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# Influences of Short-term Variations on Energy-Saving Opportunities in a Pulp Mill

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Significant opportunities for energy savings are identified in the hot and warm water system of a kraft pulp mill. Short-term variations in the process are studied in order to identify and quantify the influences of these variations on the energy-saving opportunities. Daily and ten-minute averages of measured data are used as varying input data in a heat exchanger network with fixed heat transfer areas. When the short-term variations are considered, the total energy savings are decreased by about 10%. The steam-saving opportunities correspond to at least 5% of the mill's total steam use, when the short-term variations are considered. At least 65% of the influences of short-term variations are detected already when the seasonal variations are considered.

## 1. Introduction

The pulp and paper industry is faced with great challenges with uncertain energy prices and increasing demands for decreased carbon dioxide emissions (IEA 2007). Significant energy savings can be made in the pulp and paper industry by process integration, but considerable investments are often needed to utilize the opportunities for energy savings (IEA 2007). However, it has been uncertain to what extent process variations influence these opportunities, and this makes the investments riskier. Better knowledge of such influences can be a valuable contribution to more reliable decision-making. Variations in the pulp industry have been examined before (Browne et al. 2004), but not short-term variations in the sense of energy savings. In paper production, some opportunities for energy savings with better control are reported by MacHattie (2008).

The main aim of this study is to investigate to what extent opportunities for energy savings can be realized when taking into account the short-term variations, compared to a steady-state situation. Another aim is to quantify the influences of short-term variations and compare them with the influences of seasonal variations. Examples of the short-term variations in the system are shown in Figure 3.

This study is part of a project to investigate influences of variations on the energy-saving opportunities in the pulp industry. Opportunities for steam savings and extraction of excess heat in the system studied here, and influences of seasonal variations on these

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opportunities, have been investigated in previous research by the authors (Persson and Berntsson 2008). There it was shown that all the steam used today in the hot and warm water system, representing 7% of the mill's total steam use, in addition with a considerable amount of excess heat, can be saved through retrofit of the heat exchanger network (HEN). 15 cold and 25 hot of the most important process streams were used in a pinch analysis to identify energy-saving opportunities and for retrofit of the HEN.

## 2. Studied Mill

Data were supplied by a Swedish market kraft pulp mill producing 425,000 air-dried tonnes (ADt) per year of bleached kraft pulp from both softwood and hardwood. The pulp is produced in two production lines. The study is delimited to the hot and warm water system, which here is defined as hot and warm water and other streams, such as condensates and filtrates, which need heat and hot streams that need cooling. Total steam consumption in the mill is 230 MW (16 GJ/ADt), of which 16.5 MW (1.1 GJ/ADt) of low-pressure steam is used in the hot and warm water system. Examples of the short-term variations in the system are shown in Figure 3. For a more detailed description of the mill, see Persson and Berntsson (2008).

## 3. Methodology

The same methodology of calculations as in the previous study was used to evaluate the influences of variations in this study. Further, the same process streams and a HEN, constructed with annual averages, were used from the previous study. More details about the pinch analysis, design of HEN and economic conditions can be found in Persson and Berntsson (2008). To evaluate the influences of variations, daily and ten-minute averages from one year were used as input data in a HEN design with fixed heat transfer areas. Therefore, the streams used in the HEN will vary over time, and with them, the amount of transferred heat in the heat exchangers. The heat transfer coefficients were corrected with regard to changed flow in new stream data. The variations in individual streams are assumed not to be changed when streams are rearranged in new matches. The influences on the energy-saving opportunities were estimated by comparing the results using daily and ten-minute averages with results when using a steady-state scenario. Here, the consequent opportunities with short-term variations considered were compared with results from the previous study, when using annual and monthly averages.

