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ECONOMIC BENEFITS FROM LOAD MANAGEMENT IN A CARPENTRY FACTORY

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Abstract—As a result of a National Referendum and a subsequent parliament decision Sweden will phase out its nuclear power stations before the year 2010. This source of electricity accounts for about half the total electricity usage and therefore other sources must be constructed, or the country must use less electricity. One way to accomplish this, according to economic theory, is to increase the price of electricity, and we will probably be subject to such actions, at least if there is a risk of a shortage of electricity. Hitherto, most interest for saving energy has been emphasised on space and domestic hot water heating in buildings. The major part of electricity, however, is used in industry, and is therefore worth studying in more detail. One small carpentry plant which manufactures wooden staircases and fibreboard panels for ceilings has been studied. Using monitored data for 1 year of their electricity usage and costs, the amount of money which could be saved by the owner of the factory, if different load management measures had been applied, has been calculated. Thus it was possible to find the maximum cost for equipment that can turn off some processes, such as timber dryers, for short periods. Copyright © 1996 Elsevier Science Ltd.

Keywords—Load management, carpentries, electricity, kiln dryers, economy.

INTRODUCTION

According to economic theory, the cost for using electricity influences usage in a significant way. If the price goes up the end user consumes less and the opposite is of course also valid. This has led to an increased interest in spot-price electricity tariffs [1–3]. The ordinary managers of many small industries, however, are not experts in energy issues, and therefore they just pay their bills without much consideration. Price information therefore does not affect the end-use consumer and subsequently no electricity is saved. In Sweden, wood manufacturing plants are very common and usually sited in rural areas. The managers frequently hesitate to use expertise found in universities and institutes of technology, even if they know who to contact. In order to improve this situation, ARBIO, the Employers' Association of the Swedish Wood-Products Industry, has funded education and research in wood technology at the Institute of Technology in Linköping, Sweden. One of the first companies to attract our interest was a very small plant with about 10 employees, which is sited in Rydsnäs, about 300 kilometres south of Stockholm. The energy usage, i.e. electricity, at the above company, as well as two other companies in Linköping, has been the subject of one earlier study [4]. The reference shows the electricity use for only a short period of time and only the total consumption of electricity was dealt with. There was no 'specifying of usage' for different equipment, such as the transport system for wood residuals in the form of sawdust, chips, etc. However, we were able to show that the company had too large a tariff from the electricity utility. By changing such, from one based on 150 kW to the actual requirements of about 80 kW, the owner saved about 25% of the electricity cost. Note that it was a measure of administration and hence not a single kWh was saved. Encouraged by this result, studies were continued.

CASE STUDY

As mentioned above, the electricity consumption has been monitored for 1 year at Rydsnäs Carpentry Ltd. Values are shown in Fig. 1 in a so-called 'duration graph', i.e. they are depicted in descending order.

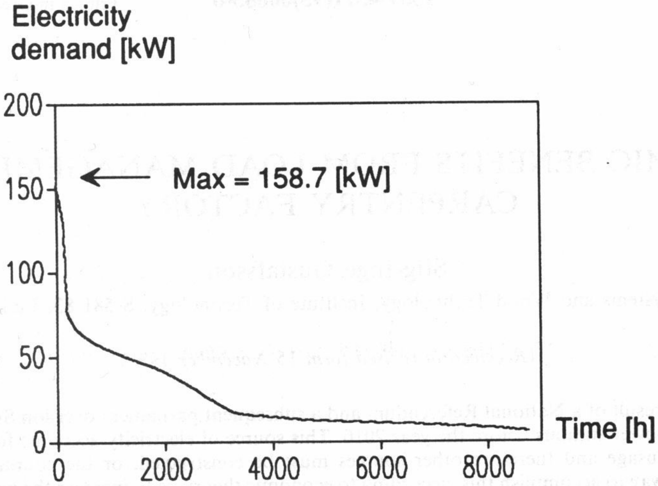

Fig. 1. Duration graph for Rydsnäs Carpentry Ltd.

It is apparent from the figure that there is a very thin peak where all the highest values are located. The main reason for load management is to reduce this peak by moving the electricity demand to later hours. The energy amount in the peak is very small and therefore it should be possible to reduce the demand and hence the electricity cost.

