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COMPUTER CONTROL OF A GROUNDWOOD MILL

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Synopsis At a newsprint mill, the running of the groundwood mill is connected with the running of the papermill in several ways by the pulp and whitewater systems and by the supply of electric power. For controlling the groundwood mill in a way that a high and uniform pulp quality is maintained and an optimum use of machinery and resources is made, the groundwood mill crew must continuously supervise this complex system. This is beyond human ability with the limited implements that the crew often has at its disposal. Studies performed at the Hallstavik newsprint mill have shown the limits of human ability in this respect.

In order to give the crew an improved implement, an on-line process computer has therefore been installed in the groundwood mill at Hallsta papermill. The objects of the computer system are planning the production of groundwood pulp and consumption of electric power for a coming weekly period, supervising and controlling the pulp and whitewater system for the entire mill and, finally, reporting.

Owing to these points, the main intention was to reach a more steady running condition of the groundwood mill and improved utilisation of the contract of purchased electric power.

The computer installation, including programs, was completed in autumn 1968, after which test runs with the process were started.

Introduction

THE instrumentation in a groundwood mill is usually rather poor compared with other processes of the same complexity. Therefore, too heavy demands are made upon the crew in the groundwood mill in its work to maintain a high and uniform pulp quality and to make optimum use of machinery and resources with the limited implements that the crew has at its disposal.

In order to give the crew improved implements, a process computer has been installed in the groundwood mill at the Hallstavik newsprint mill. The computer was started up in autumn 1968 and its principal objects are planning and supervising the groundwood mill operation in regard to the pulp and

Under the chairmanship of Dr S. A. Rydholm whitewater system of the whole mill and available electric power. The computer also controls the consumption of electric power for the entire mill.

Before describing the computer system in greater detail, it might be valuable to give a short description of the process and the problems in process control, which we considered capable of being solved with the help of a process computer.

The pulp and whitewater system of the mill

HALLSTA papermill is an integrated newsprint mill. The output from its six papermachines reaches about 1 300 tons of newsprint per 24 h. The mechanical pulp consists of groundwood pulp from 23 chain grinders and the chemical pulp consists of high yield sulphite on magnesium base.

In a mill of this size, the pulp and whitewater system contains a lot of chests, tanks and conveyance pipelines for chemical pulp, groundwood pulp, broke and whitewater. Besides necessary buffers, most of the chests and tanks are level-controlled in the usual manner. In the mill, there are also local closed circulation systems, such as the short whitewater circulation systems of the papermachines (Fig. 1). This flow chart gives a view of the interaction between different systems in the mill.

Each grinder in the groundwood mill is supplied with automatic control of the electric power, so that preset grinder load is controlling the speed of the chains. The crew tries to run the grinder at nominal load, but certain small adjustments of this load set value may be necessary during the sharpening cycle in order to support settled limits of pulp quality. The output level in the groundwood mill is therefore changed by unloading or loading individual grinders. The size of the output change depends on the sizes of available grinders, which may vary 1 500–4 000 kW. These changes of running conditions ought to be as few as possible, however, because a more constant running condition for the grinders influences the pulp quality and uniformity in a favourable way.

From the groundwood mill, the pulp SM is pumped to deckers, where the whitewater systems of the groundwood mill and the papermill are separated. After the deckers, the pulp is diluted with whitewater PW from the papermill and the pulp is then pumped to a buffer tank SV of 3 600 m^3 capacity. Total buffer capacity for the mechanical pulp corresponds to about 4 h production in the papermill. Consequently, certain differences of short duration between output and consumption of pulp can be admitted by these buffers. Before the pulp is pumped to the papermill, it passes through an equalising tank.

External water is continuously supplied to the internal whitewater system of the papermill by mechanical and chemical pulp and by the showers of the papermachines. The surplus water is pumped to a central whitewater buffer tank BV of 3 600 m^3 capacity. From this tank, a certain flow of water is continuously transferred to the internal whitewater system of the groundwood mill, where loss of water normally prevails. The entire mill has, however, a surplus of whitewater and a certain flow of water is continuously drawn from the tank BV through a fibre saveall to the receiver. Requirement of fresh water to the whitewater systems, if such would occur, is taken into the tank BV.

The grinding process requires a large additional flow of water, proportional to the pulp output. It is important that a sufficient quantity of whitewater is always available. By adding fresh water to the system, the temperature will fall, which is undesirable from process and quality points of view. Therefore, the running conditions of the groundwood mill should also be adjusted to the supply of whitewater.

The whole whitewater system ought to be controlled in such a way that inlet of fresh water to the whitewater tank is avoided if possible, because external water is inevitably added to the system at other points. Necessary outlet of surplus whitewater should be as invariable as possible in order to reach a high efficiency in the following fibre saveall. At a wire change in any papermachine, the internal whitewater system of the machine must be emptied and necessary spare capacity should therefore exist in the buffer whitewater tank BV. When the wire change is finished, the whitewater system of the machine must be filled up again and a corresponding quantity of water must then be available in the tank BV, to avoid disturbing other water consuming processes. The outflow of surplus water must therefore be planned over a longer period in order to meet these demands.

