Optimising steam load demand in a paper plant

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Introduction

In a number of process industries, energy is a critical resource. In paper and pulp industry chemicals and fertilizers, energy costs are a major proportion of the input costs and this proportion is increasing every year as energy is becoming an increasingly more expensive resource.

Energy Conservation, therefore, is extremely important in the Indian context, particularly as specific energy consumption is relatively high in various Industrial sectors. Like charity begins at home, it is best to take up first Energy Conservation measures in the Power House itself. Optimal generation and utilisation schedules introduced in the Power House, can result in considerable cost savings in terms of the total energy bill.

In this paper, we will take up the issues of optimization of load and steam demands in the power house and the efficient utilization of steam generating capacities. We will suggest certain methods which can be utilized by a process industry and show how this can held in reduced costs of energys thereby improving specific energy consumption. The schemes proposed here have been incorporated in a target plant–the plant of M/s Straw Products Limited - Jaykay Paper Mills Ltd. at Rayagada Orissa.

The optimal use of in-house energy resources can be broken up into the following problems :

a) How much electricity is to be bought from the Grid and how much is to be generated in house ?

b) If electricity is generated in house, what should be load allocation on the generating sets considering the limits of the generating units existing within the power block ?

c) What is the most efficient method of meeting process steam demands ?

d) Given a total demand on the boilers, how are the boiler loads to be allocated ?

The above assumes that there is a generating capacity within the plant and both electrical and steam demands are there on the power house. While the above can be considered as a higher level optimization problem, there are two other problems which fall within the ambit of energy optimization in the plant. An efficient control system and proper set points of excess air can increase the efficiency of the boilers.

The continuous monitoring of the efficiency of each unit using computerised efficiency calculations can be a useful and sensitive tool for evaluating the performance of the boilers, thereby, reducing fuel consumption. In case there are major steam loads, a proper schedule of the same can lead to a more even loading resulting in better utilisation of the power house steam and electrical generating capacities.

We will attempt to show below the various implementation strategies which have been adopted for the specific plant in question and indicated the various energy management schemes installed there.

An Optimal Strategy for Achieving Energy Economies

In any industry where process steam is raised and power generated in house, there are a mix of turbines and boilers to serve these needs. The problem of allocating the loads on to the turbines and boilers and

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deciding how much extraction steam is to be drawn from which turbine or PRDS is generally based on the operating staffs experience. It should be recognized that there are a large number of ways in which the process demands can be met. The most economic way can only be chosen if the problem is formulated as an optimization problem within a mathematical programming framework (1, 2). The difference between choosing the least cost option and any other feasible operating point can be as much as 4% or 6%. Over a year, this adds up to substantial saving in energy costs.

The Optimization Problem

The optimization problem can be reduced to the following physical questions or sub-problems :

i) How much power is to be bought from the grid subject to the maximum limits of power withdrawals ?

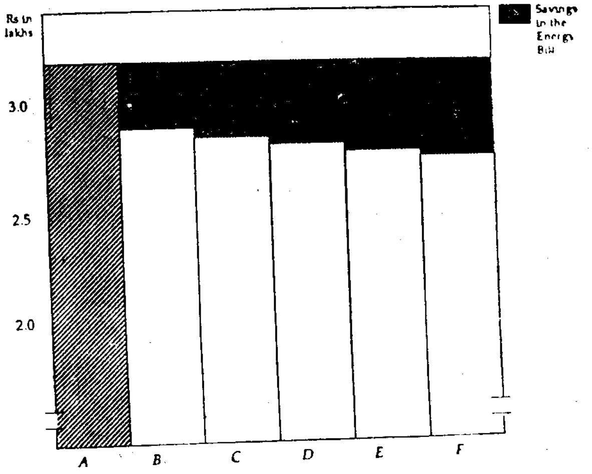
ii) How much extraction is to be done from each turbine at each pressure ?

iii) How much loading is to be done on each of the available turbo-generators ?

iv) How much steam is to be raised in each of the available boilers, after taking into account steam availability from recovery/waste-heat boilers ? In case of multi-fuel boilers, what fuel-mix to be used ?

