76

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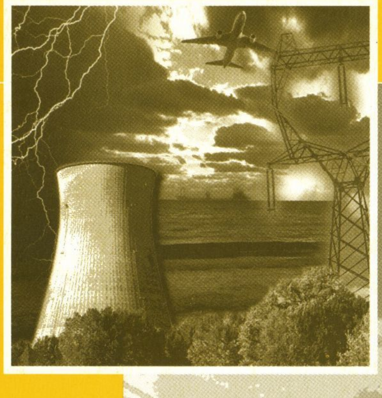

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LOAD MANAGEMENT MEASURES IN A CARPENTRY FACTORY

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SUMMARY

The wood manufacturing industry in Sweden is not very often the subject of academic research activities. In certain parts of Sweden, generally in rural areas, this industrial branch is of major importance as a local employer. If the companies could grow and prosper it would lead to a more vivid countryside and decrease migration to larger towns and cities. The council of the European Community has therefore introduced certain funds for research projects in such rural areas. This paper describes the use of electricity and heat in a carpentry factory. The result shows that energy conservation measures and load management might be of significant importance in order to make the company more profitable. Even small savings can be the difference between survival or bankruptcy. For the studied factory it is obvious that much equipment for heating purposes are in a poor state. The steam system which could be useful for decreasing the use of electricity heating suffers from leaking steam traps and other imperfections which lead to severe losses in both kilowatt-hours and money. The steam system is therefore not used in an optimal way. © 1998 John Wiley & Sons, Ltd.

KEY WORDS energy conservation; wood drying; machining electricity; load management

INTRODUCTION

The division of wood technology at the Institute of Technology started in 1992. All employees were transferred from other divisions, one of which was Energy Systems. Studies of energy issues in the carpentry industry were therefore a natural subject for our interest. The first papers dealt with a small factory which manufactured staircases, Gustafsson and Probert (1995) and Gustafsson (1996). The main result from those studies was that about 25% of the electricity cost could be avoided if the machinery was used in a more sophisticated way. This is because of the high electricity demand cost. The third paper described a factory which manufactured wooden trays of laminated veneer, Gustafsson, (1998). This showed that load management systems used for decreasing the electricity demand must be carefully designed in order to achieve profitability. All three studies, however, showed that much more knowledge must be present in order to understand how all machinery and other equipment should be combined in order to use it in a more efficient way. A new project has therefore started, funded by the county of Kalmar and European Community, task 5b, which aims at developing rural areas of Europe.

CASE STUDY

The studied company, Mörlunda Chair and Furniture Ltd., is sited about 350 km south of Stockholm. It was established in 1904 and now has about 20 employees (May 1998). A carpentry factory includes several different systems. For instance, there are kiln dryers where wood is dried from about 18–8% moisture contents, a number of wood working machines for processing planks to parts in a chair, one ventilation

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system where wood chips and saw dust are transported from the machines to wood chips storage, one steam system for heating the premises and kiln dryers, one electricity system etc. All these systems must operate at the same time. Even for small factories these systems add up to a complicated combination which must be understood in detail if measures shall be taken for a more efficient production, i.e. saving money. Only one of these systems are subject for every day monitoring, viz. the electricity system.

The supplier of electricity always has a metering device for knowing how much electricity that is used and the cost for that energy. Nowadays, this meter delivers values for each hour throughout the year to the utility and the subscriber is therefore able to see exactly how much electricity the factory has used. In Figure 1 a so-called duration graph is shown for 1997.

The total amount of electricity under the curve has been calculated to 341 MWh. The cost for electricity, however, depends on the time of the day when the electricity is used and also on the time of the year. For winter working days the cost is high while it is low during summer nights. The company exceeded the use of power by 21 kW which led to an extra demand fee and also used more reactive power than set in the subscription. The total cost for electricity is shown in Table 1, (1 ECU = 8 SEK). The cost related to the need for power, in kW, is therefore about 55% of the total cost.

In order to reduce the costs in Table 1 it is essential to know further details of the electricity consuming machines. We have therefore installed eight new electricity meters in the factory. Six of them are installed directly under the utility meter and if the registrations from these six meters are added the sum should be identical to the meter owned by the utility. In Table 2 the registrations are shown for 12 h 11 May, 1998.

