LOAD MANAGEMENT IN MUNICIPAL ELECTRICITY SYSTEMS

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Abstract

Load management is one means for reducing maximum electricity load, and hence cost for electricity. In Sweden, the cost charged for the maximum load hour might be about 200 times higher than the ordinary cost for one kWh. If the load could be reduced by certain equipment in factories and buildings, the need for new power stations and higher capacity in the grid would also be decreased. By use of electricity load data for one full year and a short computer program this paper shows how much the load could be reduced for varying postponing in time. If a part of the load could be postponed one hour only, this part should be very small if maximum benefit is considered. If longer time segments could be used, larger chunks could be transferred. The main result of the study is however that load management in practice is a very subtle task if an optimal solution is to be achieved.

INTRODUCTION

At this moment, December 1995, Sweden will phase out its nuclear power stations before the year 2010. This according to a parliament decision. If this will come to reality, new generating capacity must be built or there will be a substantial shortage of electricity. The cost for electricity will therefore increase, especially for periods when such a shortage is likely to occur. Marginal cost theory also implies that the cost for electricity should reflect the cost for producing one extra kWh or the money saved if one kWh is not produced at all. When there is a risk for a shortage this cost will be very high, i. e. it reflects the cost for building new power stations. Studies of the electricity use pattern reveal that buildings and factories produce peaks which are expensive both for the proprietors, and for the utilities serving them. One paper dealing with industrial buildings is Reference [1] where the authors discuss how to reduce the expensive peak charge and at the same time use cheap off-peak electricity for heating the premises. The authors to References [2] and [3] examine how end-use consumers react to spot-price tariffs of electricity and what measures they are supposed to take in order to avoid the highest costs. They also stress the necessity for the consumers to actually be aware of the prices in effect, and further they discuss more in detail how a tariff should be designed when based on these spot prices. In Reference [4] the avoided costs for the utility are stressed and what measures to be taken if the utility acts in an optimal way. However, they use the long-range marginal cost for finding such measures which might be accurate if a number of investments are considered. For more details about marginal cost theory see e. g. References [5] and [6]. Unfortunately, none of the papers examines in detail how a load management system should be designed in order to achieve an optimal result, i.e. to find out how much, and for how long, part of the peaks should be transferred to later hours. However, to some extent this has been dealt with in [7] where a small carpentry factory was examined. The main result of that study was that only a very small part of the peak, about 3% of the total peak load, should be moved and then only for a few hours. This result made it interesting to instead study the electricity load of a municipality where a much higher electricity demand were present.

CASE STUDY

The case study electricity load comes from the municipality Kalmar about 300 km south of Stockholm, Sweden. The values were monitored in 1990 and they have also been subject for earlier studies, References [8] and [9]. In Figure 1 a duration graph is shown, i. e. the hourly demands have been sorted in descending order.

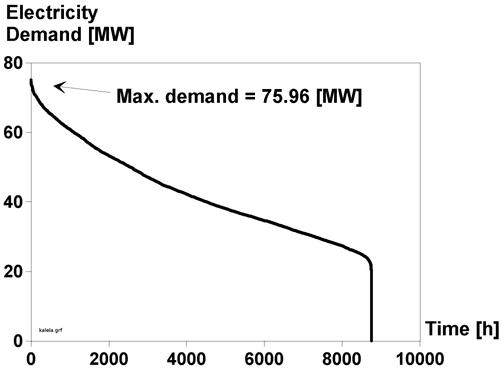

Figure 1: Duration graph for electricity load during 1990 in Kalmar, Sweden, [9]

From Figure 1 it is obvious that the peak is not very accentuated. Nonetheless, a reduction by say 5 MW would be very profitable because each MW costs about 300,000 SEK in demand charges. (One US$ equals about 7 SEK) The question is now if this could be achieved with a load management system.