The above problem has been divided into two sub-problems. In the first case, the electrical power bought from the grid is fixed and then the power house operations are optimized. This is defined as the steam load optimization problem. In the next part of the problem, the purchasing of power is also optimized. This is defined here as the electrical load optimization problem As a part of the feasibility study, we had carried out the energy improvements that would occur if an optimal load allocation was carried out all the time. Obviously, these results are only ideal and can not be achieved as there are a variety of plant constraints which make such an optimal load allocation impossible. However, the feasibility did show the scope for implementing an EMS to do the above and achieve considerable energy savings, if not the theoretical values. The results of the feasibility study is shown as Fig. 1 (a) and 1 (b).

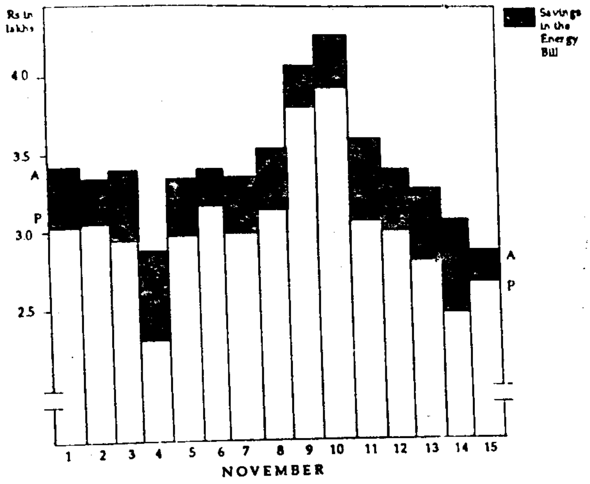
Fig. 1 (a) The Actual Energy Bill and the Potential for Cost Savings on a per day Basis



A: Actual expense on Energy, daily average for the period 1 to 15 November 1990
B - F: Energy costs as generated by the System.
B: Base Case with purchase of power from the grid fixed at Actual level
C: Base Case with higher process demand for 10 ATg steam.
D: Base Case with fluctuating intra-shift steam demand
E: Base Case
F: Base Case with lower process demand for 10 ATg steam.

Fig 1 (b)

The Actual Energy Bill and the *Potential* for Cost Savings for each of the 15 days of the reference period 1 to 15 Nov. 1990



AA: Actual expense on Energy, for each of the 15 days
PP: *Potential* Energy Costs for each of the 15 days

The plant in question has seven boilers, three TG sets, one DG set and a demand of the order of 10 MW along with about 50 tonnes/hour of process steam.

The basic configuration diagram of the generating equipment is given in Fig. 2. There are a set of four stoker fired boilers, two liquor fired boilers and one waste heat recovery boiler. The plant has two extraction turbines, one back pressure turbine, and one DG set.

In addition, the plant is also making purchases from the Grid. In this case, neither the generating equipment nor the Grid were synchronized. This made the task of shifting loads a little difficult as only blocks of load could be shifted. The major steam demands, namely withdrawals for digesters, caused fairly large fluctuations on the steam side. The task of the Energy Management System was considered to be the following :

a) An Energy Management System for allocation of electrical and steam loads for the generating equipment.