Flows of broke UM of varying quantities are circulating in thepaper mill. During periods with extremely large quantities of broke, an overflow can be pumped to the groundwood pulp tanks. The storing of mechanical pulp and broke consumes a large quantity of whitewater. Under these circumstances, high levels in the buffer tanks for these kinds of pulps should then cause a low level in the whitewater tank and vice versa. In Fig. 1, the responsibility area of the groundwood mill crew is indicated by a dotted line.

Electric power

THE grinding process also consumes a large amount of electric power and the power supply must be taken into proper consideration in the groundwood mill operation. Hallsta papermill uses about 1 750 kWh per ton of newsprint. At an output of 1 300 tons a day, this means a requirement of about 90 MW electric power, of which about 60 per cent is consumed in the groundwood mill. Fig. 2 indicates how this power need is met and power of different origin is used in the order given.

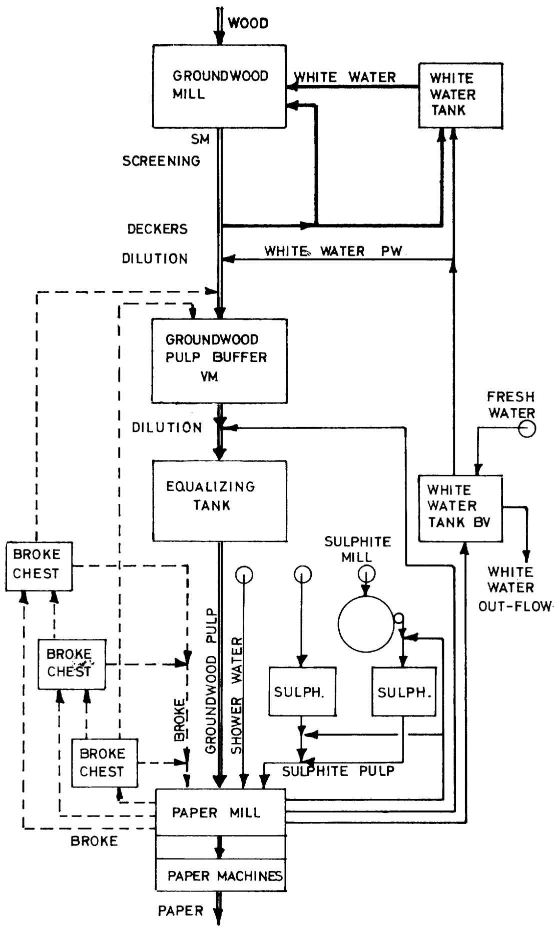

Fig. 1—The pulp and whitewater systems of the mill

Back-pressure power—The principal part of the drying steam to the papermachines is generated at 1 800 lb/in^2 and expands to 22 lb/in^2 in back-pressure turbines. Thus, the generated back-pressure power is proportional to the flow of drying steam—that is, to the output of paper. Accordingly, a break or stop on any papermachine means loss of generated back-pressure power, which is indicated in Fig. 2. Maximum generated power reaches 27 MW.

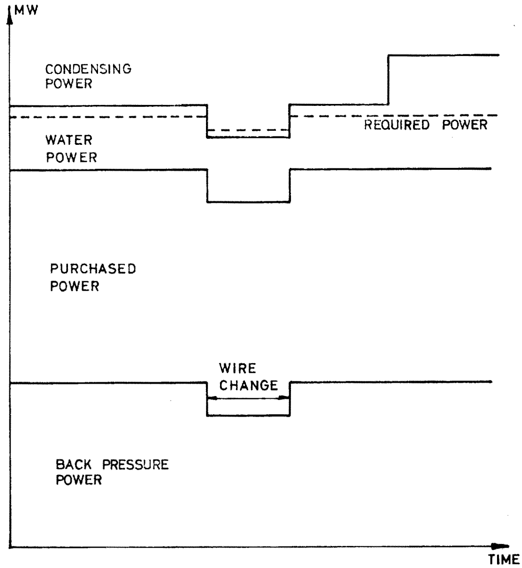

Fig. 2—Electric power consumption in the mill

Purchased electric power—The company is not self-supporting in electric power and about 65 per cent of the entire need must be purchased on a confirmed long-term contract from an external producer.

To obtain the lowest possible price per kWh for purchased electric power, a high coefficient of utilisation is pursued.

Consumption above the contracted power requirement is allowed at a proportionately high price when a surplus of power is available. The purchased power amounts to 60 MW.

Own water power—Remaining balances are supplied, if possible, with power from the company's water power stations, although water supply and transmission capacity to Hallstavik are limiting factors.

Condensing power—When necessary, condensing turbines at Hallsta can generate electric power up to 8 MW.

Under certain circumstances need of electric power might exceed available sources during a wire change on one of the big papermachines.