Measured data, in daily and ten-minute averages, from one year were collected from the mill's information system. In a few cases, data were missing during a period with the ten-minute averages. Instead, averages from nearby parts of the data period were used. Days with very low production, below 650 ADt/d, were excluded from the analysis. Process streams were extracted in consultation with mill personnel. In addition to save steam in the system, excess heat is extracted in the retrofitted HEN. Excess heat is here considered as cooling demand with a temperature of about 90°C or higher. The excess heat can for example be used in process-integrated evaporation (Algehed 2002) or for district heating. District heating is not included as a stream in the pinch analysis. Instead, it is included as a possible user of released excess heat.

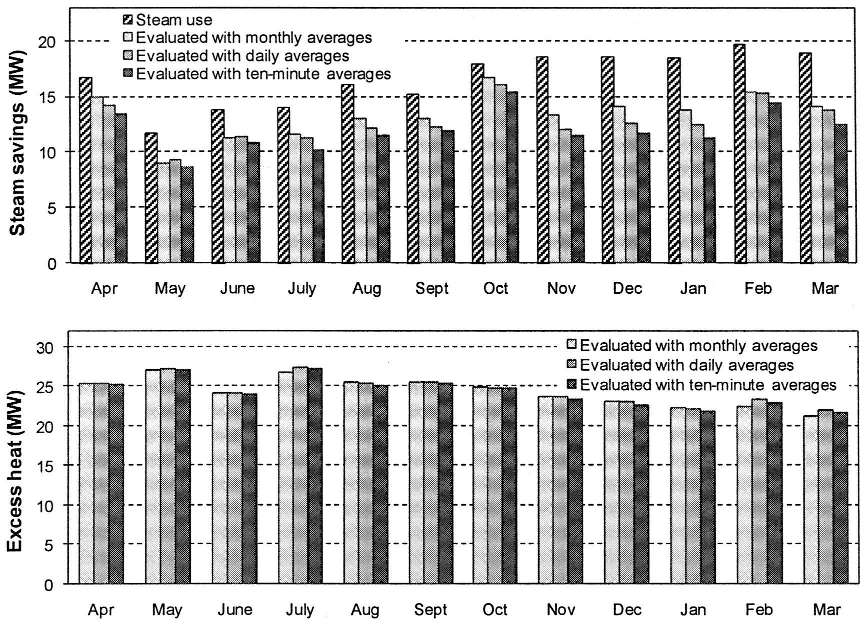


*Figure 1(a-b). Monthly steam savings and extracted excess heat when using monthly, daily and ten-minute averages.*

## 4. Influences of Variations on Energy-Saving Opportunities

Daily and ten-minute averages were used in the HEN with fixed areas and the resulting steam savings and excess heat per month were calculated (Figure 1). Opportunities for energy savings evaluated with daily and ten-minute averages (short-term) were compared with the opportunities evaluated with monthly averages (seasonal). In Figure 1a, also the total steam uses in the hot and warm water system per month are shown. The steam uses represent the theoretical opportunities for steam savings. The opportunities for steam savings are decreased by 19% when using daily instead of annual averages in the HEN, and by 24% when going from annual to ten-minute averages (Table 1). The total energy-saving opportunities are decreased by 8% and 11% when going from annual to daily and ten-minute averages, respectively. Most significant influences from the variations can be seen on the steam-saving opportunities.

*Table 1. Energy-saving opportunities when using annual, monthly, daily and ten-minute averages in the new HEN. Theoretical opportunities are from the pinch analysis.*

| | Theoretical opportunities | Averages, used in the HEN | | | | |
|---|---|---|---|---|---|---|
| | | *Annual* | *Monthly* | *Daily* | *Ten-minute* | |
| Steam savings | 16.5 | 15.7 | 13.3 | 12.7 | 11.9 | (MW) |
| *Share of annual* | | *1.00* | *0.85* | *0.81* | *0.76* | |
| Excess heat | 24.2 | 24.8 | 24.4 | 24.6 | 24.3 | (MW) |
| *Share of annual* | | *1.00* | *0.98* | *0.99* | *0.98* | |
| **Total** | 40.7 | 40.5 | 37.7 | 37.2 | 36.2 | (MW) |
| *Share of annual* | | *1.00* | *0.93* | *0.92* | *0.89* | |