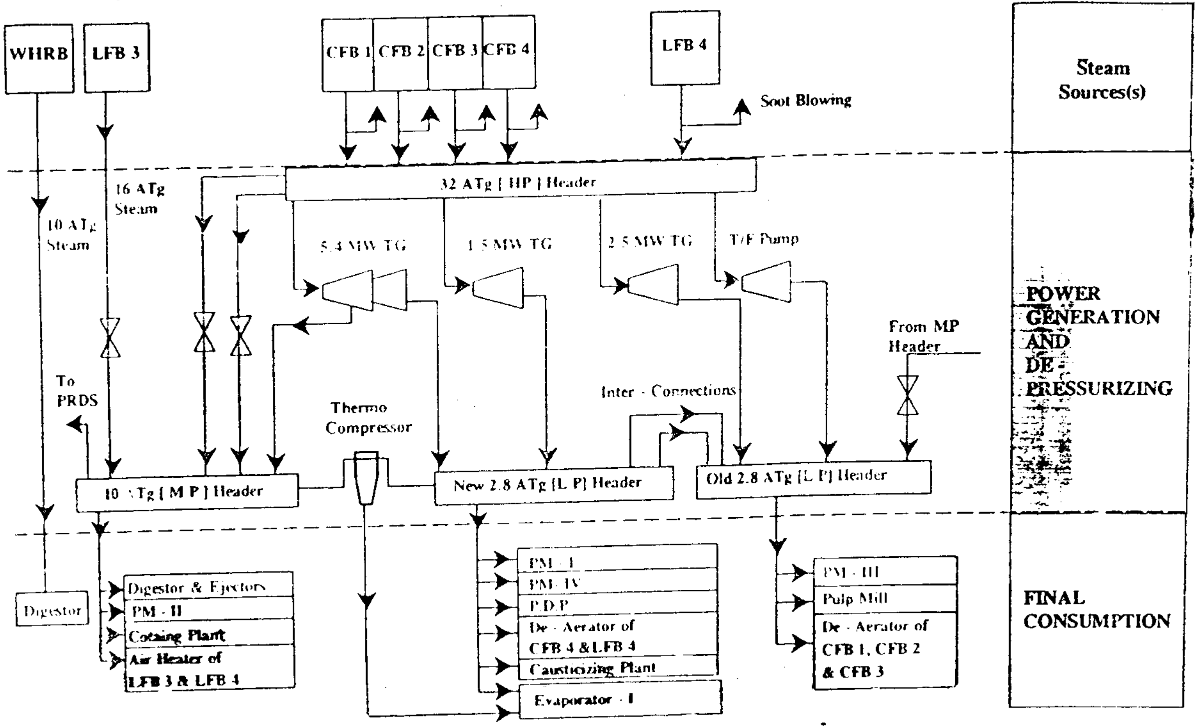
b) Providing a schedule for Digester's steaming.

c) Providing tools for continuous efficiency monitoring of the boilers.

It was felt that a three pronged strategy of the above type would lead to considerable energy savings.

Load allocation problem was first solved as an electrical load allocation problem, using a heuristic algorithm. The loads that can be shifted were only those which can take a process interruption. As the number of such loads were few, it was simple to evaluate the margins available on the turbo generators (TGs) and examine the possibilities of shifting loads from the Grid to the TGs. An off-line analysis had already indicated that under most operating regimes, the in-house generation using captive TG sets were more economical than Grid power purchase. The heuristic algorithm evaluates the cost saving that would result by meeting electricity demands from in-house sources and suggests shifting of load accordingly. Once the operator has accepted load shifting recommendations, the target electrical demand is furnished to a

(Fig 2 STEAM GENERATION, USAGE & CONSUMPTION PRESSURE & HEADER - WISE



model of the plant. The model generates the matrix which is then solved using mixed Integer Linear Programming (MILP) techniques. The resulting load allocations of turbine extractions, boilers and the PRDS provide a more efficient way of meeting the total steam demands. Once the process steam demands are met by manipulating the PRDS and turbine extractions in line with the recommendations of the Energy Management System, suggested boiler load allocations can then be carried out.

If the electrical system is synchronised in the plant, the optimisation problem can then be reduced to solving the above MILP problem incorporating the electrical system also as a part of over all energy model of the plant. This is a relatively straight toward problem and easier to implement than the two step method implemented above.

Other Aspects of the System

In the section above, only the salient aspects of the System have been described. Over and above these, the System has the ability to handle other operational problems, such as that of changing intra and intershift downstream process steam and power demands and the accommodation of spinning reserves.