The power production within the whole company, except back-pressure power, is roughly planned at the head office in Norrköping every Friday for the coming weekly period. The head office also manages the distribution of available electric power to the different production units within the company. The consumption of electric power is continuously checked and necessary steps are taken when unforeseen deviations from the plan occur. More uniform running conditions of the groundwood mill, together with improved control and information, would help the electrical department at the head office to reach improved utilisation of contracted electric power, which is of great economical importance.

The intention with the computer project

THUS, the performance of the groundwood mill is connected with the performance of the papermill in many ways and even connected with the central electric power planning within the entire company. The relative relationship of the systems can be concluded as follows—

1. The output of groundwood pulp has to follow the consumption of pulp in the papermill, except for the degree of freedom that is obtained by available buffers.
2. The consumption of electric power in the groundwood mill ought to be adapted to available power, which depends on the papermill's performance, by generation of back-pressure power.
3. The outflow of surplus whitewater should be as uniform and, above a necessary minimum, as low as possible.
4. The outflow of whitewater should be adjusted to an approaching wire change on any papermachine.
5. The systems should also be co-ordinated in such a way that the performance of the groundwood mill can be kept as uniform as possible, which will influence the pulp quality and uniformity favourably.

Thus, we have seen that the crew in the groundwood mill has to take many variables and many incidences on several places in the mill into consideration, in order to settle a suitable production level in the groundwood mill. Simultaneously, several limitations have to be observed. This is a problem of many dimensions and it is therefore beyond human ability to observe, co-ordinate and control this system in an optimum way. Studies of the manual operation of Hallsta confirmed the limitations of human ability in these respects and the following imperfections were noticed—

1. Changes in the running of the groundwood mill were due to filled tanks for the groundwood pulp, because the crew always tried to keep a high level in the groundwood pulp buffer.
2. Changes in the running of the groundwood mill were caused by loss of whitewater.

3. Periodically, large outflows of surplus whitewater were accompanied by low efficiency in fibre recovery.
4. There was unnecessary inlet of fresh water.
5. Consumption of electric power above contracted electric power occurred in spite of low utilisation of contracted energy.

Any reduction of these imperfections ought to involve several advantages and the problem was to find a suitable implement.

The connection of the groundwood mill to the papermill through pulp and whitewater systems can be described by a number of simple equations of balances. Equations for internal generation of electric power and use of purchased power can also be added. The system of equations proposed in this manner contains only such physical quantities as pressure, flow, time and electrical energy, of which some are easily measured and some could be constant during shorter periods. A correct basis of decision for controlling the running of the groundwood mill should be obtained by continuously supervising the relevant process variables and simultaneously checking them according to established equations. The problem formulated in this manner was considered as a suitable task for a process computer, installed in the groundwood mill and connected on-line to the process.

Further studies of the computer project showed that the project would be paid off in 3–4 years merely by improved utilisation of purchased electric power and decreased loss of fibre material to the receiver. These advantages should be obtained by improved planning for the running of the groundwood mill, thereby a steadier running condition for the grinders should be achieved. This last fact is a main point of the computer system. The objects for this computer system were then confirmed to comprise—

1. Planning and supervising the groundwood mill operation.
2. Planning and supervising utilisation of electric power.
3. Supervising pulp and whitewater systems in the entire mill.
4. Informing the crew so that improved process control can be obtained and the consequences of steps be rapidly surveyed.

The computer system was regarded as an implement for the crew, who still should have the responsibility for running the groundwood mill. Moreover, the system should be shaped so that the present staff in the mill could handle the system and perform necessary communication with the computer.

The final computer system was developed in collaboration with the company supplying the computer hardware and doing all programming work.

The computer system and its function

THE computer was installed in the groundwood mill and started up in summer 1968. As the computer is mainly meant for control of balances for pulp, whitewater and electrical energy, it is necessary to have a great number of input signals for, among other things, levels, power and valve positions. The total number of signals to the computer are 196 digital and 23 analog input signals and 48 digital and 2 analog output signals. Furthermore, 12 pulse signals are fed to the computer.

For the pulp and whitewater balances, the computer must have information about the levels for all cisterns and chests of importance in the mill. The cisterns, which normally or under certain other circumstances are used as buffers, are equipped with analog level signals from electrical differential pressure cells. There are also contact functions for signals, showing full and empty volume. Three groundwood pulp tanks, all broke chests (4), the whitewater tanks of the groundwood mill and of the papermill and four whitewater tanks in the papermill are instrumented in this way. The remaining chests, equipped with local conventional level control and normally operating at constant level, are equipped only with contact functions, which feel if a normal level is existing. The computer interprets an abnormal level as an empty tank. Such digital level signals are also taken from the other pulp tanks and from the machine chests and wire pits on the papermachines.

For the balances, it is necessary to have information also about the production of pulp in the groundwood mill and the consumption of pulp in the papermill. The operating conditions for the 23 grinders in the groundwood mill are given by two contact functions for each grinder, one for chain feeding and one for the pulpstone. In this way, the computer can feel which grinders are loaded and, with information about the nominal power and specific energy consumption per ton pulp stored in the computer, the actual production can be calculated. The computer is even supervising which grinders are available for loading—that means the grinders that have rotating stones, but unloaded chain motors.