The opportunities for energy savings when using daily and ten-minute averages can then be compared with the opportunities when monthly averages are used (Table 1). The steam-saving opportunities are decreased by 2.4 MW with monthly averages used, compared to 3.0 and 3.8 MW with daily and ten-minute averages used. If the opportunities with ten-minute averages are assumed to indicate almost all of the influences of variations, 63% of the total influences on the steam-saving opportunities and 65% of the total energy-saving opportunities are identified when using monthly averages. Instead, if the influences are compared with the influences when using daily averages, the cases with monthly averages identified 80% of the opportunities for steam saving and 87% of the total energy-saving opportunities. In both cases, the main part of the influences is detected when using monthly averages. Hence, in many cases it would probably be sufficient to take only the seasonal variations into consideration.

## 5. Opportunities for Additional Energy Savings

Another design of the HEN would perhaps result in additional energy savings. In principle, there are two ways of changing the HEN design: to change matches or to enlarge the heat transfer area on existing matches. A HEN designed with a winter extreme scenario was evaluated in previous work (Persson and Berntsson 2008). However, only the influences of seasonal variations were evaluated in that study. The influences of short-term variations on the winter design of HEN are not evaluated. Nevertheless, compared to the HEN designed with annual averages, no considerable differences were found in the decreases of energy-saving opportunities when going from annual to monthly averages, and the total energy-saving opportunities were lower in that case. Probably there would not be any considerable differences in the decreases when evaluating the short-term variations compared with the studied system.

A reason why not all of the theoretical opportunities can be achieved when the variations are considered is that the variations in the process streams in new matches are not synchronized on the cold and hot sides of the heat exchanger. If the new heat exchangers are dimensioned to meet the average heat transfers in a steady-state situation, the heat transfer areas will be underdimensioned to meet variations. However, the areas can be enlarged relative to the steady-state design, with opportunities for additional energy savings. Therefore, the opportunities with increased area were evaluated for all new and enlarged matches. Additional energy savings and the additional investment costs for the extra area were estimated.

The largest opportunities identified are shown in Figure 2. The streams in the matches contain a considerable amount of short-term variations (Figure 3). In three of the four measures, extra area would result entirely in additional steam savings. In the last measure extra area would result mainly in additional excess heat and a minor part of additional steam savings (up to 0.03 MW with 0.23 MW additional amount of excess heat). The measures shown in the figure are independent of each other. Therefore, the individual energy savings can be added. The cheapest measure identified could, for example, give 0.20 MW extra excess heat and 0.02 MW extra steam savings at an additional investment cost of about 11 k€.

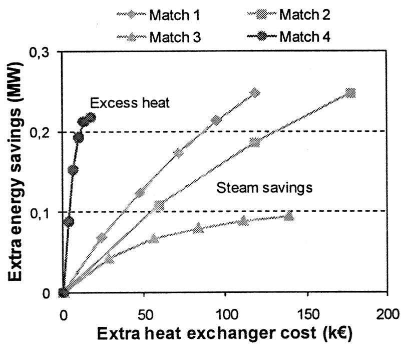


*Figure 2. Opportunities for additional energy savings with enlarged area on single heat exchangers.*

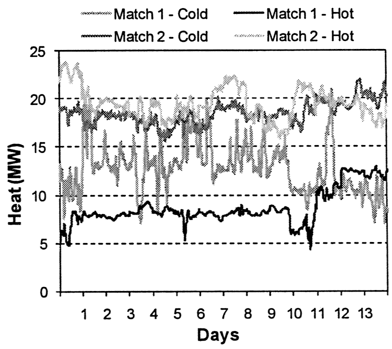


*Figure 3. Heat demand in the cold stream and available heat in the hot stream in two of the matches in Figure 2, ten-minute averages.*

In the two heat exchangers with greatest opportunities for extra steam savings, extra steam savings of 0.22 and 0.16 MW, respectively, could be attained with an additional investment cost of 100 k€ in each match. Considering the high extra investment costs in proportion to the relatively small extra energy-savings, it is doubtful if enlarged areas are profitable in these cases.

