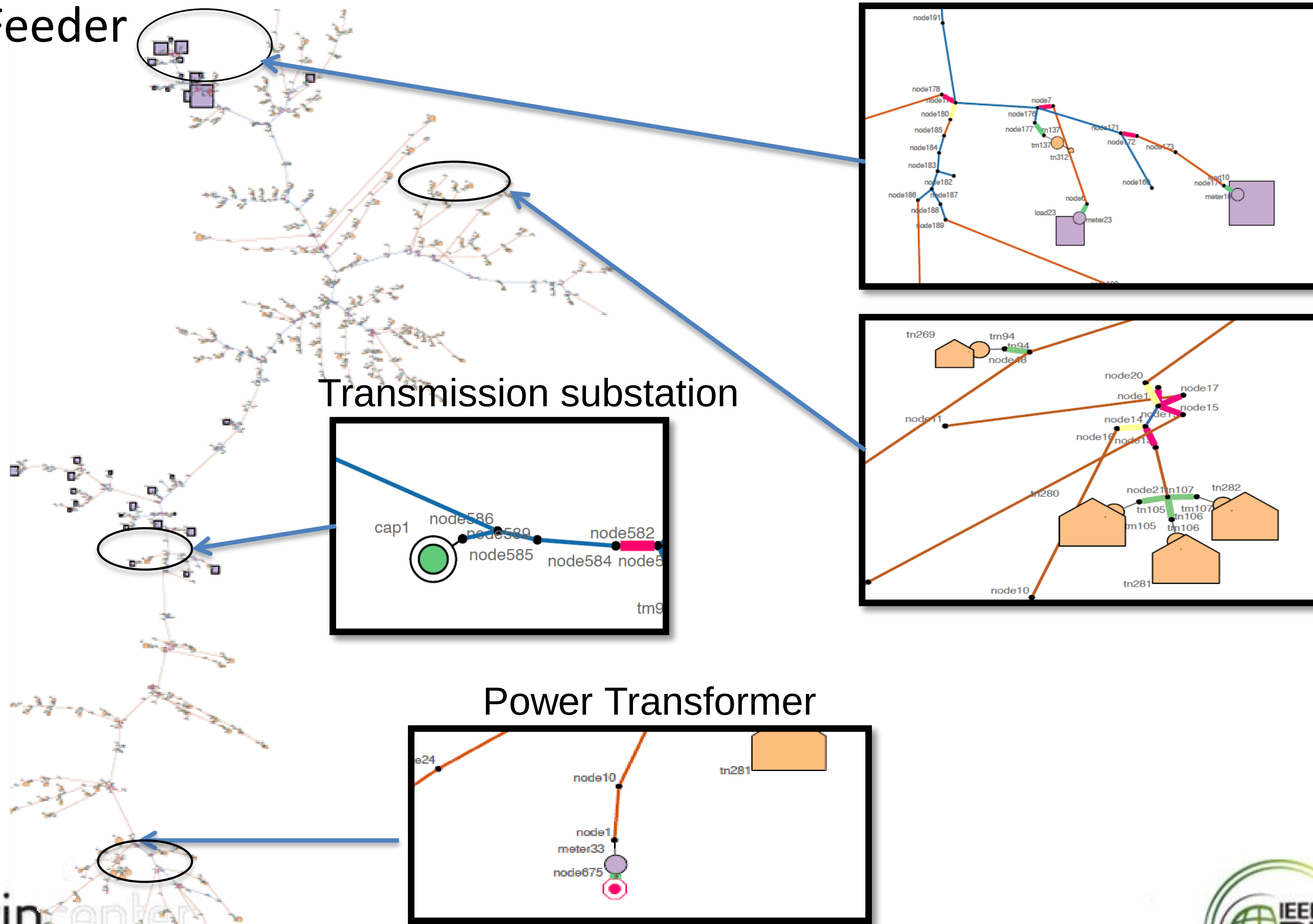
Strategies: Industrial sector can control equipments' idle time with sensor and automatic control technology to reduce energy use.

Challenge: Factories have difficulty in adjusting production schedules without production loss.

