Energy Efficient Practices For Indian Paper Mills

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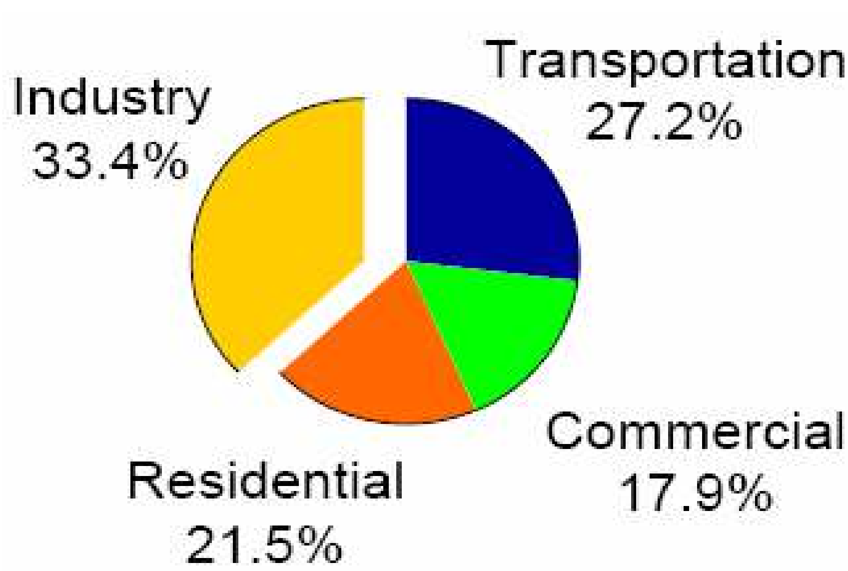
Introduction

Global concerns about climate change and declining resources mean that major companies must do their best to produce and use energy as efficiently as possible. Energy is an integral component of a modern economy. It is an essential ingredient in nearly all goods and services, but its use exacts heavy financial, environmental and security costs. A key method of reducing energy's costs while retaining its benefits is to use it more efficiently. "**Energy saved is double the Energy generated**". Energy inputs considered are Fuel, Electricity & Steam. Industry & Transportation sectors put together consume approximately 60% of the total energy used as per an Energy Audit in the recent past and Industrial sector consumption is 33%. Although hard and genuine efforts are on efficient utilization of the energy and appreciable results have been reflecting in all the Industrial operations for a better and healthy tomorrow for the future generations as well as economically viable business operations-it is imperative that improvement of Energy utilization is a continual process. Paper Industry as a sector consume approx. 7.5 - 15% of the total energy consumed by the Industrial sector depending upon the region & operational parameters. With internal & international competition, the Paper mills are compelled to devise ways & techniques for manufacturing paper more efficiently like reduction in Per ton paper energy consumption, Reduction of broke generation etc. to offload their products in to the market cost competitively. This article is an effort to bring to the industry - Small, Medium & Large various efforts taken up by governments & associations abroad and to identify the possible Energy/ Power saving measures especially related to Paper machine & Finishing House equipments and systems. The virtues of Optimum configuration of Paper machine are discussed especially focusing briefly on Head box efficiencies, Pump Motor Drive selection techniques, Drying Cylinder, Spoiler bars & Hoods in Dryer section, Motor efficiency validation techniques, Effective maintenance practices for best equipment efficiencies, State of Art low cost automation techniques for best efficiencies. Case studies are presented with details on results along with ideas how similar activities can be embarked upon in our country to reap benefits of similar magnitudes. The main objective of this article is to reach the low cost technological developments or Novel ideas of West other than whatever is already implemented in Small & Medium Paper mills to gain collectively as a single united Industrial sector.

PAPER MILL ENERGY CONSUMPTION STATISTICS - UNITED STATES OF AMERICA INDUSTRIAL SECTOR



Uses more energy than any other single sector; >1/3 of U.S. **energy consumption**

Produces approximately 30% of U.S. **greenhouse gas** emissions

Accounts for more than 35% of U.S. **natural gas** demand

Accounts for 28**%** of U.S. electricity demand

Energy is key to **economic growth** in domestic manufacturing

Many companies have been unable to pass higher energy costs on to their customers, which has sharply reduced their profit margins" - National Energy Policy pages 2 & 4

