

Electrical and Production Load Factors

TJ Sen

Dept. of Mechanical Engineering
Texas A&M Industrial Assessment Center

Introduction

- Industrial Assessment Centers
- Database
- Methodology
- Results
- Discussion

Industrial Assessment Centers

- Department of Energy funded program
- Currently centers at 26 universities
- Perform industrial assessments on small to medium sized manufacturing plants

Plant Qualifications

- Between \$100,000 and \$3 million annual energy costs
- Fewer than 500 employees
- Less than \$100 million in gross annual sales
- No in-house energy expertise

IAC Database

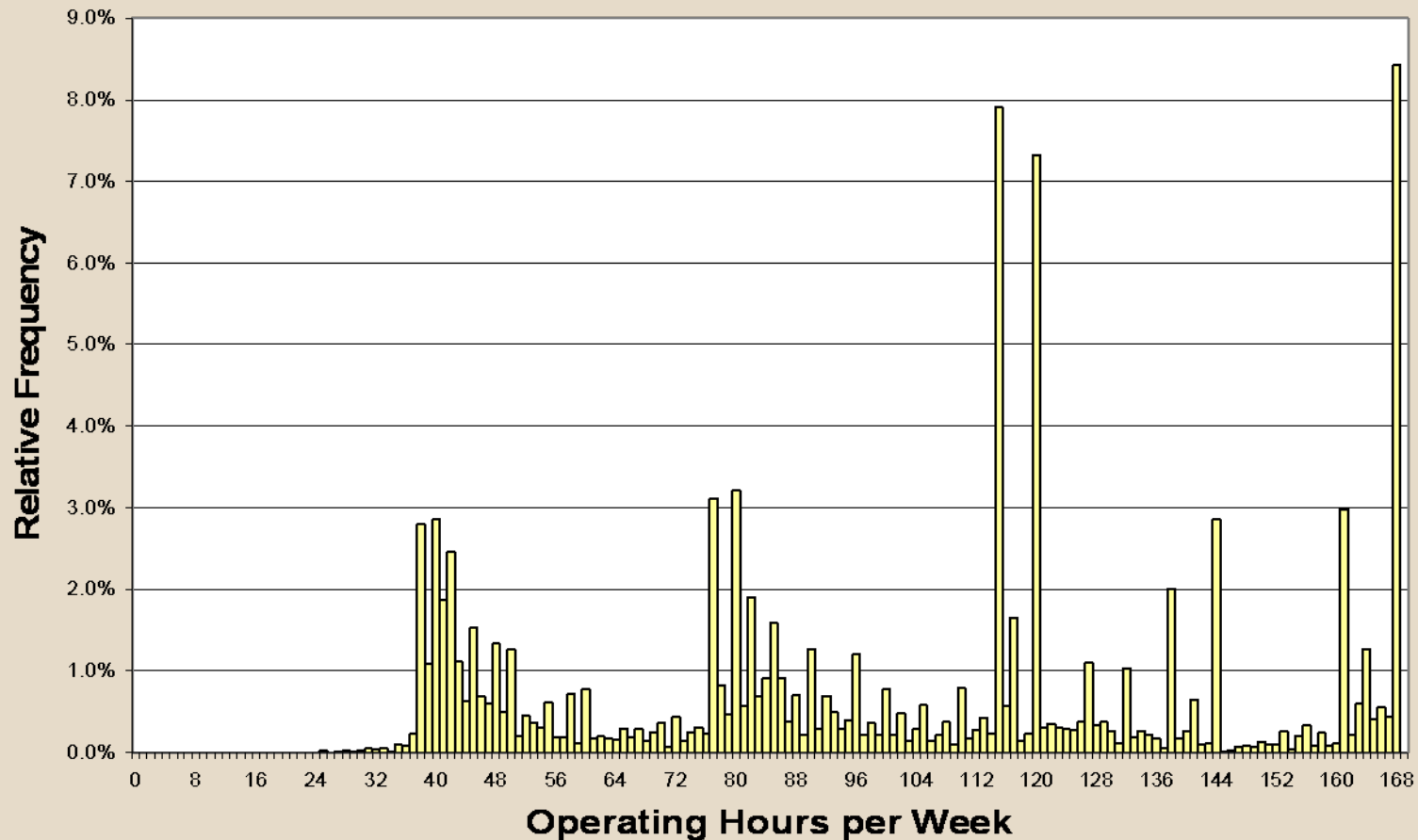
- Maintained by IAC field manager's office at Rutgers University
- Energy data provided by plant personnel
- Information from over 14,000 assessments
 - Almost 105,700 recommendations
 - Plant size and operating hours
 - Annual energy consumption and cost
 - Principal manufacturing products
- On average:
 - Plant size of about 200,000 square feet
 - Gross annual sales of around \$30 million

Background

- Load factors yield the average demand over peak demand for a period of time
- Electrical load factor (ELF)
 - Based on billing period
 - Theoretical maximum value is one
- Production load factor (PLF)
 - Based on operating hours
 - Value over one indicate energy use outside hours
- Both are good diagnostic tools for electrical energy efficiency.