The running conditions for each of the six papermachines are controlled by three contact functions. The running condition *on/off* is obtained by a contact signal from the cut-off valve for machine stock to the papermachine. Two break indicators, one just before the dry end and one after the calender stack, signal any break in the papermachine and whether the break lowers the steam consumption, with consequent proportional decrease of generated back-pressure power. Constants for medium production, medium break time and the generation of back-pressure power corresponding to the dry steam flow for each papermachine are stored in the core of the computer.

The outlet of whitewater from BV is measured with a magnetic flow meter. On the basis of this signal and calculated total water volume in the entre mill, the computer controls the whitewater valve, which is the only closed loop control in the system.

The total external power—that is, purchased contracted power as well as own generated water power—is recorded with a central electrical energy meter. At the beginning of every measuring period, this meter is automatically set to zero so that the power consumption during exactly one hour is continuously metered. At the end of every hour, the consumed energy during the hour is recorded and this figure is the same as the average of electric power consumed for this hour. By a pulse transmitter, the signal is continuously read from this power meter into the computer. In the same way, signals from five other energy meters, indicating the internal generated power, are recorded by the computer.

For the six most modern grinders, the power consumption of the pulpstone motors are recorded in the same way. Together with signals from tachometer generators on the feeding chains, the computer can calculate and control the specific energy consumption per ton of groundwood pulp.

Communication between the crew and the computer is made possible by a special manoeuvre desk.

The computer is a serially working machine with a memory cycle time of 5 μs. The memory consists of an 8 K core memory and an external 16 K drum memory. The word length is 24 bits. It is possible to enlarge the core memory as well as the drum memory and the units for output and input signals in modules. The computer is also equipped with a tape reader, a tape puncher and two printers, one for logging and one for alarming. Certain information about consumed electrical energy, which is calculated by the computer, has to be transfered to the head office and is therefore punched on a tape. This tape is translated in a special flexo-writer to a cable code tape and the information can then easily be cabled to Norrköping. Information about available electrical energy is also cabled in the opposite direction.

The computer program system consists mainly of programs for—

1. Weekly planning of the running of the groundwood mill and planning of the electric power consumption for the entire mill.
2. Controlling conditions of the process in relation to existing limitations.
3. Reporting.
4. Alarming.
5. The man's desk.
6. Input and output signals.

The different programs are administrated within the computer by a central executive control program. Every program is written in the assembling language PAL.

The main objects of the computer system are to be found in the programs for weekly planning and control. A further description of these two programs will give a survey of how these problems are tackled by the computer system.

Weekly planning—Every Friday, the different production units within the company forecasts the running conditions during the coming weekly period. Knowing these forecasts, the electrical department at the head office establishes manually a rough plan over generation of electric power and distribution of available power to the different production units. These data are then cabled to the computer room in Hallsta papermill and fed into the computer, together with data for planned stops of papermachines and grinders, projected output of paper in ton per hour for each papermachine and necessary adjustments of constants and parameters, stored in the computer memory. When starting the computer manually, it plans the running of the groundwood mill for the next weekly period for a performance as steady as possible in the following way.

Based upon the process condition at the time of planning, the computer examines through repeated calculation which output level in the groundwood mill will give the longest running time without adjustment. Here, the computer takes fed prerequisites, stored limitations and recorded process conditions into consideration. When the best running condition has been found, the computer calculates the value of the system variables at the end of this period of constant adjustment. These values then constitute the starting point for a new planning calculation for the next period of constant adjustment and the computer continues in this manner until the final moment of the weekly period has been reached. Besides planning the grinding power, the computer also calculates available power for the groundwood mill, necessary flow of wood and any loss of grinding capacity that may occur for every period of constant adjustment. The results are printed out on the logprinter and planning data for electric power are punched on tape.

The result over such a weekly planning period has been plotted in Fig. 3. The thin curve stands for medium consumption of groundwood pulp in the papermill given in MW. The drops of the curve depend on the predicted stops of the papermachines for wire changes, which reduce consumption of groundwood pulp. The running of the grinders ought to be planned in such a manner that these wire changes cause minimum adjustments in the groundwood mill.

The thick curve stands for available electric power for the grinding process, calculated from the information from Norrköping. The available power varies between day and night, which depends on limitations of transferred electric power to Hallsta during daytime. From this curve, it is also evident that stops on the papermachines involve decreased available electric power.

In this case, the computer has recommended a production level in the groundwood mill, according to the dotted line, causing four smaller adjustments in the mill. Other variations in pulp consumption can be taken up by the buffer tank, which is shown by the lowest curve.

Of course, the uncertainty of the weekly plan thus calculated will increase towards the end of the planning period, since many unforeseen incidences will occur in the papermill. New planning can therefore be manually initiated whenever required.