[Source: U.S. Department of Energy]

Integrated model

- Feeder



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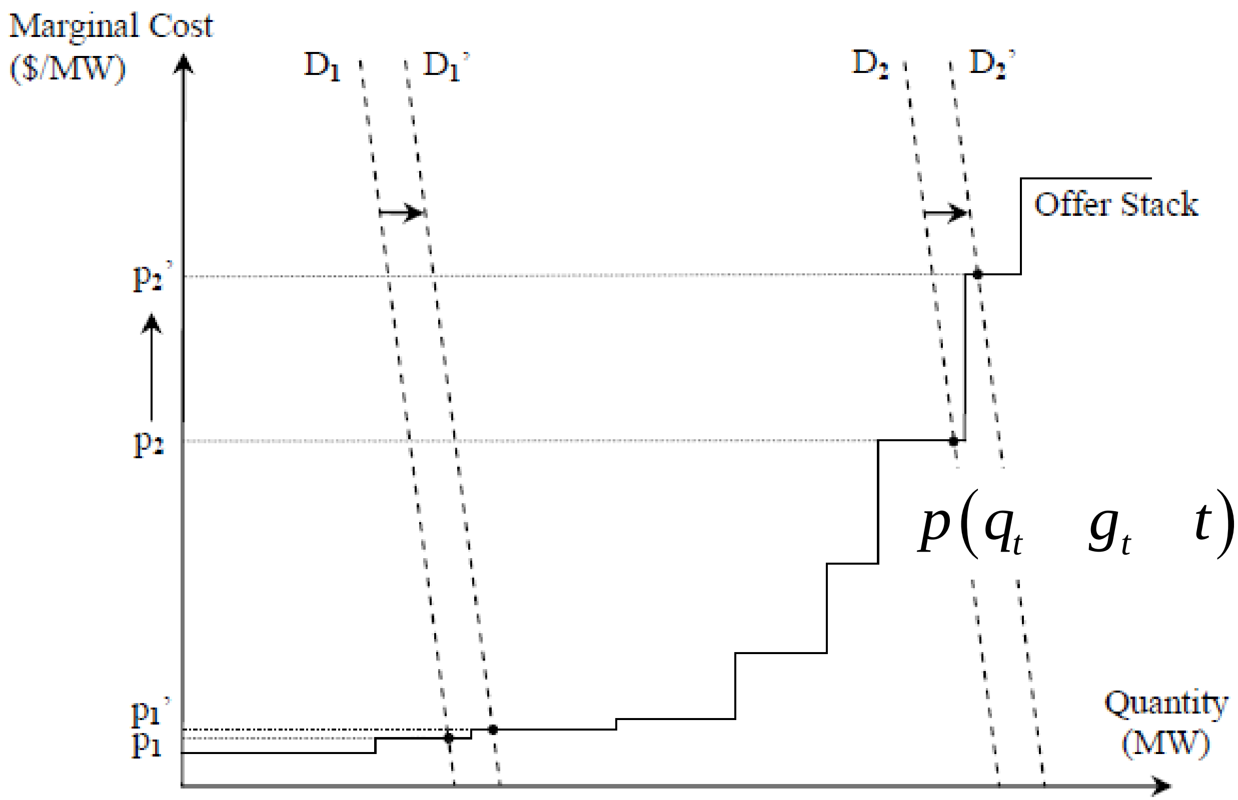

$$p\left(q_t \quad g_t \quad t\right) = g_t^{\gamma} \exp\left[\alpha q_t^2 + c\left(t\right)\right]$$

- The price at time t (P_t) as the product of a function of the marginal generator's fuel price (g_t) and a function of the load (q_t).
- c(t) is a deterministic seasonal function that accounts for seasonality in both demand and supply

$$N_{it} = 0, (t = 1, \ldots, p_i - 1; i \in \mathrm{M})$$

$$N_{it} = \sum_{k=1}^{t-p_i+1} y_{ik}, (t = p_i, \ldots, T, i \in \mathrm{M})$$

Determine the number of products that have finished on machine *i* until time *t*.

$$N_{it} \geq N_{i+1,t} + x_{i+1,t} - x_{it} + \delta_{it}, (i \in \mathrm{M} \setminus \{m\}; t \in \mathrm{T})$$

$$\delta_{it} \leq x_{it}, (i \in \mathrm{M}; t \in \mathrm{T})$$

$$\delta_{it} + x_{it} \leq 1, (i \in \mathrm{M}; t \in \mathrm{T})$$

$$x_{it} - x_{i+1,t} \leq \delta_{it}, (i \in \mathrm{M} \setminus \{m\}; t \in \mathrm{T})$$

Ensure that the products are produced in a flow shop

$$N_{mT} \geq N_0$$

$$N_{it} \in \{0, \ldots, \infty\}, (i \in \mathrm{M}; t \in \mathrm{T})$$

$$x_{it}, y_{it}, \delta_{it} \in \{0,1\}, (i \in \mathrm{M}; t \in \mathrm{T})$$

