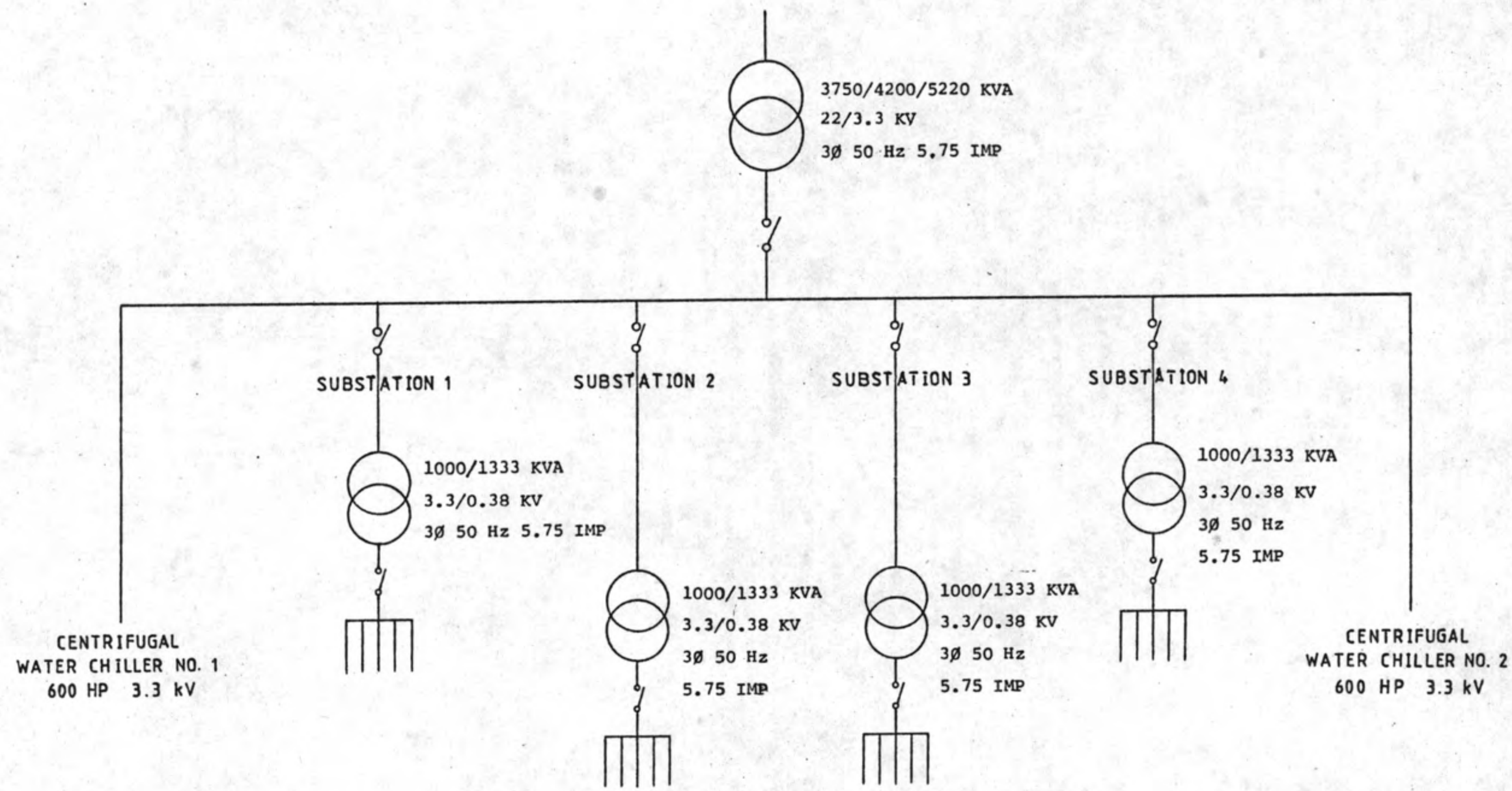
CHAPTER V

AN INVESTIGATION OF THE ELECTRICAL SYSTEM

Introduction

The factory that was studied has been utilizing electricity supplied by the Provincial Electricity Authority (PEA) through its local substation in Samutsakorn provice. The incoming power must be transformed before entering the factory facility system. At the beginning state, electricity of 22.9 kV is adjusted by a 3750 kVA transformer to attain the output of 3.3 kV. After the transformer, this electricity flows separately in 6 directions, to 4 substations in the production plant and to a chiller plant of the utility building. The 3.3 kV electricity at the 4 substations will be further transformed to a level acceptable for electrical equipment and other facilities throughout the factory. Four transformers required at this state are of 1000 kVA. Power output at 380 V from these transformers is consumed by various equipment in each section of the factory. The other two(2) branches of 3.3 kV from the bus bar after the first transformer flow directly to two 600 HP induction motors of the water chiller compressors. A single line diagram illustrating the power distribution is given in Figure 5.1 below. Detailed information of energy consumed by individual equipment is given in Appendix B.

In the following sections, estimated breakdown of the total electrical energy consumption is considered using data gathered during electrical equipment auditing stage. Demand and lightings controls are



Figur 5.1 Single Line Diagram of Power Distribution

studied to identify energy reduction opportunities. The air conditioning system, a high potential energy-consuming facility is investigated separately in Chapter 6.

Electrical Load Distribution

1. Description of Energy Audit Procedure

The study carried out in this section includes descriptions of the plant energy-using characteristics, identifying energy consuming machinery and processes, measuring or estimating the amounts of energy used and summarizing some information so that it may be used in decision-making as well as in future analysis.