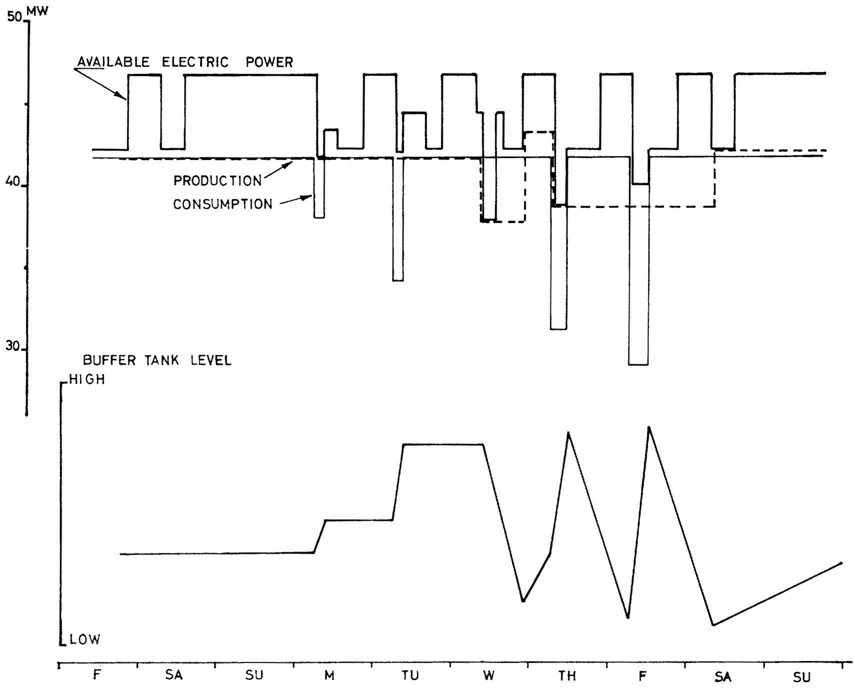

Fig. 3—Planned groundwood mill production for a weekly period

The results of the detailed computer planning of electric power consumption is cabled to head office. With this knowledge, the electrical department can, if necessary, modify its providing plan, among other things reduction of the electric power generation during periods of predicted power surplus, investigation of further generation through, for instance, condensing power during periods of predicted shortage of power. Before the calculated weekly plan is settled, the groundwood mill crew communicates with the electrical department about the possibilities of, for instance, avoiding extra adjustments to the running of the mill because of limitations of power of short duration.

Control and supervising—On the basis of the settled plan for electric power, the computer continues with controlling and supervising the conditions of the process in relation to the existing limits. The supervision comprises among other things the running conditions of the groundwood mill and of the paper-mill, no exceeding of planned consumption of electric power and level control of pulp and whitewater tanks.

The supervision of the groundwood pulp buffer consists of the level as well as its derivate. At the computer, level control in relation to a high and a low alarm limit, the volume of broke is taken into consideration according to the unequality—

$$VM_{min} < VM < VM_{max} - (VU - VUL)$$

which means that the level in the groundwood pulp buffer VM may not fall below the lower limit VM_{min} and not exceed the upper limit VM_{max} corrected with the volume of broke that exceeds a fixed normal level VUL. The derivate of the buffer level is limited according to Fig. 4. These limits depend on the

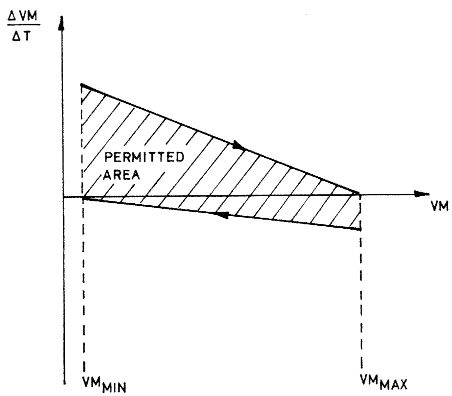

Fig. 4—The limitations of the buffer tank level derivate as a function of the level

level in such a manner that the permitted positive derivate of the level decreases to zero when the level approaches the upper limit and the permitted negative derivate of the level decreases to zero when the level approaches the lower limit. The shape of these curves can easily be adjusted by parameters, which thus make an implement to adjust the controlled level of the buffer. If any of these limits are reached during the supervision function of the computer, new planning is automatically initiated according to the principle described above. The results of this planning are printed on the alarm printer and this recommends to the crew what adjustment ought to be made to the running of the groundwood mill.

When the providing of electric power for Hallsta is planned, a margin of 2 MW is calculated to the upper permitted limit of purchased contracted electric power. This margin allows one normal break on one of the large papermachines during the measured hour without exceeding the power limit. If a break at the same time should occur on another papermachine, it would be impossible to keep the power limits, owing to loss of generation of back-pressure power. Therefore, as soon as any break signal is recorded by the computer, a control calculation of the electric power situation is automatically started. If no deviation from the planned running and no breaks on the papermachines occur during the power measuring period, the calculated margin between maximum permitted consumption of purchased power and real consumption will be obtained.