Methodology-Operating hours

- Identify most common ranges of nominal operating hours from the IAC Database



Methodology-Operating hours

- Four prominent nominal values of work-week length identified
- Ranges developed for each nominal work-week length

Operating hours/week			Shift pattern deduction [S=shift, D=days/week]	Relative frequency, %
Nominal work-week length	Lower limit	Upper limit		
40	38	50	1S/5D	19
80	77	100	2S/5D	22
120	115	120	3S/5D or 2S/6D	18
168	161	168	3S/7D	15
			Total	74

Methodology

- Calculate annual electrical load factors (ELF_{an}) and production load factors (PLF_{an})

$$ELF_{an} = \frac{E_{an}}{\frac{D_{an}}{12} \times 8760} \qquad PLF_{an} = \frac{E_{an}}{\frac{D_{an}}{12} \times L_{oh,an}}$$

- 60% of entries in database are neglected
 - Entries in database missing information
 - Theoretically impossible values

Methodology

- Load factors statistically analyzed for each nominal work-week length
 - 95% confidence intervals
 - Standard deviation
 - Upper quartile: Median of upper half
 - Lower quartile: Median of lower half
- One way analysis of variance test (ANOVA) using a 95% level of confidence
- ELF and PLF based on 2 digit SIC codes

Methodology

- SIC codes classification of industry
- Database has data based on SIC from 1981
- Updated by North American Industry Classification System (NAICS) in 2002
- Data analyzed for SIC group 20-39

NAICS Code	SIC Code	Description
-	20	Food and Kindred Products
311	-	Food Manufacturing
312	-	Beverage and Tobacco Product Manufacturing
313	22	Textile Mill Products
315	23	Apparel And Other Finished Fabric Products
321	24	Lumber And Wood Products, Except Furniture
337	25	Furniture And Fixtures
322	26	Paper And Allied Products
323	27	Printing, Publishing, And Allied Industries
325	28	Chemicals And Allied Products
324	29	Petroleum Refining And Related Industries
326	30	Rubber And Miscellaneous Plastics Products
327	32	Stone, Clay, Glass, And Concrete Products
331	33	Primary Metal Industries
332	34	Fabricated Metal Products, Except Machinery And Transportation Equipment
333	35	Industrial And Commercial Machinery And Computer Equipment
-	36	Electronic And Other Electrical Equipment And Components, Except Computer Equipment
334	-	Computer and Electronic Product Manufacturing
335	-	Electrical Equipment, Appliance, and Component Manufacturing
336	37	Transportation Equipment
-	38	Measuring, Analyzing, Controlling Instruments; Photographic, Medical, Optical Goods; Watches
339	39	Miscellaneous Manufacturing
511	-	Publishing Industries (except Internet)

Results

- ELF_{an} based on operating hours

Nominal work-week length, hours	Mean	Q1	Q3	Std. Dev	Theoretical Max.
40	0.36	0.28	0.43	0.130	0.24
80	0.47	0.38	0.55	0.133	0.48
120	0.56	0.48	0.64	0.130	0.72
168	0.70	0.62	0.81	0.147	1.00

Results

- PLF_{an} based on operating hours

Nominal work-week length, hours	Mean	Q1	Q3	Std. Dev	Lower Limit	Upper Limit	$0.75 \leq PLF \leq 1.0$ %
40	1.43	1.08	1.71	0.552	1.38	1.47	13
80	0.95	0.75	1.10	0.341	0.93	0.97	44
120	0.83	0.69	0.92	0.302	0.80	0.85	47
168	0.76	0.63	0.83	0.318	0.73	0.78	45

Results

- ELF_{an} based on 2 digit SIC codes and operating hours

SIC	40 Hours/week		80 Hours/week		120 Hours/week		168 Hours/week	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
20	0.45	0.159	0.54	0.131	0.59	0.122	0.68	0.129
24	0.32	0.104	0.45	0.105	0.52	0.143	0.65	0.176
34	0.34	0.115	0.45	0.121	0.55	0.133	0.66	0.158
35	0.36	0.119	0.47	0.126	0.56	0.121	0.65	0.139

20: Food and kindred products

24: Lumber and wood products

34: Fabricated metal products

35: Industrial, commercial machinery and computer equipment

Results

- PLF_{an} based on 2 digit SIC codes and operating hours

SIC	40 Hours/week		80Hours/week		120Hours/week		168Hours/week	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
20	1.37	0.538	0.87	0.296	0.83	0.225	0.73	0.233
22	1.48	0.575	1.07	0.509	0.88	0.399	0.79	0.205
25	1.38	0.540	0.90	0.285	0.80	0.189	0.71	0.250
35	1.43	0.611	0.96	0.386	0.79	0.229	0.74	0.298

20: Food and kindred products

24: Lumber and wood products

34: Fabricated metal products

35: Industrial, commercial machinery and computer equipment

Discussion

- As expected, ELF values increase with operating hours
- ANOVA test reveal load factors for each shift are significantly different
- Standard deviation is much higher for PLF values than ELF
- PLF values decrease with operating hours

Discussion

- PLF should be invariant with operating hours
- Values are significantly high for single shift operations
- PLF exceeding unity is theoretically indicative of unnecessary energy consumption

Discussion

- Typically, a PLF value between 0.75 and 1.0 is considered good
 - 13% of plants operating at 40 hours/wk
 - 45% of Plants operating between 80 and 168 hrs/wk
- Single shift facilities perhaps present most opportunities for energy conservation
- Such plants are however more likely to have energy usage outside nominal operating hours
 - Energy consumption may take place outside the time of operation of core manufacturing area

Possible sources of Error

- SIC code contains broad ranges of industry
 - Major group 35 range from turbines to office equipment
- Definition of operating hours
 - ELF for lower nominal operating hours greater than maximum
 - High PLF values for single shift facilities
- Discrepancies in energy and demand data
- Seasonal variation in energy use

Questions