It should always be realized, however, that in performing an energy audit a good measurement is an essential part of the job. The measuring instruments must be reliable and equipped sufficiently. But, it is not an uncommon practice for most industrial plants and organizations to have only one kilowatthour meter installed by the power company for metering the consumption of electricity throughout the organizations. This is true in the factory discussed in this report. Therefore, the energy audit is carried out by measuring, with a clip-on energy meter, the input of individual equipment. Average hours of daily operation for each equipment was then estimated using operation records as well as information suggested by the factory personnel to obtain the amount of energy consumed by the equipment.

For this primary study, errors due to some uncertainties arising in the estimation process unavoidably occurs. However, the results do, to a certain degree, portray the overview of the present energy situation of the factory.

The method employed at this stage is not new. Donald L. Gochenour (12) and William D. Wyant of West Virginia University and Bradley N. Windon of the Stering Faucet Co. performed an energy audit in the Stering Faucet Co. in 1981 using this estimation procedure. Gordon A. Payne (2) stated that in the initial stages of a programme, even approximate values are often useful.

2. Estimated Breakdown of Electricity Consumption

2.1 Electric Energy Usage-by Operation Areas

Based on the results obtained from equipment audit (see Appendix B) and those from lighting audit, electrical energy usage by each main functional areas may be secured. The necessary computations are summarized in Table 5.1 in which a ranking of the areas by electricity usage is accomplished. It is clear from Table 5.1 that the majority of electricity is consumed by the spinning and the take up processes, i.e. 34.2 % of the total of 2010 kilowatt. This is a result of both the capacity of the equipment and hours of operation. Office and dormitories are exhibited to be the two least electrical energy consumers in this ranking. Beside departmental comparisons, a column analysis can be done to discover the amount of energy flowing from the 3750 kVA transformer to each of the four substations. The flows of electricity within the factory are shown by a flow diagram in Figure 5.2 using the data in Table 5.1.

2.2 Electric Energy Usage-By Major Equipment

Another way to describe electric energy used is to consider its flow through the various companywide equipment. Some more information than that described in the preceding Section is anticipated.

Table 5.1 Estimated Breakdown of Energy Usage by Operation Areas

From substation / To Department	1	2	3		4	subtotal	% Loading
			TO EQUIPMENT	TO LIGHTING			
Spinning & Take up	198	474	1	14	0	687	34.2
Utility	106	0	0	3	553	662	33.0
Polymerization	270	0	9	10	86	375	18.7
Draw-Twisting	0	0	244	26	0	270	13.4
Office	0	0	0	1	12	13	0.6
Dormitories	0	0	0	3	0	3	0.1
Subtotal	574	474	254	57	651	Grand Total 2010	
%Loading	28.6	23.1	12.6	2.8	32.4		100.0

Remark: All entries, except for those of % Loading, are in kilowatt.