The electricity tariff

The electricity subscription applicable for Rydsnäs Carpentry Ltd is based on a time-of-use rate, where the utility charges a high cost for each kWh of electricity during daytime, 06·00–22·00 hours. From October to April such a cost was 0.415 SEK (£1 equals about 10 SEK). In the middle of the night, i.e. between 22·00 and 06·00 hours, cost is reduced to 0.308 SEK/kWh. Saturdays and Sundays are likewise low tariff periods. From May to September the cost is even lower, i.e. 0.215 SEK/kWh, irrespective of the time and day. The main emphasis of this study, however, is the demand charge which in 1994 was 430 SEK/kW. If one could save or transfer the kWh used when the load is at its highest level, each of these kWh has a value 200 times higher than the ordinary cost for electricity. This is because the utility calculates a mean average of the four largest values in kW for the total year. However, only one value between May to August can be included.

Monitored electricity use and load management

Table 1 shows values from the first complete month, i.e. April 1994, during the monitoring period.

Firstly, note that the maximum demand in April 1994 was 70.1 kW, i.e. far from the subscribed 150 kW mentioned above. Secondly, if a load management system had been used to decrease the load on 18 April at 09·00 by, say, 10 kWh and had added this energy to the next hour, i.e. hour No. 418, this would have aggravated the problem. At that hour the load was already 60.3 kW and an added 10 kWh would result in a load of 70.3 kW, which is higher than that of hour No. 417. In contrast, if the equipment had cut off only 5 kW at hour 417 the position would be improved

Table 1. The 10 largest values of electricity demand in kW for April 1994, Rydsnäs Carpentry Ltd

Hour No.	Date and time	Weekday	Value in kW
417	18th, 09·00	Monday	70.1
416	18th, 08·00	Monday	67.4
466	20th, 10·00	Wednesday	64.2
153	7th, 09·00	Thursday	63.8
465	20th, 09·00	Wednesday	62.9
441	19th, 09·00	Tuesday	62.5
135	6th, 15·00	Wednesday	61.8
442	19th, 10·00	Tuesday	61.1
633	27th, 09·00	Wednesday	61.1
418	18th, 10·00	Monday	60.3

Table 2. Electricity demand in kW for the first hours of 1 April 1994

Time	Demand (kW)	Time	Demand (kW)
00·00–01·00	10.9	06·00–07·00	9.6
01·00–02·00	10.7	07·00–08·00	9.3
02·00–03·00	10.5	08·00–09·00	9.3
03·00–04·00	10.6	09·00–10·00	9.4
04·00–05·00	10.4	10·00–11·00	9.7
05·00–06·00	10.0	11·00–12·00	9.8

because hour 418 would no longer have been among the four largest values of interest. Therefore, the magnitude of the 'cut off' load has importance for the economic situation. If the 'cut off' could be postponed 2 hr, instead of 1 hr, one must examine what happened at hour 419. A closer look at the data set showed that the load had decreased to only 10.2 kW and there would be no obstacle to adding 10 kWh in that hour. It is obvious that the length of the period of possible postponement is of vital importance as well. Of course, it would have been possible to cut off, for instance, 10 kW in hour No. 417 and only add 7.1 kWh to hour 418 and the rest at No. 419. The load at hour No. 418 would then equal that in hour No. 416. It would be preferable, however, to reduce the load so much that the resulting subsequent loads are lower than the top 4 hr, which would result in a sustantial average decrease.

One of the major problems is that one does not know in advance exactly what will happen the next hour. Only when it is lunchtime or the working day is over may one assume that there is no risk of moving kWh to later hours. By studying the electricity load pattern, one is sometimes able to see when maximum loads will probably occur. The hours from 08·00 to 10·00 seem to be represented more often in Table 1 than other time segments. In small factories, such as the one studied here, load management equipment must be very cheap and therefore no expensive computer could be used for this purpose. There is a need, however, for a device that counts the pulses from the electricity meter and turns off equipment when the added kWh exceeds the last maximum value. In order to clarify the situation one must study the first hours in April, see Table 2.

1 April 1994 was a Friday but because it was Easter all workers were free and only some of the equipment which is never turned off was in use. Hence, the electricity demand was as low as 10.9 kW in the first hour. Load management in these hours is of no economic interest because the owner of the factory is charged a fee for at least 60% of the subscribed amount, i.e. 48 kW. The load management equipment therefore must have a default limit of 48 kW, and if the demand is lower, no actions should be taken at all. If there is no such limit, the first hour will always be subject to load management. The first occurence when demand was higher than 48 kW emerged between 06·00 and 07·00, 5 April, which was the first working day that month. The load was 54.6 kW and therefore the load management device came into operation. If it was possible to postpone 10 kW to the next hour between 07·00 and 08·00, the load that hour would increase to 60.9 kW, which was not exceeded until 14·00 the next day. This time, 10 kW could be postponed without exceeding the earlier level. The same is valid for the next peak, i.e. 7 April at 09·00. The fact is that only one more peak that month would be of interest for peak shaving and this occurred on 18 April, between 07·00 and 08·00, see Table 1. Only a few hours during each month will thus be subject to load management and the negative consequences will hence be minute.