Load management

The demand charges in Sweden are based on the maximum demand during one month. The average of four or five of these values is then multiplied by the demand charge which is expressed in SEK per kW. In the case of Kalmar the maximum load during the monitored year emerged in January 17 at 11.00. However, the load management system always will start to operate the first hour of the month, i.e. if no default lowest value is set into the apparatus. In Table 1 the monitored values of January 1 are shown.

Hour	Demand [MW]	Hour	Demand [MW]	Hour	Demand [MW]
01.00	40,379	09.00	40.911	17.00	49.222
02.00	39.017	10.00	41.067	18.00	48.144
03.00	37.923	11.00	42.380	19.00	47.188
04.00	36.198	12.00	43.672	20.00	46.073
05.00	39.931	13.00	44.678	21.00	44.384
06.00	39.015	14.00	45.120	22.00	42.492
07.00	40.143	15.00	45.969	23.00	40.626
08.00	41.468	16.00	47.808	24.00	37.987

Table 1: Monitored electricity demand January 1, 1990, in Kalmar, Sweden

The first hour of the year, the monitored load was 40.379 MW. Suppose for a start that 100.0 kWh could be transferred to the next hour. The load will reduce to 40.279 kW and the next hour will receive the moved energy amount, resulting in a demand of 39.117 MW at 02.00 this first day of the year. So far the system worked fine. Seven hours later the load was 41.468 MW and the system once again moves 100 kWh to the next hour which also worked fine. At 11.00 the monitored load was 42.380 MW and again 100 kWh were moved, but now the load at 12.00 was 43.672 MW and the added energy aggravated the situation resulting in 43.762 MW. The fact is that the system operates six times at January 1 but makes the situation worse for three of their adjacent hours. For January 2, four hours were subject to load management and all of them made the load higher later hours. Interesting to note is also the fact that the system operates more frequently in the beginning of each month than in the end of it. This because the lowest peak level increases when higher and higher loads emerge. This can be studied in more detail in Table 2.

Date	Number of ”hits”	Original max load [MW]	New max load [MW]
1	6	49.222	49.122
2	4	67.205	67.305
4	1	67.635	67.535
7	2	70.221	70.121
8	1	70.240	70.140
9	1	70.403	70.303
14	2	75.225	75.325
15	1	75.665	75.565
17	1	75.955	76.055

Table 2: Load management operation January, 1990. Level 100 kW, transfer 1 hour

After January 17 no new peaks emerged and thus the system would have operated 19 times.

Suppose, instead, a level of 1000 kW was used for the system. The first hour in January would of course still be subject to load management resulting in a new load of 39.379 MW. The second hour would then hold a load of 40.017 kWh so this later hour will now be of interest which was not the case above. Table 3 shows this new situation.

Date	Number of "hits"	Original max load [MW]	New max load [MW]
1	5	49.222	49.144
2	2	67.205	67.248
4	1	67.635	67.525
7	2	70.221	70.813
14	2	75.225	75.023
15	1	75.665	76.665

Table 3: Load management operation January, 1990. Level 1,000 kW, transfer 1 hour

This time 13 load management "hits" were registered compared to 19 in Table 2. If the level is increased the system would be less frequent in operation. Interesting is also to note that in spite of a higher level, the resulting peak increased. The situation therefore became worse than it was without the load management.

One means to improve the system would be to allow just a part of the transferred load to be added the next hour and let the rest move to the second next one. Consider once again Table 1 and a level of 1,000 kW. The first hour will be reduced to 39.379 MW. Now, only 362 kWh is allowed to be added to the second hour which results in, likewise 39.379 MW, while 638 kWh are added to the third hour in January 1 which in turn will have a demand for 38.561 MW. The situation therefore improved. The next time the system will operate is at hour 07.00. If 764 kWh are transferred the previous peak is not exceeded. The next hour will therefore achieve a load of 42.232 kWh and the system must operate once again, now with a full 1,000 kWh resulting in 41.232 MW at 08.00 and 41.911 MW at 09.00. Further, the procedure must be repeated at 11.00 leaving a load of 45.678 MW at 13.00. This somewhat tedious discussion shows that the load management system operates more frequently if a longer transfer time is allowed but also that the resulting peak load might be reduced. However, a closer study revealed that the peak for January now became 76.295 MW. Longer transfer times and higher levels will hence not always lead to a lower peak. In Figure 2 the situation is presented for all combinations of levels between 100 to 1,000 kW and transfer periods from 1 to 6 hours.