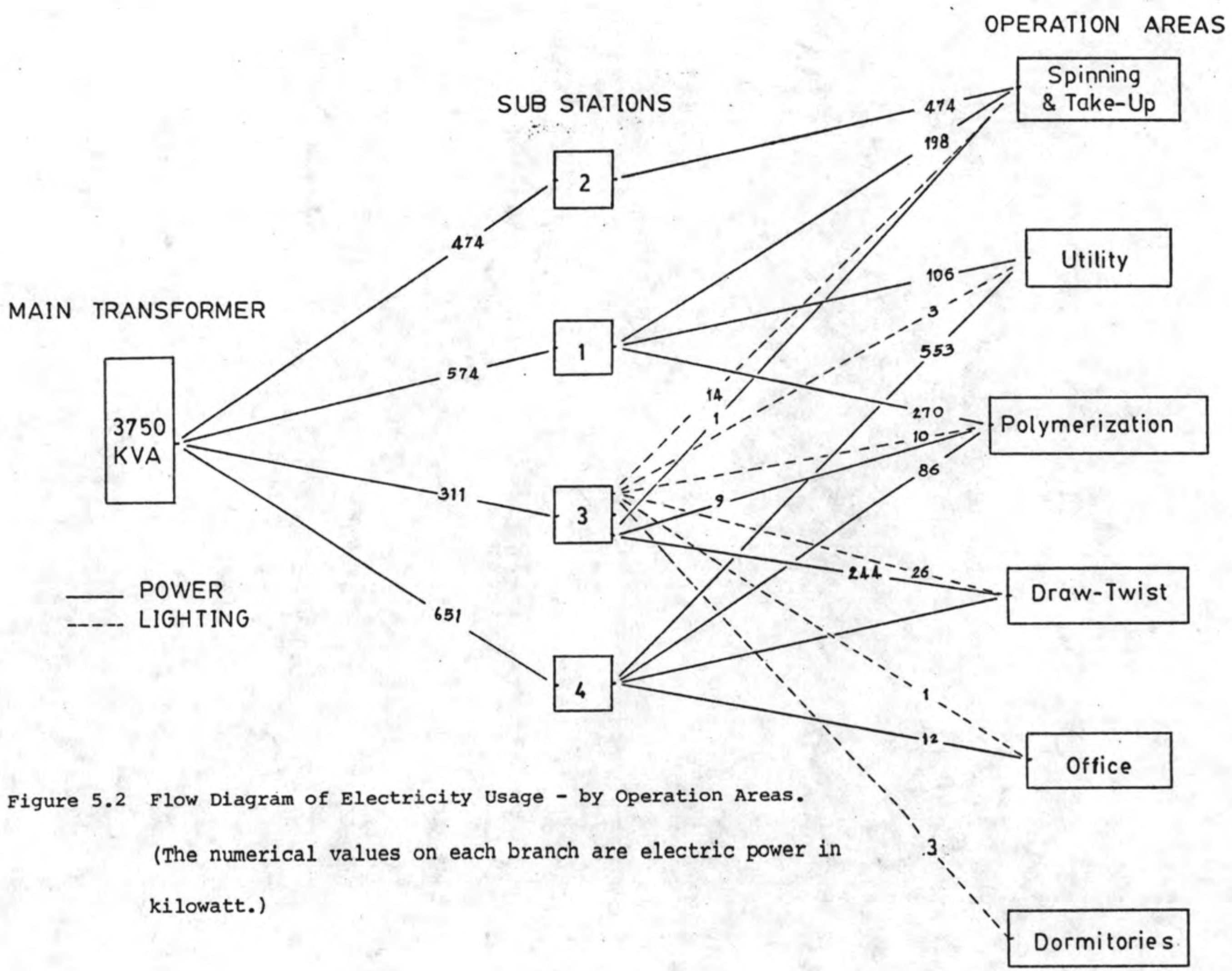


Figure 5.2 Flow Diagram of Electricity Usage - by Operation Areas.

(The numerical values on each branch are electric power in kilowatt.)

Table 5.2 Electric Energy Usage by Major Equipment Groups

Equipment group	AVg. Power kW	Percent loading
1. Production system		
1.1 Motors, pumps, drives, fans and blowers	570	28.4
1.2 Electric heaters	534	26.6
1.3 Others (for delusterant, finishing oil, DM water, lift and burn out furnace)	13	0.6
Subtotal.................................	1117	55.6
2. Air conditioning system		
2.1 Chiller compressors	391	19.5
2.2 Chilled and cooling water pumps	230	11.4
2.3 Cooling tower and ventilation fans	126	6.3
Subtotal.................................	747	37.2
3. Lightings	57	2.8
4. Air compressors	55	2.7
5. Steam production & distribution (fan and pumps)	6	0.3
6. Other supplies and services (deep well pumps and aerator)	28	1.4
Grand total.............................	2010	100.0

Remark: Electric energy data were obtained by energy auditing as given in Appendix B.

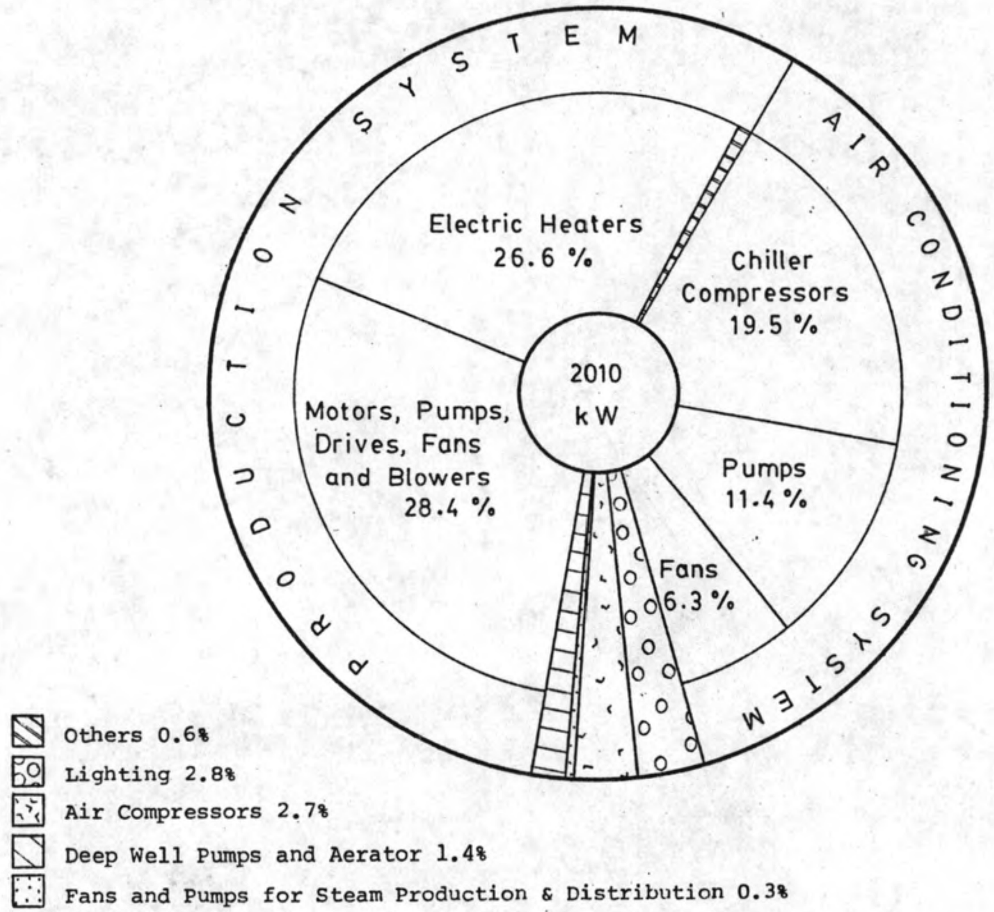


Figure 5.3 Estimated Breakdown of Electrical Energy Use-By Major Equipment

It is obvious that the energy consumed by the factory's equipment falls into two types. The first type, and the most significant, is the electricity supply to the areas which carry out specific processes, i.e. the production system in Table 5.2. This energy consumption is dependent in some way on the throughput of material and is analogous to the direct costs of an accountant. The second type, providing for example air conditioning and lighting, are ancilliary to the main production process. Such consumption is usually independent of the material throughput and is analogous to the accountant's indirect costs.