From Table 2 it is obvious that there are small differences between our sum of the electricity meters, i.e. 1486 kWh and the utility meter, 1460 kWh. However, the difference is only about 2%. The first meter, M1,

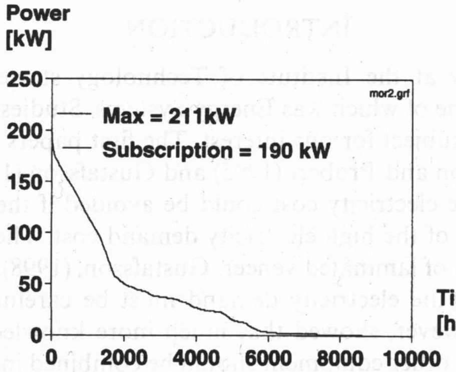

Figure 1. Duration graph for electricity, Mörlunda Chair and Furniture Ltd., 1997

Table 1. Costs for electricity in SEK, Mörlunda Chair and Furniture Ltd., 1997

Energy cost	102 772
Demand fee	27 537
Subscription fee, winter	79 800
Subscription fee, year	7 030
Demand fee, extra	19 194
Reactive power	2 665
Total	246 998

Table 2. Registered electricity consumption, Mörlunda Chair and Furniture Ltd., 11 May 1998

Time	M1	M2	M3	M4	M5	M6	Total	Utility
05·00	7	7	4	0	0	0	18	17
06·00	17	7	24	2	2	43	95	95
07·00	27	10	40	5	5	78	165	163
08·00	26	10	41	7	7	77	167	166
09·00	16	8	34	5	5	44	112	111
10·00	26	10	37	9	7	80	169	167
11·00	20	10	42	9	7	82	170	168
12·00	24	9	38	5	7	71	153	152
13·00	13	6	33	4	6	44	107	106
14·00	21	6	34	4	7	76	150	148
15·00	21	6	35	6	4	71	145	143
16·00	6	6	4	1	0	0	17	16
17·00	6	7	4	1	0	0	18	18
Sum	232	104	367	58	57	667	1486	1460

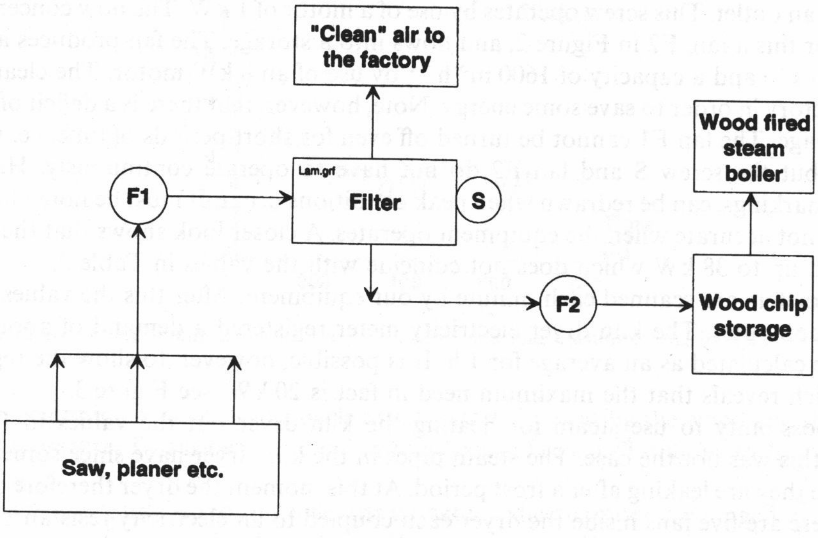

Figure 2. Part of the wood dust transportation system, Mörlunda Chair and Furniture Ltd

serves a kiln dryer, a planer moulder, a rip saw, a wood chip machine and a fan for transporting these wood chips to the storage. Further, there are two fans for transporting wood dust from the planer moulder and the rip saw. One electricity meter was located at the kiln dryer and it registered about 6 kWh each hour. In order to reduce the demand for power in the factory some of these equipment must be turned off for some time. The wood chipper and the fan connected to it must be avoided during peak conditions. The same is valid for the electric resistance heaters and the fans in the kiln dryer. There is also a possibility to turn off part of the saw dust transportation system, see Figure 2. From the saw and planer the wood residuals are transported in an air stream with a velocity of about 1·2 m s^{-1} and a capacity of about 4200 m^3 h^{-1}. This is achieved by the fan, F1 in Figure 2, and a motor which was marked with a current of 43·5 A for 380 V. Thus, this motor should have a demand of about 23 kW.