The System has been implemented in an *off line* mode. Here, all the plant-specific engineering and other logistic information are embedded into the System. Only the parameters that tend to change, namely steam and power demand, equipment availability and operating conditions, are fed into the System by the operating personnel, through an interactive mechanism. The System then generates the *least-cost set-points* and the plant has to be run by the operating staff at these set-points to realise the energy savings.

A real time or on line version of this System which can interact with the Control System of the plant, has also been developed. This version ensures that the plant is run along the *least-cost* path all the time. This system can be hooked in with most existing control systems, thereby allowing for automatic data acquisition and remote set-point loading.

Converting the off-line Energy Management System to an on-line form is not difficult and has already been outlined elsewhere (3). This would consist of linking up the Energy Management System with plant instrumentation and controls so that on line data can be directly furnished to the package instead of being entered manually. Suggested set points can also be implemented by incorporating suitable ramp rates furnished by the computer to respective controllers while limiting such changes to stable and safe operating regimes of the plant.

Boiler Efficiency Calculations

A continuous monitoring of boiler performance would provide important information with regards to operational data as well as maintenance decisions. Thus the monitoring boiler losses can help in deciding when the boiler needs to be taken out for maintenance. Therefore, certain maintenance decisions can be helped by knowing the amount of losses that the plant is incurring as against the losses involved in a boiler shut down. It is also possible to see what is the most efficient point of operation in terms of the set points for minimising losses. From both considerations, an efficient calculations package provide effective monitoring tools for the plant management.

Efficiency calculations package for a coal fired boiler should be preferably based on the heat loss method. The American Association of Mechanical Engineers (ASME) provides both alternatives-input/out put and heat loss method for computing boiler efficiency(4). However, as the coal input measurements are generally inaccurate, the input/output method is held to be far less accurate than the heat loss method(5). The package developed for the target plant therefore uses the heat loss method.

The heat loss method computes the boiler losses-stack losses and other losses like unburnt fuel, radiation and other fixed losses. Dynamic measurements required are few, namely excess air/O_2, input/output temperature to the boiler and the boiler load. Other data are derived from the coal analysis. The method is fairly accurate though it needs certain performance data from boiler manufacturers. Alternatively, American Boiler Management Association (ABMA) charts are available for computing some of them.

The excess air losses and the unburnt losses for each load point can be generated for the most efficient performance of the boiler, thus helping to improve boiler efficiency, It is known that the curve for excess air losses and the unburnt losses are inversely corelated. The corelation of excess air and the unburnt fuel is plotted against excess air increase. It is obvious that the plant should operate close to the intersection of the two curves in order to minimise losses (see Fig.3). The efficiency calculation therefore helps in identifying the point of optimal operation for each load point.

For the target plant, the fixed losses have been computed using the ABMA charts and aggregate plant computations for efficiency of the power block. The package was found to give a good correspondence to the plant computations of efficiency. The efficiency calculations have the advantage that they are based on each actual boiler data and therefore can be used to optimise the efficient performance of individual boiler unlike the current method which only does aggregate computations of all the boilers. The plant was using a variant of the input/output method, as the coal flow is available only for the power house as a whole, therefore only aggregate efficiency of the power house as a whole was available.