Using information available in Table 5.2, a Pie Diagram (Figure 5.3) can be constructed to illustrate the relative magnitude of energy consumption among the equipment groups. Production equipment, the largest user of energy for the factory system, prominently occupies more than a half of the circular area, i.e. 55.6 % of the total electrical energy required by the entire system. Before the energy audit, details concerning energy use and costs in the functional areas and manufacturing processes were masked in the aggregated plant-wide figures.

Energy Conservation Opportunities

The system, identified by the relative order of energy usage, by major equipment, will be now considered to institute energy conservation programs. Some of the ideas given in these guidelines can be executed directly by the area occupants, owners, or managers without delay or the need for further advice; while other measures, even though they do not entail significant capital costs, may require further analysis.

In controlling and reducing cost of electricity, attention should be given to three main aspects of utilization:

- Reducing the total amount of electricity used by greater efficiency and the eradication of unneccesary uses.

- Developing a more uniform load, in order to reduce the maximum demand and improve the load factor.

- Examining the application and performance of electric motors and other "reactive" loads in order to improve power factor.

Consider the entire system of the factory, several measures may be established to save money for electricity. Some of the opportunities are given below.

For the production system:

1. Carry out a detailed study of existing process flow patterns. Modify electric heaters to improve effective capacity if possible.

2. Attempts should be concentrated on achieving the optimum condition for all steps throughout the production process in order to avoid over-processing. This measure contributes directly to the quality of the processing material as well as to the reduction of wastes (chips and yarn) found at each stage of the process. These contributions, finally, decrease the specific energy consumption of the finished product.

3. Improvement of load factor. A detailed study will be made later.

4. Establish a maintenance program to maintain the equipment in good working condition. Correct lubrication, aligned bearings and tightened belts of motors, for instance, can reduce frictional loss significantly. (For more details, consults Appendix E.)

5. With an aid of the maintenance program, motors that always show low load factors can be replaced on suitable occasions.

For the air conditioning system, see Chapter 6 for more details.

For the compressed air system:

1. Determine the optimum pressure required for satisfactory operation of all items of equipment. Do not use higher pressure than neccessary.

2. Match compressors to pressure and volume requirements and avoid oversizing.

3. Operate compressors at just below their maximum capacity, but do not overload them.

4. Provide separate compressors or boosters for items of equipment which operate intermittently or which require pressures markedly different from those needed by the main system.

5. Switch compressors off when not in use.

6. Use non-working periods to find and rectify leaks and to clean the system. Do not install further compressors without first thoroughly checking for leaks.

7. Maintain simple records of compressor performance to enable faults to be detected quickly.

8. Site air inlets in cool, dry, clean positions and clean filter regularly. Cool the air between and after compression stages.

9. Keep air distribution lines clean, dry and warm. Avoid any accumulation of water or oil by sloping lines correctly towards accessible drain points.

10. Challenge every use of compressed air, particularly for continuous applications.

For the lighting system, detailed study will be made later.

The equipment which are referred to as the two last group in Table 5.2 i.e. fan, pumps and aerator motor can be operated more efficiently and economically by employing the measures described for those equipment of production system.

Load Factor Improvement

After all unnecessary uses of electricity have been eliminated, the next step is to reduce the peaks and generally the spread demand. Adequate metering and records are essential to establish the load profile and to identify the peaks. Systematic listing of all items of plant and equipment that use electricity will assist the identification of offending items.

For the plant being studied, electricity supplied by the power company must be metered by two instrument, i.e. the watthour meter and the varhour meter to indicate the amount of electrical energy consumed by the whole plant during a specified period. Figure 5.4 shows the picture of these two measuring devices. By this measurement, approximate values for the power factor of the entire factory system, the load for the main transformer, as well as the load curve for electrical energy consumption may be accomplished.

Table 5.3 shows a summary of electric energy consumed by the factory during three random periods, i.e. an 8 office hours of a typical weekday, a 16 non-office hours of a weekend and an 8 consecutive hours of a weekend. Figure 5.5 demonstrates the distribution of electricity consumption using data in Table 5.3. These patterns of energy consumption, together with those available from equipment auditing will be considered in the peak demand control of this section.

The electric energy consuming equipment of the factory may be categorized into 2 major groups, the continuous operation group and the intermittent one. For the study of this section, only the latter is considered. The equipment items, their operation times as well as some remarks on each item are summarized in Table 5.4.

Under the current practices, the peak load may be reached with the highest probability in the daytime operations, especially when the delusterant is taken into operation. The greatest contribution to the peak by the part-time equipment operations, possibly occured in any 15-minute interval, may be calculated to be 686 kilowatt using the data available in Table 5.4.

In order to reduce the peak, this group of equipment must be rescheduled. One of the many possible methods will be now described.

In operating the factory, the 24-hour cycle may be devided into 3 intervals mid-night (12.00 p.m.) to 7.00 a.m., 7.00 a.m. to 5.00 p.m. and 5.00 p.m. to 12.00 p.m. The electrical loads attached to each part of the cycle time for the proposed schedule are shown in Table 5.5.