A break signal from any papermachine initiates the computer to make a control calculation to find out if available electric power margin will be exceeded during the present measured hour. This control calculation is based upon values for every papermachine concerning medium break time and loss of generation of back-pressure power in connection with a break, which are stored in the memory of the computer. The principle of the calculation is shown in Fig. 5. The two upper curves stand for the upper limit of purchased contracted power NL_{max} and corresponding limit NL_{PL} used at the planning. Thus, the difference between these two levels is the margin of 2 MW mentioned above. During the measured hour, a break on a papermachine has occurred and an increased need for purchased power during the break time is required (the dotted increase). The lower curve shows consumption of purchased energy metered during the measured hour. When the break occurs, the control calculation is initiated in the computer and the energy consumption is predicted to the end of the measured hour. In this example, the break caused the predicted consumption of purchased energy to exceed the permitted consumption at the end of the hour (dotted curve). The computer gives an alarm to the crew if the predicted energy consumption is to exceed the permitted consumption and when this will occur. The crew may then decide how to avoid this 'overconsumption' either by blowing off steam in order to avoid decreased generation of back-pressure power or unloading a grinder or simply by ignoring it. If the break on the papermachine should be longer than the medium break time, stored in the computer, the break will be interpreted as if one more break has occurred.

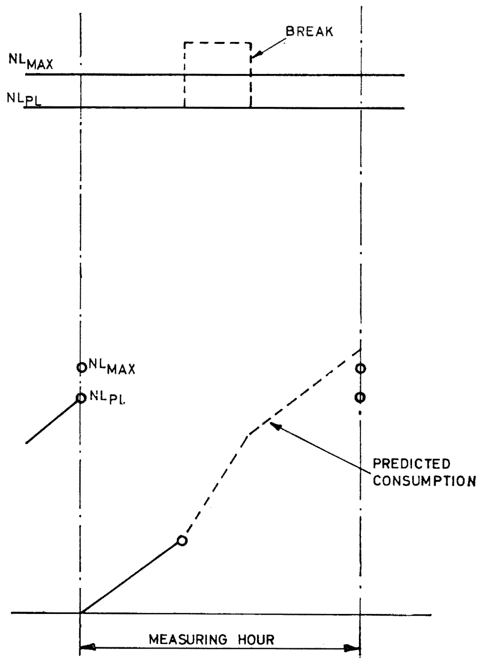

Fig. 5—The principal control calculation of the electric power situation

A continuous outflow of whitewater is needed to keep the total quantity of whitewater in the system in balance. The computer calculates the total water content of the system from the knowledge of all level signals. The deviation of this water content from a set value constitutes the control deviation, after which the outflow of whitewater is adjusted. The set value calculated in this way is compared with the real outflow and the difference constitutes the control impulse.

In connection with planned wire changes, the computer controls the outflow of whitewater so that necessary space exists in the whitewater system at the starting point of the wire change to take care of the whitewater, pumped over from the wire pit of the papermachine. When the wire is changed, the necessary quantity of water should be available to refill the whitewater system of the papermachine without taking in any fresh water.

The computer also informs the crew about the condition of the process. The most important area of this information ought to be the calculation of specific energy consumption per ton pulp for every six grinders in our No. 3

groundwood mill. These calculated values are printed out once an hour as medium values during the hour. Medium values are also calculated for every shift and every 24 h.

Certain supervised variables are put together in a day report, which comprises, for instance, running time for the grinders, specific energy consumption, stop time and break time for the papermachines and medium value of outflow of whitewater.

Conclusion

ON THE whole, it has been possible to bring the computer system into operation according to the prearranged time schedule. About 6 months' delay in delivery of the central unit, however, caused a corresponding delay in starting the system, which took place only in the autumn of 1968. During the short period of running the computer system, the work has mainly involved the trimming of some programs, program parameters and measuring signals. Therefore, any analyses of the results from the installation have not yet been performed.

Experiences so far indicate, however, that the computer system will be functioning according to projected plans—that is, steadier groundwood mill performance and improved utilisation of contracted electric power will be reached. It has also been possible to discover that the grinders whose specific energy consumption is supervised by the computer produce a more uniform groundwood pulp quality than do the other grinders.

At Holmens Bruk, we hope to have an opportunity of returning to this subject on a later occasion and then give a description of results reached with this computer installation.

Reference

1. Sandblom, H., International Federation of Automatic Control, IFAC Congress, Warsaw, June 1969 (paper 66.1)

Discussion

The Chairman This session has taken us through the forest operations, the chemical pulping of the wood, its semi-chemical and its mechanical pulping and the interphase to the papermill.

Mr G. E. Annergren Mr Alsholm mentioned updating of the packing of the measuring wheel in the continuous digester. Have you done so? If so, how and what accuracy have you obtained?

Mr O. Alsholm I said that possibly we could get greater accuracy by doing so. We are looking into this matter, so I cannot give you an answer at present.