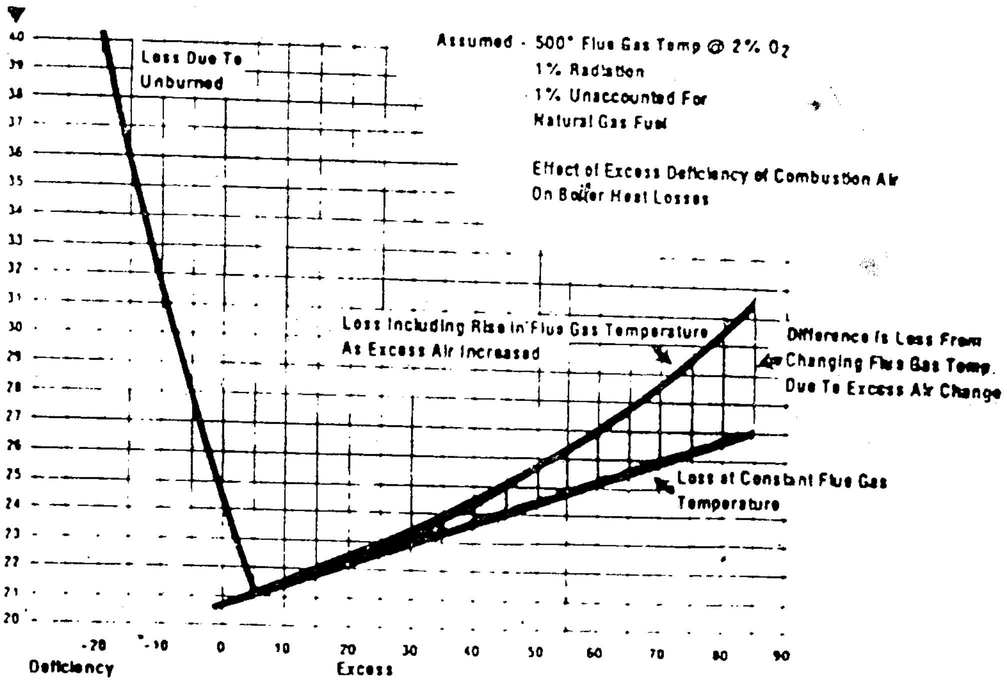


Fig. 3 SOURCE : IMPROVING BOILER EFFICIENCY BY SAMUEL G DUKE LOW

Steam Load Schedule

Scheduling of major steam loads on the boiler house can considerably smoothen the load curve. Further, if the load curve is smooth, the performance regimes of the turbines are conducive to a more efficient operating regime. For the target plant, the major loads which could be scheduled to smoothen the load curve are the Digestors' steaming and Soot blowing operations of the boilers themselves. It is obvious that unless a certain amount of discipline is maintained for the above, a sudden demand on the boiler house would cause major problems for the plant. The plant had already a scheduling scheme for the Digester steaming. For operational reasons, it was necessary to provide a Digester schedule which would not be radically different from that of the current one. The scheduling for six number of digesters available in the plant, produce a certain number of peaks and troughs. The trick was really to fit in the soot blowing operations within the troughs produce by the Digester schedule. Figs 4 and 5 show the Digester schedule, the steam consumption of the Digesters as well as the total steam consumption including soot blowing. The algorithm used was a heuristic one by which troughs were recognized by some predefined criteria and the soot blowing operations scheduled within the trough period. The resulting steam demand produced a relatively smooth load curve and reduced the peak demands on the power house.

Conclusions

The sections above have detailed three major areas included in the energy management scheme of the target plant. Scope of the Energy Management System package can be considerably enhanced if the electrical system are synchronized and the computerised Energy Management system interfaced with the plant instruments and control system. The approach adopted here is perfectly general and can be used for any other plant where there are similar load and steam demands. It is felt that given the current specific consumption of energy in our products, considerable scope exists for improvement, with the power house providing a good staring point.