Figure 5.6 shows a load curve for the proposed scheduling. It should be noted that by the time intervals described above, the burn out furnace, requiring only about 1 hour per day in operation, can be started at either 5.00 a.m. or 4.00 p.m. Moreover, when the evening is free from chemical laboratory overtime operation, such furnace may be run at any time between 4.00 p.m. and mid-night.

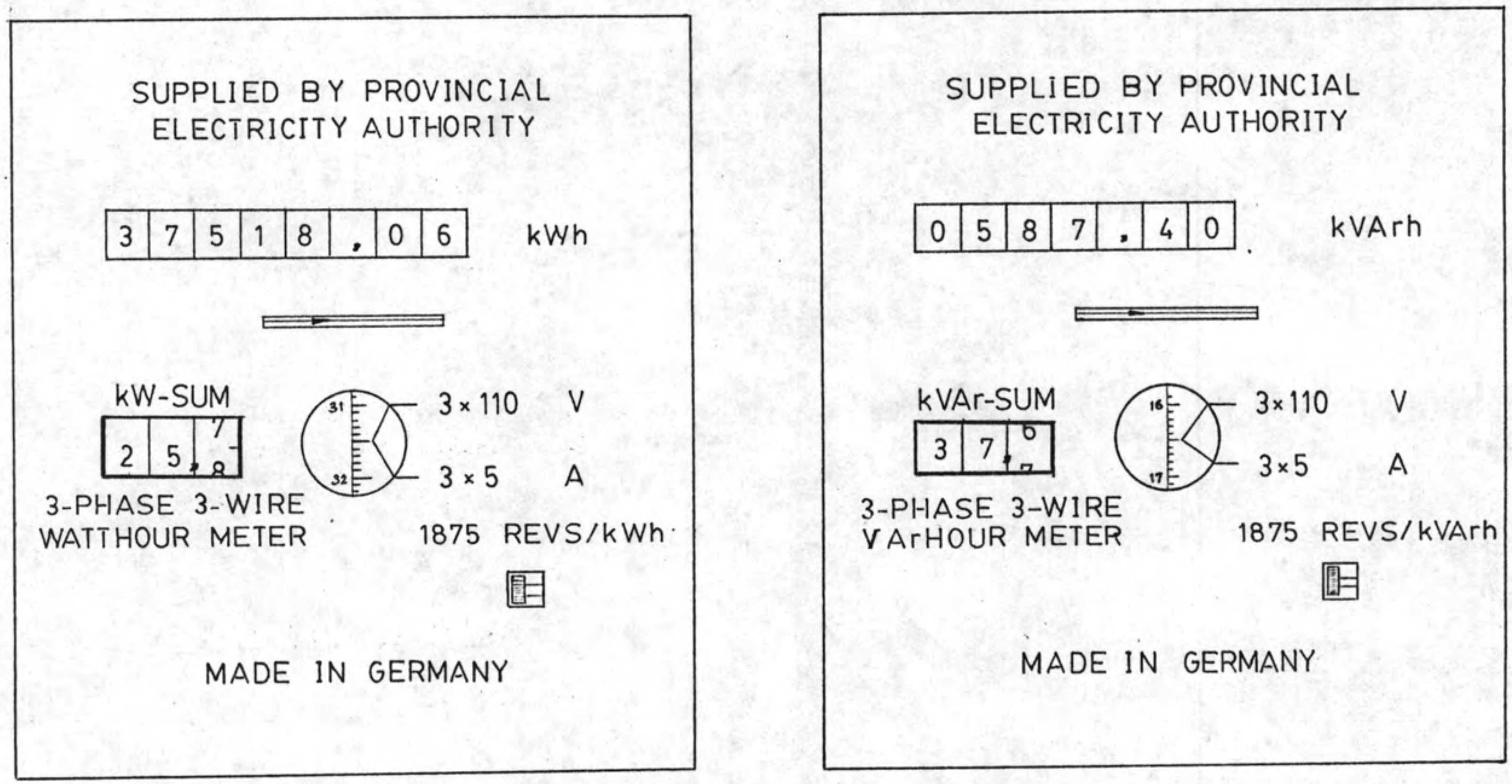


Figure 5.4 The Utility Company Meters for the Factory under Study Showing the Two Meterfaces

ble 5.3 Electricity Consumption for a Typical Office Hours, a Non-Office Hours, and a Weeken Daytime

Time / ate	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8
13/3/86																									
60 kWh		32.5	29.3	30.0	31.1	32.1	29.0	31.0	29.8	31.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60 kVArh		16.4	14.7	14.8	16.0	17.1	15.0	16.0	15.5	16.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23/3/86																									
60 kWh		-	-	-	-	-	-	-	-	-	31.7	30.9	30.9	31.25	31.55	31.8	31.2	30.7	31.0	31.3	30.6	30.3	30.3	30.1	32.5
60 kVArh		-	-	-	-	-	-	-	-	-	16.7	16.0	15.9	16.3	16.7	16.7	16.1	16.2	16.3	16.0	16.2	15.1	15.1	14.6	15.9
30/3/86																									
60 kWh		30.42	30.0	29.7	30.2	29.9	30.7	30.3	30.2	30.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60 kVArh		16.42	16.4	16.8	17.6	17.6	18.0	17.9	17.6	17.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