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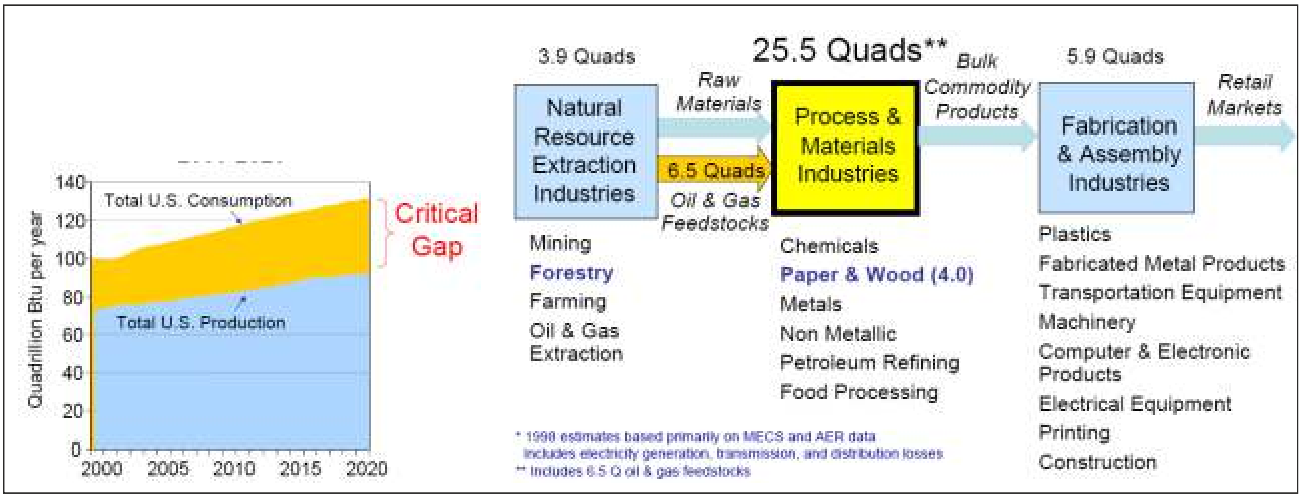
Projected Energy Use - Total U.S. Energy Production vs. Consumption, 2000-2020 & INDIVIDUAL SEGMENT ENERGY CONSUMPTION



MISSION OF US DEPT. OF ENERGY Industrial Technologies Program Strategy

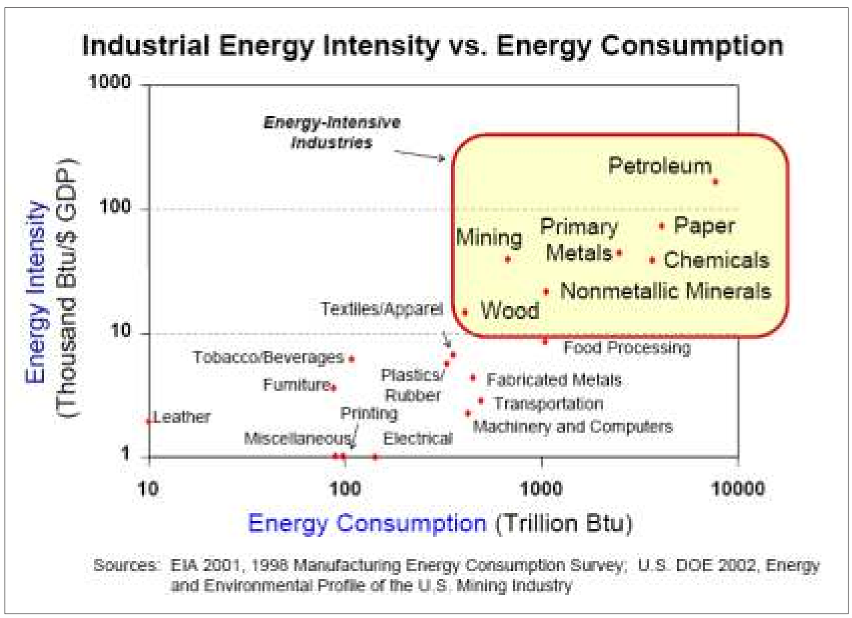
To improve the energy efficiency of U.S. industry through coordinated **research and development, validation, and dissemination** of innovative technologies and practices.