Mr Annergren We have tried to do so, but we have failed so far.

Dr N. K. Bridge May I direct two questions to Mr Alsholm.

I think you said in your paper that the production scheduling program uses 15 K words and takes about half an hour to run, off-line. Could you give us a breakdown of this program? For instance, could you indicate how much of the program is involved in the Pontryagin optimising calculations and how much in the scheduling routine proper?

The second question is— to what extent have you written the program in order to take care of the mishaps that occur in the best regulated mills, such as the machine wire dropping off?

Mr Alsholm On the first question about size, our variable core is 8 K. The calculating part requires just about this size. The rest of the 15 K are divided into one input and one output core load.

In the sense you have mentioned constraints, we have now ordered a 56 K machine (2 μs) with floating point hardware. Without this, the calculating time is about half an hour off-line, corresponding to maybe more than an hour on-line. It is rather unlikely that we are able to use this program to the full extent before we get the features mentioned. We plan that, if the wire drops off, as you say, to run the program again. I also think it will be important for the production management to be able to run trials that take only, say, 5 min on the computer and change the input if necessary (and if possible).

Mr J. A. Robinson Can you give us any specific figures of the accuracy of your method of calculating chip moisture content? Secondly, the method seems to imply that all changes in chip bulk density are in fact caused by changes in moisture content. I would like your comments on the validity of this assumption in the general case of a mill receiving chips from many sources?

Mr Alsholm Starting with the last point, we are at this stage assuming a constant packing density independent of moisture content. I have not shown any accuracy figures today, because we are working on this. We are trying to see, for instance, if the high speed of the chip metering wheel will give higher offsets compared with manual samples? Moreover, if it is very dry, as it was during this very hot summer, do we get other packing densities, etc.? The only comment that I am prepared to make now is that we use the calculated moisture for closed loop control!

Mr D. L. Cooper Have you found the model that you use sensitive to the parameters introduced at the beginning—for example, the conditions that the tank should begin and end at a 50 per cent level and vary between not more than 15 per cent and 85 per cent? The figures in the diagrams indicate that the levels change by almost the full amount that you allow. I wonder whether the restriction that they should be at 50 per cent at the beginning and start of the operation constrains the model unduly.

Mr Alsholm In the calculation, we always start with the levels that we can measure 'now', but we do not intend to run on recommended schedule until we reach the end of the period. Before we reach that point, we recalculate, maybe several times. We have to have some goal for the future, though this may not necessarily be 50 per cent. We have found that 50 per cent gives us better 'chances' in the next planning.

Mr B. Pettersson In principle, another choice of end point will change the production schedule. This fact is not so critical, however, since the solution technique developed implies that we try to reach the end points if we can. If we cannot, we will achieve final levels as close to the fixed ones as possible.

Dr L. G. Samuelsson With what accuracy was Mr Alsholm able to calibrate the moisture gauge on the machine by the weighing of the reel?

Mr Alsholm We have been investigating the accuracy of this method, especially when we had a fixed head meter. Today, we have a traversing meter and it is not so critical any longer. I recall the estimated accuracy, however, to be $\pm 0{\cdot}3$ g/m^2 (at 70 g/m^2), in reality better than ± 1 g/m^2. The calculated changes are of the order of less than 0·5 g/m^2.

Dr D. B. Brewster The paper by Alsholm & Pettersson gave a detailed description of the mathematics involved in production scheduling at Billerud. The problem at Holmens Bruk is similar, but no information is given in the paper on the method for its solution, except to say that it involves some simple equations.

Mr O. Svensson We are using a heuristic model with very simple mathematics.

Dr Brewster That covers a broad field.

Dr R. L. Grant Would Mr Alsholm please give us his estimate on the time that it took (or will take) to pay off the cost of installing and starting up the installation and tell us of the areas from which the improvements in economics came?

Mr Alsholm That is a very interesting question. There is no basis of comparison on a new machine, for you do not know how the machine would have started up without computer control. Some of our findings are as follows. We started up the second project by putting the digester control on before the papermachine control. This resulted in a very significant rise in production capacity of the papermachine. We have not seen the same large rise when closing the loops on the papermachine itself. Other parts of the system were of great help during start-up for process studies. Being somewhat concerned about the NSSC sulphate pulp ratio, we designed a system, for example, that continuously calculates heat transfer coefficients in the evaporators. I think that nobody in the world has the ratio of about 130 000 tons per year NSSC pulp to about 150 000 tons per year of sulphate pulp.

The process control was not meant to be the bread and butter, only the bread. It would break even and it would give some return on the investment, but the major point was the entire planning system, as we considered that optimum scheduling could not be achieved manually. We have not yet put this part into operation, so I could not give you the whole answer today. On the other hand, the process control part seems to be more profitable than expected. In addition, the intangible benefits from, say, the extensive reporting system have to be credited.