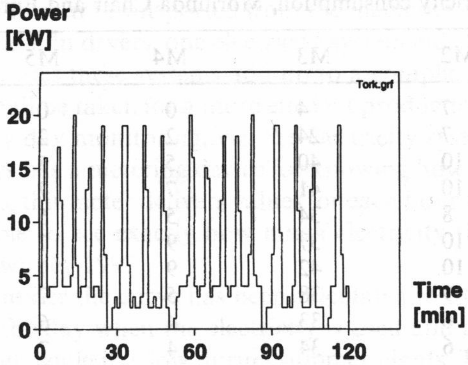

Figure 3. Electricity demand in kW for kiln dryer no. 1 at Mörlunda Chair and Furniture Ltd., starting 23·00, 11 May 1998

The air and wood dust stream then passes a filter which consists of a large box where the air is separated from the wood residuals. The wood dust falls down to the bottom of the box where a screw, S in Figure 2, moves the dust to an outlet. This screw operates by use of a motor of 1 kW. The now concentrated wood chip stream passes after this a fan, F2 in Figure 2, and flows into a storage. The fan produces an air stream with a velocity of $9{\cdot}1\ \mathrm{m\,s^{-1}}$ and a capacity of $1600\ \mathrm{m^3\,h^{-1}}$ by use of an 8 kW motor. The clean and warm air is returned to the factory in order to save some energy. Note, however, that there is a deficit of air because of the stream to the storage. The fan F1 cannot be turned off even for short periods of time, i.e. when the saw and planer are used, but the screw S and fan F2 do not have to operate continuously. Hence, about 9 kW according to the markings, can be redrawn when peak conditions occur. It must be noted here that the marks at the motors are not accurate when the equipment operates. A closer look shows that the three motors and the kiln dryer add up to 38 kW which does not coincide with the values in Table 2.

The electricity meters are scanned each minute by our equipment. After this the values are stored on the hard disk in the computer. The kiln dryer electricity meter registered a demand of about 6 kW when the 1 min values were calculated as an average for 1 h. It is possible, however, to show the registered values on a 1 min basis which reveals that the maximum need in fact is 20 kW, see Figure 3.

There was a possibility to use steam for heating the kiln dryer but the values in Figure 3 show the conditions when this was not the case. The steam pipes in the kiln dryer have since some years not been in operation because they are leaking after a frost period. At this moment the dryer therefore can only be heated by electricity. There are five fans inside the dryer each coupled to an electricity resistance heater of 2·7 kW. The air stream in the dryer is reversed after 20 or 30 min and this pattern could be observed as well.

There is also another wood dryer which operates solely on electricity. The load pattern from this is very different, compare Figures 3 and 4. The maximum demand is 8 kW. The dryer originally used a heat pump where the moisture condensed on the cold side and the heat was returned to the drying chamber. At this moment, however, the heat pump is out of order which must lead to a higher electricity use than was originally expected. The electricity use in the number 2 kiln dryer has not been measured separately. Our investigation showed that a copying–shaping milling machine is coupled to the same circuit. This machine is not in operation during night time so a relatively accurate assumption could be made about the use of electricity in the dryer. The company also has two kiln dryers where only steam is used for heating. These are, however, not described in this paper. The method to scan and store values each minute revealed the used electricity demand in kW for the kiln dryers of interest. It is interesting as well to see how long each drying cycle is. In Figure 5 values for the first kiln are shown. The drying cycle started on 14 April and had not ended by about 13 May at the time this is written. However, it is obvious that almost all the available power is used during the first hours of operation, i.e. 16 of 20 kW, compare with Figure 3. Note that not all fans are used