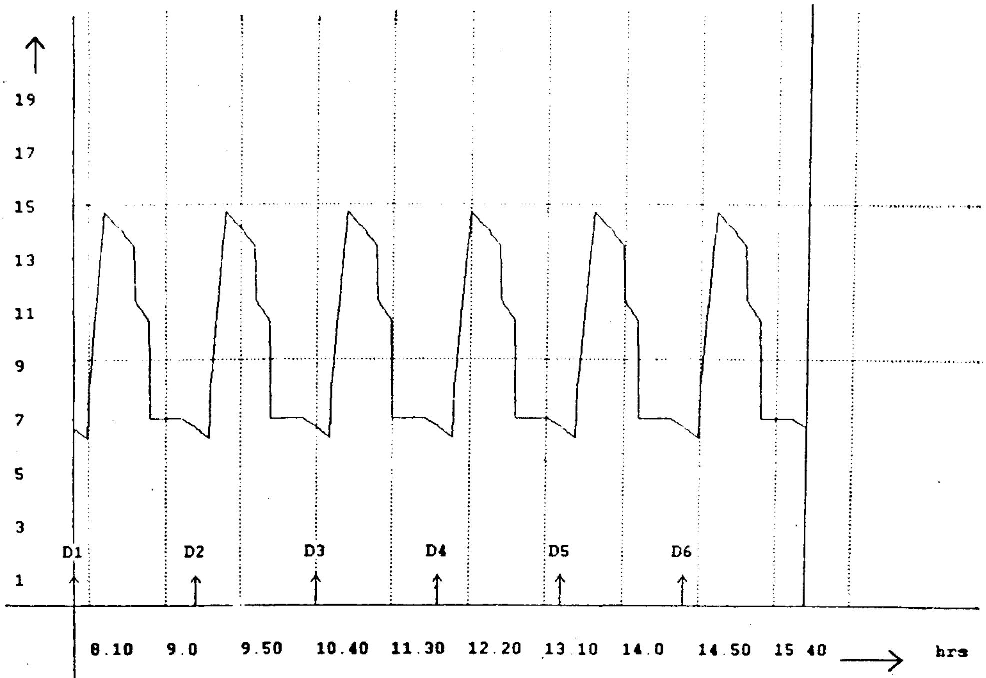
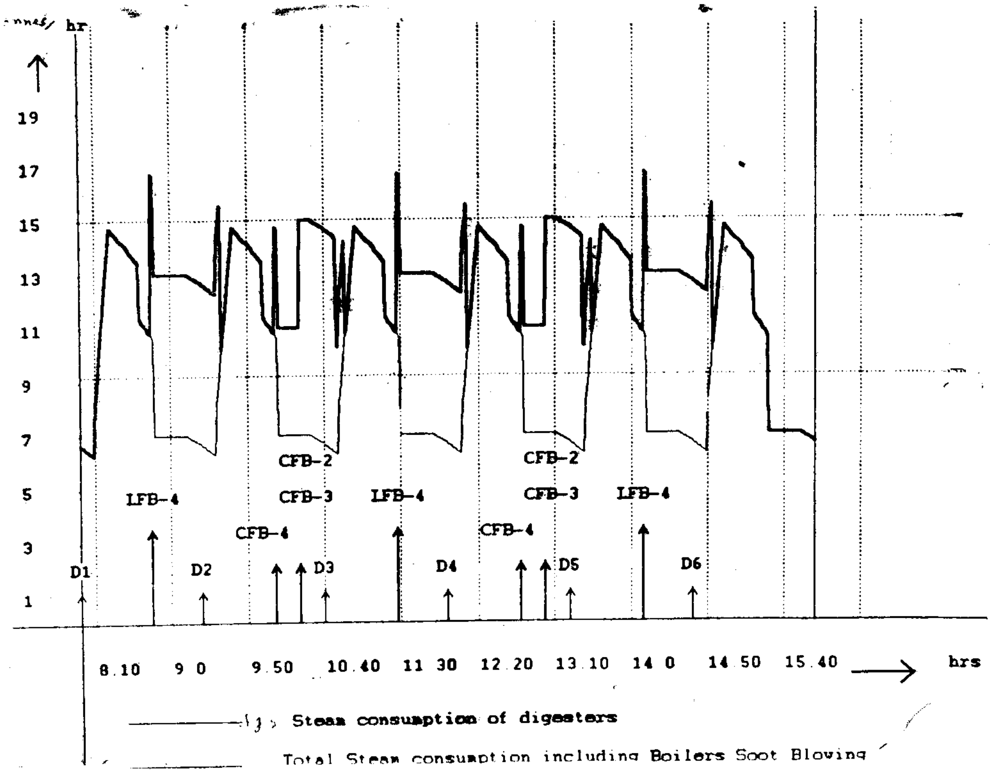


Fig 4 Steam consumption of digesters



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