Mr H. B. Carter I wonder if either of the two speakers has considered the possibilities for changing the system with all the new facilities available. Actually, in spite of a large amount of control equipment in the form of computers that have been installed at Sundsvall, we apparently have not changed the system; we still have the same people working, we are going the same way and the other mill at Hallsta still has the same large number of tanks. Does anybody consider with all this sophisticated brainpower that we might be able to do away with the pure man on the papermachine?

Mr Alsholm I think this is a very important point. During our last expansion and even more during the coming one that I mentioned, we have worked and will work along the systems engineering path. We have made very thorough simulations to see how large the storage tanks need to be and so on. On the other hand, we have done nothing really revolutionary, although we have, for example, a rather unconventional machine chest configuration for our fourth papermachine.(2) I believe such solutions are of real importance and that more of such things will have to come—of course, Rome was not built overnight.

Your question about the number of people is 'a wrong question', as savings in personnel yield very little compared with an increase in production.

We have decreased the number of people in the papermill, however, about as much as we have the people on the computer project. In the new fluting mill, for example, we have one man at the chip pile, one at the digester, three at the papermachine and two at the winder. This is a 130 000 ton per year mill, which gives a very low man-hour/ton figure.

The Chairman There is a project management in between also.

Mr J. A. Smith Ever since Pontryagin's work became known, there have been papers that aimed to apply his work to a practical situation. About halfway through many of these papers, however, the mathematics became quite intractable. The problem would then be modified to allow of a solution that was computationally feasible, but no longer applied to the practical problem. The authors are to be congratulated for reaching the same moment of truth about halfway through and inventing some new mathematics to allow the original problem to be solved.

My question relates to a mill producing pulp for sale as well as for supplying the papermachines for which maintaining the maximum rate of pulp production is the extra objective. In this case, does the solution of the problem lead to intractable computations once again or can the methods described in the paper cope with this?

The Chairman You really scared me, because we have recently changed the project to involve market pulp as well in the program and I hope therefore Mr Pettersson does not have to do all those formulas over again.

Mr Pettersson It is not necessary to develop other methods, we can handle this case, too. It is quite possible to include in the optimising function a requirement for maximisation of the pulp production.

Dr J. H. Sandblom In this last discussion on whether or not a computer system can have any influence on the papermill layout, it is quite obvious that it may. In the Hallstavik case, the computer strategy and the process was simulated in a way that is well-known nowadays at the ASEAS computer centre. This gave rise to changes in the process, specifically to buffer tanks and a few pipes.

The planning program in the Hallstavik systems is simple in principle and straightforward. It is an iteration procedure, in which the computer in each iteration lays out the electric power limits, calculated from the given power limits, production and consumption at every instant of the planning period for all the mills in the Holmens Group. The reason for this, of course, is that all the machines in the various mills are consuming power, but are also producing power when in operation. The program searches the best way through all the various limitations.

Dr J. Grant One of my principle interests is pulps from non-woody fibres and these are usually produced in comparatively small mills in out-of-the-way places of the world where the problems are entirely different from those we have been talking about.

Firstly, such mills are usually in countries that have little or no pulp or papermaking industry background. Secondly, they are comparatively small; thirdly, they handle raw materials that are mostly entirely different from wood; fourthly, the cost of installing computer control may be a very much larger proportion of the total cost of the mill than for a large woodpulp mill. Fifthly, the question of saving labour is seldom important—in fact, in many cases, an object of the mill is to provide employment. It seems, however, that computer control not only saves labour, but also performs operations more accurately than by hand—an important consideration on its own. Sixthly, there is the problem of the maintenance of delicate instruments and sophisticated electrical systems in a developing country.

Can anyone here guide me how to estimate in advance whether one should install a computerised system and, if so, to what extent, bearing mind that these are usually integrated pulp and papermills? This is a very important question that frequently arises.

Mr K. D. Blundell My experience in developing countries suggests within the context of the question the use of simple and minimum essential instrumentation only. Unfortunately, in these areas, the skills required for the maintenance of sensitive equipment are not easy to come by.

Mr A. J. Ward Could I ask Mr Svensson to enlarge on the point he made in his presentation that they decided not to develop the computer control scheme themselves, only contributing one man to the team. In our experience, the computer control field is extremely volatile and we would feel very reluctant to allow an outside organisation provide so large a part of the technical skills. Could you enlarge on the decisions that were taken and the criteria that were used?

Mr Svensson Our philosophy was to take out a sector of our process where computer control indicated that it would give satisfactory profitability. This sector constituted the first phase of a greater project, which would be profitable in itself. The first phase is now completed.

Our intention was also to buy the whole system as a package from a supplier with a minimum share in the programming work. I think our way of realising this computer project was the most convenient for our company.

Mr Alsholm I think we have so far taken the stand that we should be able to do everything ourselves. This does not mean that we are doing or will do all ourselves. Certain development of standard packages must be the responsibility of the vendor and you may need assistance during expansion periods from a systems consultant. So long as you build up a system on which you want to continue to work, I believe you should carefully decide how much you buy from others.