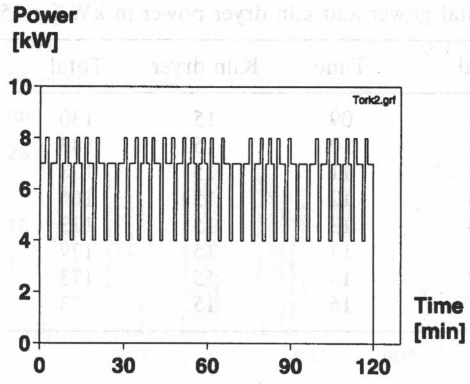

Figure 4. Electricity demand in kW for kiln dryer no. 2 at Mörlunda Chair and Furniture Ltd., starting 23·00, 11 May 1998

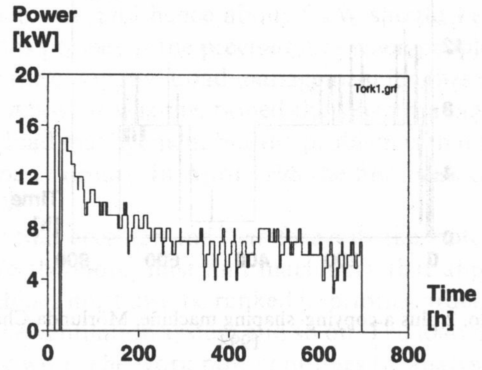

Figure 5. Electricity use in kiln dryer no. 1 at Mörlunda Chair and Furniture Ltd., 14 April–13 May 1998

continuously. The beginning of each drying cycle usually starts by heating the wood and the drying chamber up to a certain temperature. This is before actual drying occurs. See e.g. (Tsoumis, 1991), page 279 for details about wood drying.

When the temperature comes up to this level the climate in the chamber is changed by letting out part of the very humid warm air through the dampers and letting in dry cold air from the outside.

In order to find out how the kiln dryer adds up to the total use of power for the company, 24 h of the drying cycle are shown in Table 3. (For 14 April there were only a few registered values.)

The maximum total need for power occurred between 09·00 and 10·00, i.e. 183 kW. At that hour the dryer used 15 kW. By turning off the dryer the total need would be reduced to 178 kW, but now the peak would become 179 kW occurring between 13·00 and 14·00 instead. Hence, also that hour must be subject to load management but only one kW exceeds the limit and, therefore, the dryer needs to be turned off only for a few minutes. If the total need is studied for the whole drying it is found that there are no higher values than 183 kW. The next highest value is 179 kW which occurs at three occasions. For the studied period only 4 h therefore were of interest for kiln dryer load management. A closer look at Table 3 shows that the kiln dryer should be turned off between 09·00 and 10·00. It is not possible to recover the lost energy the next hour because the total need would then exceed the new limit of 178 kW. There is a gap of 10 kWh between 11·00 and 12·00 but it is not possible, due to the lack of installed thermal power, to recover more than say 4 kWh. There is therefore a possibility that the temperature in the dryer will fall slightly for the hours after load

Table 3. Total power and kiln dryer power in kW for 15 April 1998

Time	Kiln dryer	Total	Time	Kiln dryer	Total	Time	Kiln dryer	Total
01	12	34	09	15	130	17	15	60
02	0	15	10	15	183	18	14	47
03	0	15	11	15	178	19	15	48
04	0	15	12	15	166	20	14	47
05	0	14	13	15	123	21	14	47
06	15	98	14	15	179	22	14	48
07	15	177	15	15	173	23	14	47
08	15	177	16	15	73	24	14	46

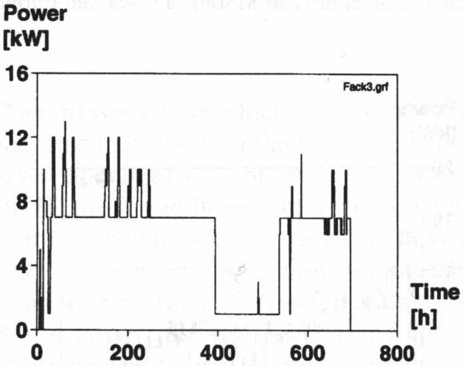

Figure 6. Electricity use for kiln dryer no. 2 plus a copying–shaping machine, Mörlunda Chair and Furniture Ltd. 14 April–13 May 1998

management operation has occurred. From 14·00 there is, however, an available gap between the total limit and the actual need. It is also possible to increase the temperature in the dryer before load management is likely to be introduced. i.e. before 07·00.