From Figure 2 it is obvious that a load management system will reduce the peak load. The original maximum load was 75,955 kW while the lowest value found in the figure is 75,580 kW, a reduction by 380 kW. The number of times the system operates increases with the allowed number of hours for postponement but this will not always lead to a lower peak. For low levels about two hours seems to be optimal, while four hours seems to be sufficient for e. g. a 1,000 kW level. Because of the fast increase of the "hits", which could be a drawback for industrial processes and so forth, one must not choose longer postponements than necessary. The fact is that the lowest value found in this

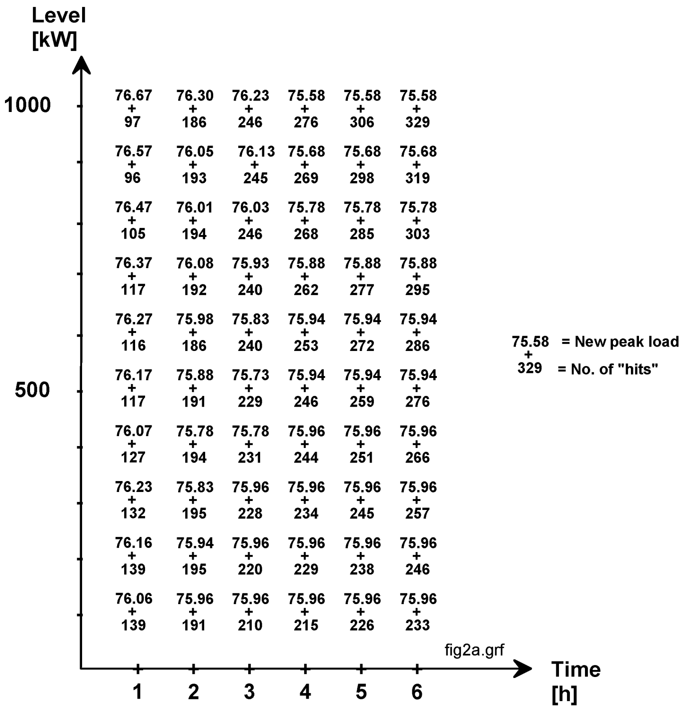

Figure 2: Peak loads, and number of "hits" during one year, for different combinations of load management level and postponements.

study emanates from a level of 1,500 kW and a postponement time of five hours resulting in a new peak of 75,225 kW. Even if the level was increased to 4,000 kW the situation did not improve. The optimal level for load management was therefore about 2 % of the original peak load. If there are problems in finding processes that could be postponed for such long time the level of load management should be decreased. For example the lowest value found for a two hour postponement is about 400 kW or only about 0.5 % of the original peak. However, the economic benefits might be substantial. A decrease of 400 kW will reduce the electricity cost by 120,000 SEK each year and therefore profitable load management measures must be possible to find. Important to note is also that the electricity tariff for the municipality not always might reflect the real marginal cost. In certain areas the grid, or other equipment, may be used to their maximum limit. If the cost for replacement to more powerful equipment could be avoided, or at least reduced, the economic benefits will increase.

CONCLUSIONS

The optimum level of load management in the municipality of Kalmar was found to be 1,500 kW which is about 2 % of the original peak load. However, this level implied that a five hour postponement must be introduced which might be hard to achieve without severe drawbacks for e.g. industrial processes. If shorter postponements must be used, the level of the load management must also decrease. A two hour postponement will result in an optimal level of about 400 kW or about 0.5 % of the original peak. Even if the optimum level is very low compared to the original peak load, substantial economic benefits might arise because of the high demand charges. If there are capacity problems in e.g. the electricity grid these economic benefits will substantially increase.

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