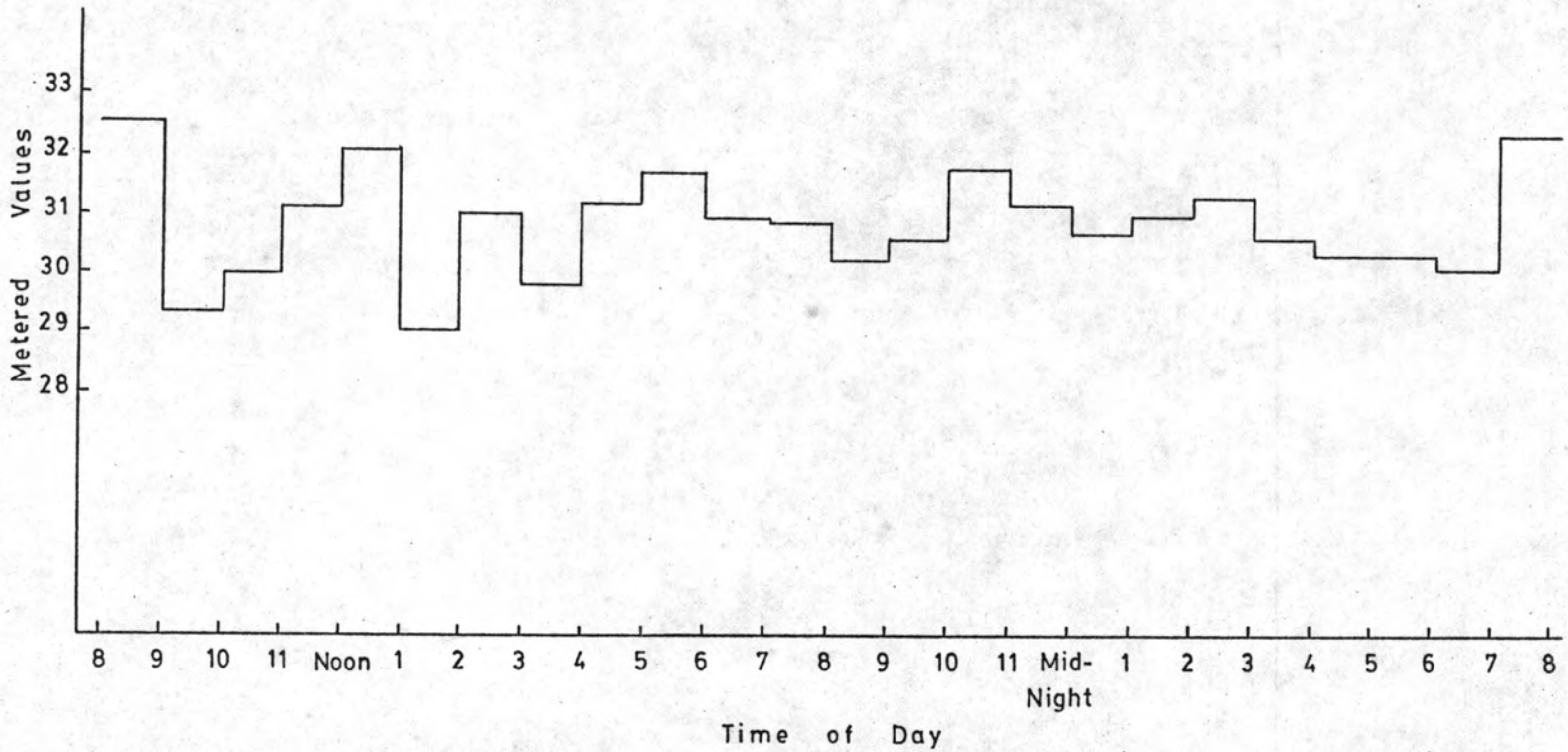


Figure 5.5 Hourly Load Curve of Electricity Consumption for the Entire Plant.

Table 5.4 The Equipment Rearrangeable for the Peak Demand Control

Equipment item	Nameplate Capacity	Department	Operation Time	Remarks
1. Office air conditioning	49 kW	Central office	8.00 a.m. - 5.00 p.m.	
2. Aerator	15 kW	Utility	6.00 a.m. - 7.00 p.m.	
3. Textile lab. equipment	12 kW	Q.C.	7.00 a.m. - 11.00 p.m.	
4. Chemical lab. equipment	36 kW	General service	7.00 a.m. - 4.00 p.m.	with O.T. on some occasions
5. Dry chip transfer blower	30 kW	Production	Do not have a fix. time	1 hr per batch, 4 bathes per day
6. Arc welder	13 kW	General service	Do not have a fix.time	
7. Lift	15 kW	Production	Do not have a fix.time	for raw material handling
8. Burn out furnace	20 kW	Production	Do not have a fix.time	about 1 hr per day
9. Delusterant	36 kW	Production	5 hrs of the daytime	about 4 days per week
10.Draw-twisters (17 machines)	440 kW	Production	Do not have a fix.time	each machine run about 18 hrs per day with 3-4 starts.
11.Back winder	10 kW	Production	Do not have a fix.time	based on the product quality from draw- twisters.
Total	686 kW			

Table 5.5 Proposed Equipment schedule for Load Factor Improvement

Time	Electric Energy Consumers	Nameplate Power Requirement, kW	Remarks
12.00 p.m.	Additional lighting		
To	(at night)	15	
7.00 a.m.	Delusterant	36	
	Blower group	30	
	Draw-twister and back		
	winder	450	all busy machines
			allowed
	Total..............	531	
7.00 a.m	Aerator	15	
To	Office air conditioning	49	
5.00 p.m.	Laboratories	48	
	Blower group	30	
	Draw twisters and back		
	winder	389	15 busy machines
			allowed
	Total..............	531	
5.00 p.m	Additional lighting for		
To	dormitories and security		
11.00 p.m.	(approx.)	15	
(without	Textile laboratory	12	
chemical	Blower group	30	
laboratory	Draw twisters and back -		
overtime)	winder	450	all allowed
	Total............	507	