Load management economy

It is most important, however, to choose demand-saving measures with great care. As is shown in the example above, load management may make the situation worse if saved kWh must be used

Table 3. Load management for different levels in kW, number of 'hits' and electricity demand cost in SEK. Load postponed 1 hr

Level (kW)	Hits (No.)	New demand (kW)	Demand cost (SEK)
0	—	(152.0)	65,370
1	89	151.1	64,962
5	67	150.6	64,790
10	40	154.8	66,564
15	37	159.3	68,499
20	34	161.1	69,284
30	32	165.8	71,305

Table 4. Load management for different levels in kW, number of 'hits' and electricity demand cost in SEK. Load postponed 2 hr if applicable

Level (kW)	Hits (No.)	New demand (kW)	Demand cost (SEK)
0	—	(152.0)	65,370
1	156	151.0	64,940
5	138	148.3	63,748
10	135	153.4	65,962
15	130	155.0	66,662
20	126	153.5	65,983
30	79	157.4	67,673

the next hour. This is shown in more detail in Table 3, where we have examined the whole year, from 19 March 1994 to 20 March 1995. No default limit in kW for the load management equipment was used, and therefore the system operated frequently at the beginning of the months and more seldom at the end of them. The new demand is calculated as the average of the four largest values during the year for each month, according to the tariff. The demand cost was 430 SEK/kW.

From Table 3 it is obvious that not much money could be saved by the use of too simple a device. Note that the load increased for the levels 20 and 30 kW, respectively. Only 580 SEK differs between the lowest cost and that where no system was used at all, compare lines 1 and 3 in Table 3. Assuming that the equipment could be used for 5 years and, further, a real discount rate of 5%, would result in a net present value of about 2500 SEK, which should be an upper cost limit for the peak shaving system described above.

Suppose there was a more intelligent system in use, where it was possible to add only a part of the saved kWh from one hour to the next, and the rest to the following hours and so on. In Table 1 this could be described as cutting off, for instance, 10 kW in hour 417, and only adding 2.7 kWh at hour number 418 and the rest, 7.3 kWh, at hour number 419. This is shown for the total year in Table 4.

The lowest cost which emerges in line 3, see Table 4, has now changed to 63,748 SEK, i.e. the savings are three times higher than found in Table 3. A present value calculation shows that about 7000 SEK could be invested and the equipment would still be profitable. A 3-hr postponement of shaved peaks does not change the situation very much. The first two levels are identical, i.e. 151.0 and 148.3 kW, while the 10 kW level results in a small decrease to 150.6 kW. For levels 20 and 30 kW, respectively, the situation is aggravated and the resulting loads after peak shaving are higher than for a postonement of 2 hr. Load management therefore has the potential to be profitable but the equipment must be 'finely tuned' for each factory in order to achieve the best result. In our case only low levels of peak shaving, about 3% of the total load, were found profitable.

KILN DRYERS

One process was identified at the Rydsnäs factory which was probably suitable for load management, i.e. two kiln dryers for wood timber. The dryers are electrically heated even though the factory has a boiler fired with wood residuals, such as sawdust. The question is if the kilns are used in such a way that load management would be of interest. The manager of the factory inserts planks, mostly pine, in large batches of about 6 m^3. The temperature inside the kilns is about 40°C. One of these batches then yields enough raw material for several weeks. Figure 2 shows the electricity demand for a drying cycle.

Figure 2 shows that the electricity demand is about 11 kW at the beginning of a drying cycle. This level is constant for about 100 hr when the demand drops to about 3 kW. There are also relatively short peaks after 250 and 350 hr, respectively. The cycle in its entirety lasts about 375 hr. 28 November 1994, i.e. when the cycle started, was a Monday. If the dryer had been put into operation on the earlier Friday instead, the added 10 kW demand would have been less negative for the factory owner because between Friday night and Monday morning the total load was very low. As has been shown above, a load management system, where about 5 kW could be transferred to later hours, would be profitable. The wood in the dryer has a very high heat capacity and therefore the temperature would not decrease very much, even if the kiln was to be turned off for a few hours or operated at lower power. The next drying cycle was initiated about 3 weeks later. Unfortunately, the monitoring period for the electricity consumption in the kiln dryer was much