Ensure that for each job the number produced at the end time T is at least N_{mi}

$$x_{it} = \sum_{k=0}^{t} y_{ik}, (t = 1, \ldots, p_i - 1; i \in \mathrm{M})$$

$$x_{it} = \sum_{k=t-p_i+1}^{t} y_{ik}, (t = p_i, \ldots, T; i \in \mathrm{M})$$

$$\sum_{k=t}^{t-p_i+1} x_{ik} \geq p_i y_{it}, (t = 1, \ldots, T - p_i + 1; i \in \mathrm{M})$$

They ensure that once a job is processed on machine *i*, it could not be interrupted until it is finished

$$f = \min \sum_{t=1}^{24} I_{t,load} * p(q_t \quad g_t \quad t)$$

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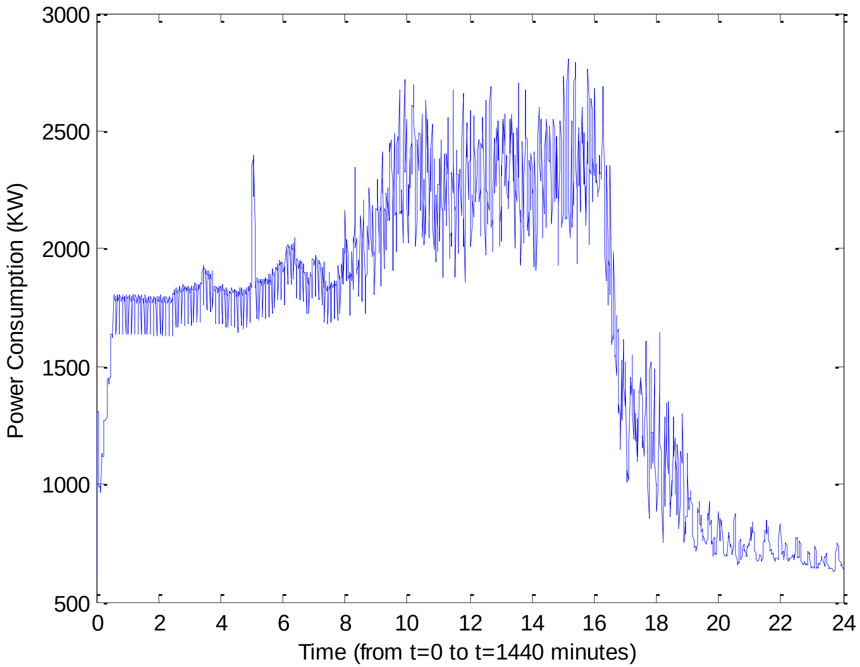
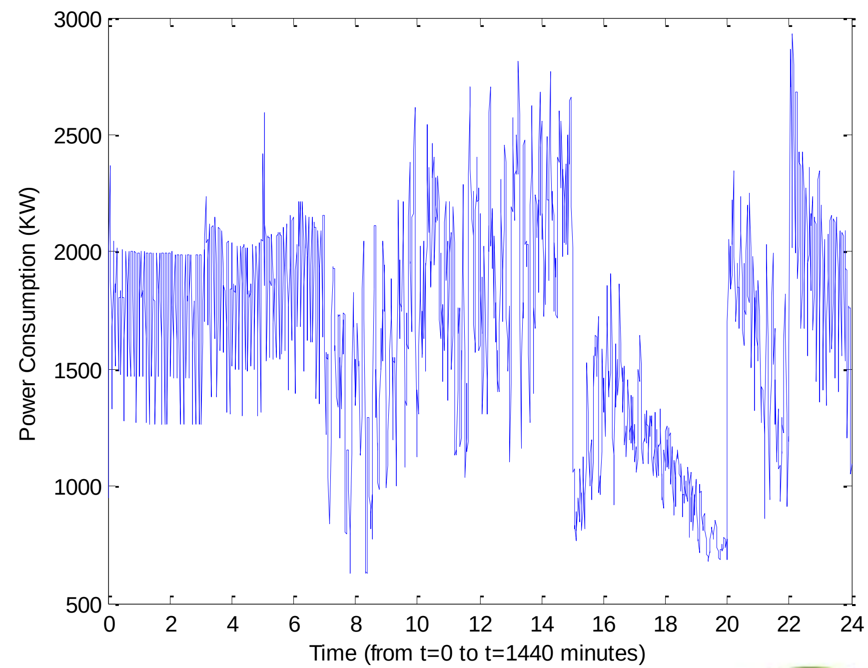
	Processing time (minutes)	Power (kW)
A	4	20
B	5	21
C	6	21
D	4	21
E	5	24
F	4	22
G	6	24
H	4	25



Power profile (Business as usual)

8-machine flow shop w/production quota=162/day



Power profile (w/ new schedule)