Table 5.5 (Con't)

Time	Electric Energy Consumers	Nameplate, Power Requirement) kW	Remarks
5.00 p.m. To 11.00p.m. (with chemical laboratory overtime)	Additional lighting for dormitories and security (approx.)	15	
	Laboratories	48	
	Blower group	30	
	Draw twisters and back winder	438	at least one of the machines (No. 1-15) stop
	Total..............	531	

Remark: The blower group given above consists of item no. 5,6 and 7 in Table 5.4

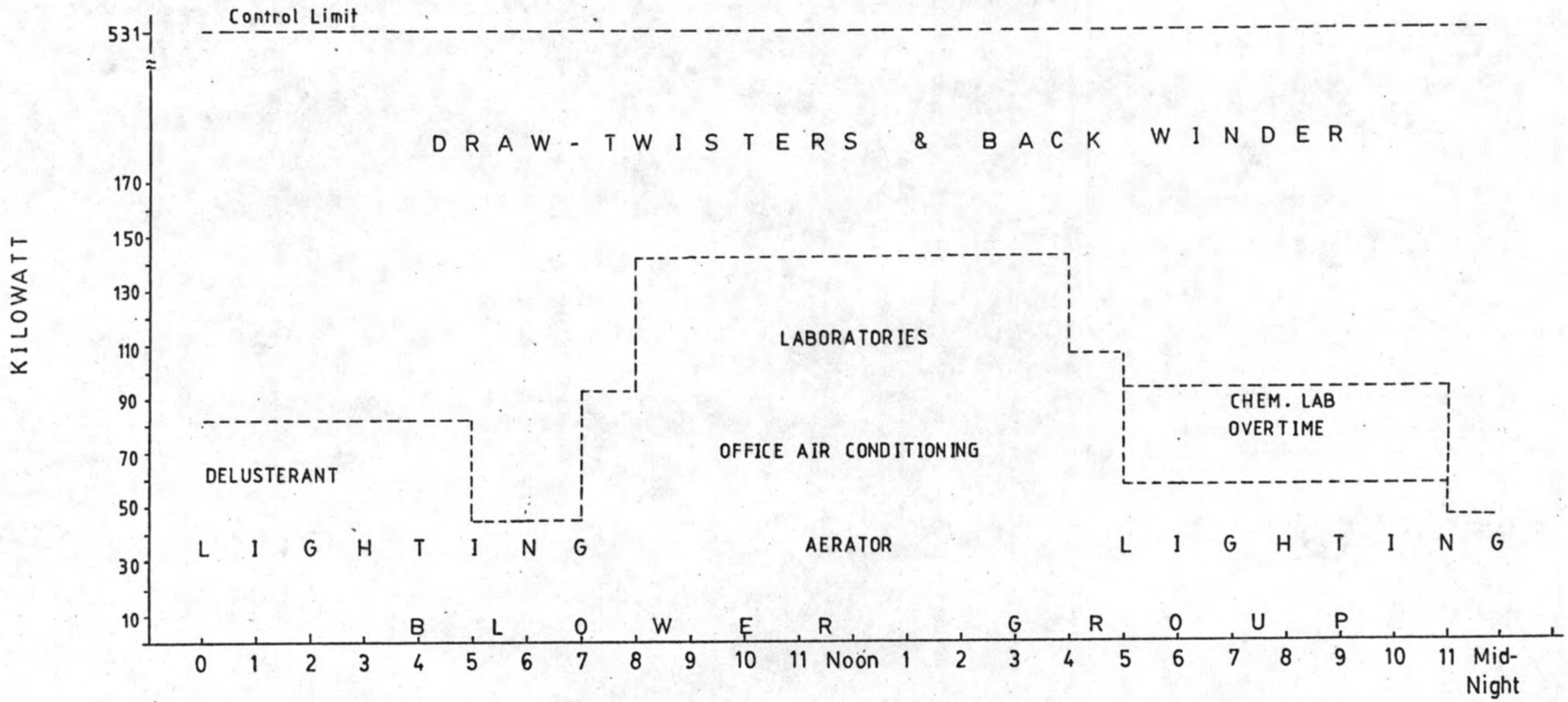


Figure 5.6 Expected Load Curve after Rescheduling the Equipment.

It is advisable in implementing the program not to start two major electricity consuming equipment within any time interval of 15 minutes.

Electrical energy conservation anticipated from this program may be computed as follows:

Present condition (worst case) requires............686 kW

Proposed condition requires.....................531 kW

Reduction in maximum demand....................155 kW

From the formula for total charge[ψ],

$$M = 106.6\ P + 1.41\ E$$

Where M = total payment for electricity consumed, baht

P = the peak demand, kW

E = total electrical energy consumed, kWh

We can easily calculate the reduction in energy cost, by decreasing the maximum demand, to be 16,523 baht per month or 198,276 baht per annum.

Lighting Control

When people think of saving energy, the first thing that comes to mind is to restrict the use of artificial lighting, this being the visible and brightest symbol of electric consumption. Saving electrical energy does not mean sacrificing efficiency, and creating unsafe working and living condition. Rather, it is achieving good

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[ψ]This formula is derived from electrical bills issued by the PEA in 1985.

lighting with the minimum usage of electricity.