Partner with industry to Save energy, Improve productivity, **Reduce reliance on foreign oil &** Reduce environmental impacts

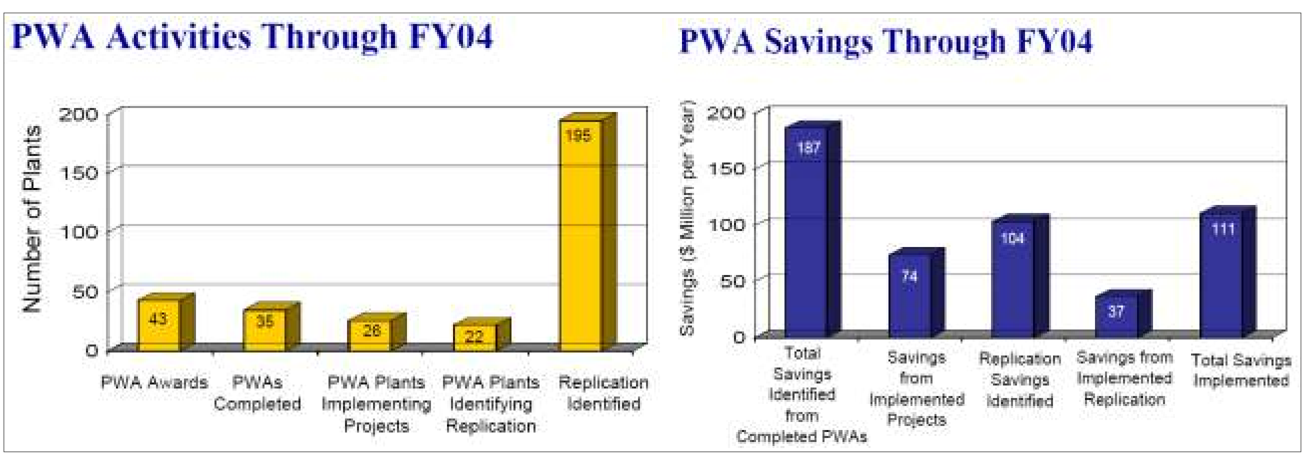
Major Energy-Intensive Industries US DOE AUDIT

The Department of Energy USA has been adapting three pronged approach for delivering Technology Solutions

1. **Partnership with Industries**
2. **Collaborative R & D**
3. **Technology delivery**



Plant Wide Assessment activities & Results



PAPER MILLS CASE STUDIES

Plant	Location	Annual Savings Identified in PWA	Case Study Web Address
Appleton Papers, Inc	West Carrollton, OH	$3.5 million	www.oit.doe.gov/bestpractices/factsheets/newapple.pdf
Augusta Newsprint	Augusta, GA	$1.6 million	http://www.oit.doe.gov/bestpractices/factsheets/fp_cs_augusta_newsprint.pdf
Blue Heron	Oregon City, OR	$2.9 million	www.oit.doe.gov/bestpractices/factsheets/fp_cs_blue_heron.pdf
Boise Cascade	International Falls, MN	$707,000	www.oit.doe.gov/bestpractices/factsheets/boise.pdf
Caraustar	Rittman, OH	$1.2 million	www.oit.doe.gov/bestpractices/factsheets/caraustar.pdf

Plant	Location	Annual Savings Identified in PWA	Case Study Web Address
Georgia-Pacific	Palatka, FL	$2.9 million	www.oit.doe.gov/bestpractices/factsheets/fp_cs_georgia_pacific.pdf
Georgia-Pacific	Crossett, AK	$9.6 million	www.oit.doe.gov/bestpractices/factsheets/fp_cs_georgia_pacific_crossett.pdf
Inland Paperboard	Rome, GA	$9.5 million	www.oit.doe.gov/bestpractices/factsheets/inlandpaper.pdf
Weyerhaeuser	New Bern, NC	$2.9 million	Case study not complete
Weyerhaeuser	Longview, WA	$3.1 million	www.oit.doe.gov/bestpractices/factsheets/fp_cs_weyerhaeuser.pdf

Targeted Assessment Results

Summary of Results Through FY 03			
System	No.	Annual Identified Energy Savings	
		Medium	Range
Pumps	23	$148,000	$13,000 - $2.0 Million
Process Heating	13	$1,207,000	$170,000 - $2.1 Million
Steam	15	$225,000	0 – 1.6 Million
Compressed Air	18	$145,000	$12,000 - $270,000
Insulation	5	$540,000	$13,000 – 1.1 Million
Total	84		

Systems to be Analyzed & Corrected

a) Compressed Air Systems
b) Pumps
c) Steam & Condensate Systems
d) Process Heating Systems
e) Fan Systems
f) Motor driven system efficiencies

CASE STUDIES

I. Caraustar (Recycled Paperboard)

Several steam and motor projects identified at the Rittman, OH plant:

- Motor procurement and efficiency improvements
- Backpressure steam turbine generators
- Boiler feed pump VSDs
- Stack heat recovery to vapor absorption systems
- Pulper fill-water heat exchangers
- Steam pipe insulation