## 6. Discussion

The results indicate that the opportunities for energy savings will decrease by about 10% when consideration is given to the short-term variations. The decrease of the opportunities is probably of the same order of magnitude as what can be expected from errors in measurement. In process industry, systematic errors of 5-10% are common in flow measurements (Laukkanen and Launonen 2008). However, the relative correspondences of flow measurements are generally good (Dahlquist 2008). The relative qualities of the measured data are more essential than the absolute ones for estimating the influences of variations, since the distance from the average value describes the variation.

When evaluating short-term variations, time periods shorter than one day are preferable, to avoid lack of information in the variations. Periods shorter than ten minutes are generally not preferable, because it is difficult to control variations with shorter time periods (Dahlquist 2008). In this study, both daily and ten-minute averages were used. Ten-minute averages will best cover up the variations in the system. However, several problems are conceivable with use of ten-minute averages in a HEN analysis. Time delay effects will probably arise if a stream is used in another location, since the transportation times often are longer than ten minutes. With daily averages, most of the delay effects can be avoided, but it is uncertain whether all of the influences from variations will be detected. However, there are no drastic differences between the results with daily or ten-minute averages (Table 1), and the daily averages seem to cover up most of the influences. Therefore, and because of the uncertainties with ten-minute averages, it would probably be a fairly good estimation to calculate with daily averages.

Even though the subject of this study was not to evaluate possible improvements of the control system, the matches in the hot and warm water system were evaluated to find any easy control improvements. As an example, in one match hot water and bleaching effluent to a washing press were heated with steam; there the flow of bleaching effluent is affected by recurrent disturbances. If the disturbances can be avoided through better control, the opportunities for steam savings will increase by 3%, from 0.78 to 0.81 MW, evaluated with ten-minute averages. If this opportunity is valid for other streams, it indicates the potential with improved control.

## 7. Conclusions

- With the short-term variations considered, the total energy savings are decreased by 8% and 11% when going from annual to daily and ten-minute averages, respectively. Most of the decrease is caused by decreases in steam-saving opportunities. Accordingly, in reality it would be possible to extract about 90% of the opportunities that are identified using annual averages.
- The main part of the influences of variations is detected when using monthly averages. Compared with using ten-minute averages, 65% of the influences on the total energy-saving opportunities are identified when using monthly averages.
- Enlarged heat transfer area would give additional energy savings in some matches, but it is doubtful if the extra investment costs justify the relatively small savings.

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## References

Algehed J., 2002, Energy Efficient Evaporation in Future Kraft Pulp Mills. Doctoral Thesis, Chalmers University of Technology, Göteborg.

Browne T., Miles K., McDonald D. and Wood J., 2004, Multivariate analysis of seasonal pulp quality variations in a TMP mill. Pulp & Paper Canada 105(10):35-39.

Dahlquist E., 2008, Personal communication with Professor Erik Dahlquist of Mälardalen University, Västerås.

IEA, 2007, Tracking Industrial Energy Efficiency and CO2 Emissions. IEA Publications, Paris.

Laukkanen V. and Launonen U., 2008, Onsite quality assurance of large flow and energy measurements in paper and pulp mills. 62nd Appita, Rororua, p. 321-326.

MacHattie R., 2008, Better control for energy savings, Paper Making & Distribution, 17(6):16-20.

Persson J. and Berntsson T., 2008, Influences of Seasonal Variations on Energy-Saving Opportunities in a Pulp Mill. Submitted for publication in Energy 2008.