According to the lighting audit, see Appendix C, the lighting level for most areas throughout the factory appears to be lower than the CIE Standard (Appendix D). This is a result of conservation measures conducted by the factory before this study was undertaken. Some actions that were taken include: removing lamps from fixtures, replacing standard fluorescent lamps by ones of the energy saving type, as well as reducing levels of illumination in most working areas. In particular, localized lighting has been provided for specific operations, example is the electrical workshop and maintenance room.

The current possible conservation measures should be 1) encouraging everyone to switch off lights when they are not required, 2) further replacing the standard fluorescent lamps with energy saving type ones, 3) installing more switches to enable smaller groups of lights to be controlled, 4) modifying the existing fixtures and their location in the room to provide a greater amount and better quality of lighting 5) cleaning dirt accumulation on lamps, fixtures and lenses to increase the quantity of light falling on the task, 6) using ballasts of high power factor type when they require replacement, and so on.

The followings provide detailed analysis for some selected ECOs.

1. Providing Sufficient Switches to Turn off Unnecessary Lights

Some opportunities for shutting off lights which are not needed were found when conducting the lighting audit. A list given below indicates such areas including the number of occupants (and region activites) in each space and the length of time that each space is

Table 5.6 The Areas with High Potential to Save Energy in the Lighting System

Area Name	Wattage	Occupants	Activities	Lighting hours/day	Remarks
1. Production office	983	9	paperwork	18	only one switch exists
2. Extruding area	1187	0	extruding*	24	several switches exist
3. Electrical workshop	569	6	repairing	24	several switches exist
4. Chemical laboratory	873	6	service	8	several switches exist
5. Poly. toilet (2 nd floor)	53	10	service	24	daylight available
6. Draw-twisting lady toilet	255	15	service	24	lamp removal possible
7. Take-up core storage	459	1-2	storage	24	lamp removal possible
8. Packing area	2635	14	product packing**	24	do not work at night

*Day lighting available and the extruding process run automatically.

**Usually, final inspection and packing are performed between 8.00 a.m. and 5.00 p.m.

Table 5.7 Evaluation of Energy Conservation Measures

Area Name	Possible Measures	Investment Required	Expected Saving kWh/day	Expected Payback Period
1. Production office	provide 3 more switches	about 90 baht	5.0 (7.80)	12 days
2. Extruding area	turn off all lamps during daytime and some at night	none	21.0 (32.75)	immediately
3. Electrical workshop	turn off during unoccupied period	none	6.0 (9.36)	immediately
4. Chemical laboratory	turn off 7 near the door when they are not wanted	none	1.5 (2.30)	immediately
5. Poly toilet (2 nd floor)	using daylighting during daytime	none	0.7 (1.10)	immediately
6. Draw-twisting lady toilet	remove 2 lamps and ballasts	none	2.5 (4.00)	immediately
7. Take-up core storage	remove 2 lamps and ballasts	none	2.5 (4.00)	immediately
8. Packing areas	turn off during unoccupied period	none	31.6 (50.00)	immediately
	Total saving		70.8 (110.45) or 40314.25 baht per year	

Remark:

The numerical values in parentheses are of bahts per day.

lighted. Electrical energy saving may be anticipated from the areas mentioned in Table 5.6 by some appropriate measures. Table 5.7 summarizes the possible energy conservation opportunities for each area, invesment required and payback period expected.

2. Improving Lighting Efficiency by Maintenance /Preventive Maintenance

Once installed, the efficiency of a light source depends to a large extent on how well the fixtures are maintained. A lamp that produces 3200 lumens (40 W Fluorescent lamp) when installed may actually distribute only 1600 lumens when covered with dust. The reflecting value of fluorescent fixtures is directionally correlated to their illuminating ability, and their tendency to collect dust may be countered by frequent cleaning. Bulbs should be replaced when they first begin to dim, not after they have completely burned.

When surveying the buildings, it was observed that some of the lamps in the take up section were covered with a film of finishing oil. A better utilization of lighting system can be achieved by a good lighting maintenance program. The following procedures are recommended:

2.1 Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps which are exposed to an atmosphere with substantial amounts of dirt, dust, grease, or other contaminants should be cleaned more frequently than lamps in a relatively clean atmosphere.

2.2 Clean ceiling, walls, and floors frequently to improve reflective qualities. In rooms or areas where natural daylight is used to maintain light levels, wash windows frequently.

2.3 If any renovating or painting is planned, the use of white or light colours will improve light quality.

Summary

In this chapter, interest was given to electrical energy usage by various components throughout the factory as well as to energy conservation measures applicable to each system.

Data gathered from the energy audits were employed in estimating the energy distribution in the plant.

The breakdown of electrical energy consumption by operation areas was investigated and the spinning and take up process was identified to be the largest electric consumption area. The breakdown of electricity consumption by major equipment was also studied and found that the equipment used in the production system was the equipment group that requires the biggest amount of electricity.

Beside the general procedures recommended for saving energy costs in each equipment system, detailed studies were carried out to show some practicable measures in controling the maximum demand and in controling the lighting system, respectively.

The study for the maximum demand control revealed a possibly load rescheduling that can save electrical energy costs by 16,523 bath per month or 198,276 bath per annum. In addition, the study conducted for the lighting system indicated that by simply adding some on-off switches along with shutting off lights which are not needed, the cost saving of about 40,000 baht per annum may be anticipated.