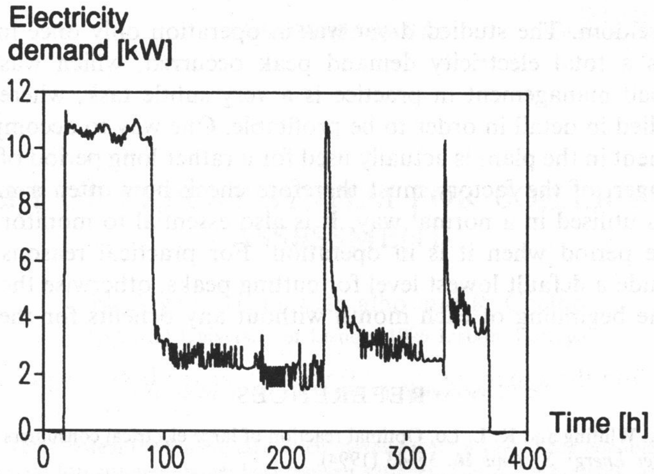

Fig. 2. Electricity demand for the kiln dryer, Rydsnäs Carpentry Ltd, 28 November–13 December 1994.

shorter then the total demand monitoring period. It is therefore not possible to calculate the exact savings in SEK during 1 year. A closer look at the data files revealed that November 1994 was not of interest for peak shaving because the maximum load then was only 80.4 kW. We focused our attention instead on the months of January, February and March, 1995, when the maximum demands were 149.4, 158.7 and 158.7 kW, respectively. The first drying cycle in January started 1 January but lasted only 4 days and then the total load was too small for beneficial load management, as was also the case for the next two cycles. The fourth cycle started on 26 January but it was not until 31 January at 09·00, that a very high load occurred at the same time as the drying equipment was operating. The time segment of interest is shown in Table 5.

In Table 5 a peak occurs between 08·00 and 12·00 and the fact is that this peak was decisive for the total month maximum value. Earlier in the month a load of 144.5 kW had emerged but then the kiln dryer was not operating. However, if a load management system had been installed about 5 kW could have been postponed from 09·00 to 10·00 to later hours and these 2 hr would have been enough. In February the maximum load was 158.7 kW but once again the kiln dryer was turned off on that specific occasion. Unfortunately, no registrations were made for the kiln during March 1995. The fact is that the dryers, despite their potential for load management, are used too seldom for beneficial load management. The fact that there are two dryers probably improves the situation but nonetheless no substantial amount of money is likely to be saved.

CONCLUSIONS

We have shown that load management, where part of the electricity load is postponed to later hours, has a potential for reducing the electricity bill for a studied company. The savings, however, are surprisingly small, about 7000 SEK or £700 calculated as a net present value, because electricity saved in one hour will aggravate the situation at later hours. Therefore, the resulting maximum load was many times higher after load management had been in operation than it was originally. An optimum level for load management was found to be about 5 kW out of a total of 150 kW, or about 3%. It was also found very important to find equipment in the plant that could be turned off for more than 1 or 2 hr. Plausible equipment for this in the factory were two kiln dryers for wood timber, with an installed power of about 11 kW each. However, a closer study showed that

Table 5. Total electricity demands drying equipment demands for 31 January 1995, Rydsnäs Carpentry Ltd

Time	Total (kW)	Kiln dryer (kW)	Time	Total (kW)	Kiln dryer (kW)
05·00–06·00	25.4	1.9	11·00–12·00	130.9	2.1
06·00–07·00	26.9	2.6	12·00–13·00	78.3	2.3
07·00–08·00	52.8	2.7	13·00–14·00	65.6	2.6
08·00–09·00	140.8	2.4	14·00–15·00	73.6	2.6
09·00–10·00	149.4	2.0	15·00–16·00	76.3	2.6
10·00–11·00	140.1	2.7	16·00–17·00	72.8	1.6

they were used too seldom. The studied dryer was in operation only once in the examined year at the same time as a total electricity demand peak occurred, which was significant for the electricity. Hence, load management in practice is a very subtle task, where measures for peak shaving must be studied in detail in order to be profitable. One way to accomplish this is to study how different equipment in the plant is actually used for a rather long period of time, say 2 months. The owner, or manager, of the factory must therefore check how often a machine is used, and turned off, when it is utilised in a normal way. It is also essential to monitor the actual need for electricity during the period when it is in operation. For practical reasons, load management equipment must include a default lowest level for cutting peaks, otherwise the system will operate very frequently at the beginning of each month without any benefits for the owner.

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