The monetary value of the 15 kW depends on the total need for power. If this is below the subscription level it was worth 601 SEK/kW and 914 SEK/kW if that limit was exceeded. For the studied period in Table 3 the lower value applies and, hence, about 9000 SEK could have been saved. If a present value for 5 yr with a discount rate of 5% is calculated, about 40 000 SEK could be invested in equipment before the life-cycle cost becomes negative. The kiln dryer no. 2 has a lower electricity demand than the no. 1 device. The average use of electricity for 1 h is about 7 kW, see Figure 4. The pattern for the period 14 April–13 May is shown in Figure 6. Note that a copying milling machine is connected to this circuit. For most of the time the dryers have been used simultaneously and a closer study of the data set showed that the dryer operated for those hours where peaks occurred in the total electricity demand. By also turning off this dryer a few hours, 7 kW could be shaved from the peak.

The money supposed to be saved by this operation is about 4000 SEK each year.

The ventilation and wood chip transportation system shown in Figure 2 included some motors which could be subject for load management. The exact demand for these motors is not known at this moment but by reducing the kiln dryer no. 1 data from the registrations for the specific circuit some hints can be achieved, see Figure 7.

If it is assumed that all the machinery connected to the circuit were used for the peak of 30 kW about 20 kW could be assigned to the ventilation system. The motors which runs the screw S and the fan F2 in

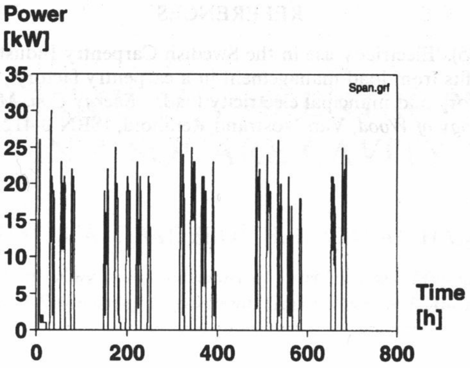

Figure 7. Electricity use for part of the ventilation system, a planer, a wood saw, etc., at Mörlunda Chair and Furniture Ltd., 14 April–13 May 1998

Figure 2 are smaller than the F1 motor and hence about 5 kW should be an approximate value for load management. This electricity load is present at the precise times when people are working in the factory so it must add up to the total peak for the company. Load management for these motors is therefore supposed to save about 3000 SEK each year. Above it was mentioned that load management is a very subtle task. The kiln dryers seem to be perfect for load management but the problem is that they are not always in operation when the total peak for the company occurs. In April 1998 the first peak over 150 kW emerged on 2 April 07·00 with a magnitude of 182 kW.

None of the dryers were used at that occasion and therefore only the motors S and F2 could be used which would save only about 5 kW. We therefore must find machinery that almost always are used but can be turned off for about 1 h. The machines must also be ranked in priority order so, e.g., the dryers are turned off first and after this the motors to the ventilation system and so on. The load management system must always be able to find something to work with. The work now continues by analysing the electricity load in further detail.

CONCLUSIONS

By installing electricity meters on separate circuits in a carpentry factory and at the same time monitoring the total load at the utility meter a number of equipment have been found suitable for load management. The most obvious items are two kiln dryers and two motors connected to the wood chip transportation system. Turning these devices off for less than 4 h each month, might save about 16 000 SEK each year by reducing the electricity load by 28 kW, or about 13% of the maximum registered load for 1997. Present value calculations shows that an amount of about 70 000 SEK could be invested in order to achieve this without a negative financial result. One problem is also emphasized. If the devices which were thought to be subject for load management are used too seldom, the system might not reduce the load at all. It is therefore important to have at least one or two machines that almost always are turned on and at the same time can be turned off perhaps only one or two times each year. For all other peaks, equipment with lower priority should be used.

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CONTENTS

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