Caraustar Results

1. $1.2 M/yr cost savings
2. 11,000,000 kWh/yr energy savings
3. 4-month to 2.5-year $3 M initial capital requirement
4. Reduced air emissions
5. Corporate procurement program developed for purchase of power transmission and payback electrical equipment from a single source

II. Inland (Paperboard & Packaging)

31 Energy-saving opportunities identified including:

- Replace two existing mechanical drive steam turbines on No. 2 paper machine with variable speed motor drives.
- Reduce water and steam use at paper machine and support systems.
- Rebalance steam distribution system

Inland Results

1) $9.5 M/yr cost savings
2) Energy savings 21,600,000 kWh/yr & 2,900 MMBtu/yr
3) 6-month payback
4) $4.5 M initial capital requirement
5) Reduced air emissions
6) Decreased water, steam, and electricity usage

III. Appleton Papers (Pulp & Paper)

Assessment identified 21 projects at West Carrollton, OH mill:

- Recover heat from paper machine vents
- Recover fiber from low-consistency screen rejects
- Install oxygen and carbon monoxide monitoring equipment to control boiler combustion
- Reuse uhle-box water
- Reduce silo temperatures
- Add a fluidized bed boiler

RESULTS

1) $3.5 M/yr cost savings Energy savings
2) 4,800,000 kWh/yr & 150,000 MMBtu/yr
3) Payback period of ~1.2 years/project.
4) $2.5 M initial capital requirement
5) Decreased waste disposal costs
6) Increased paper production
7) ADDITIONAL $2.6 M/yr savings with installation of a fluidized-bed boiler.

Few Energy saving opportunities identified & explored for confirmed results

a) Replacement mechanical variators with Electrical variators with detailed study & analysis.

b) Electricity, Water & Steam consumption audit & optimization.
c) Rebalancing Water and Steam & Condensate systems
d) Rewound Motors exact efficiency measurements, new motor replacements and net efficiency improvements
e) Perfectly engineered Variable Speed Drives for Centrifugal pumps
f) Pulper fill-water heat exchangers
g) Steam lines thermal lagging
h) Modify processes to decrease effluent flow and energy consumption
i) Recover heat from paper machine vents
j) Recover fiber from low-consistency screen rejects
k) Install oxygen and carbon monoxide monitoring equipment to control boiler combustion
l) Reduce silo temperatures
m) Upgrade the boiler & peripherals to present day state of art technologies
n) Demineralized water heating
o) TPM combustion air preheating
p) White water heating
q) Improvements in fiber line washing efficiency
r) Close vacuum pump seal water loop and heat shower water
s) Recover heat from vacuum pumps, Uhle boxes, and TMP wastewater
t) Heat shower water with reboiler steam and vacuum pump seal water

HEAD BOX

Head box in a paper machine is the most critical equipment for perfect Paper making. The performance levels of head box decide the machine runnability and efficient paper making apart from market acceptance of the paper manufactured. The efficiency of head box operation depend on following few factors:

1. Selection of type of head box based on paper to be manufactured.
2. Material of Construction, head box manufacturing & maintenance practices.
3. Hydraulic flow range capabilities of the head box.
4. Control configuration & tuning
5. Design & deployment of Approach flow system as per international standards like TIPS 0404 -54.
6. Avoidance of Lumps of stock accumulation in the Hydraulic flow path.
7. Ripple less, Stable hydraulic flows by way of deployment of correct attenuators etc.

I. Material of Construction & Head box manufacturing & maintenance practices

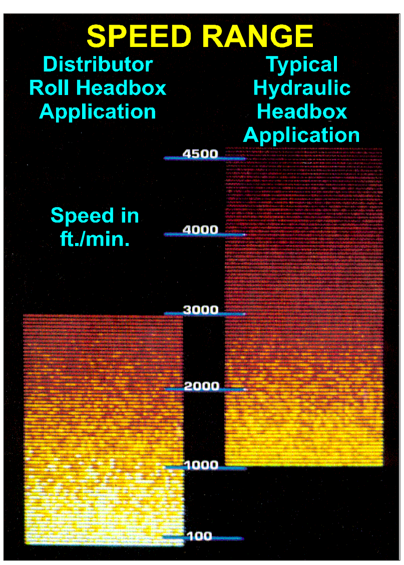
It would be extremely difficult to measure the difference of flow characteristics, or resistance, between a head box having an interior electro polished finish and one has a so-called standard 2B finish. It would take highly sensitive equipment under carefully controlled conditions to make any sort of a resistance comparison between the two polished finishes. Also there is no such thing as "stainless steel". The highest grade of stainless is "stain resistant" but not corrosion proof. The slightest scratch in the highly polished finish can allow paper making chemicals to take hold and start the process of pitting corrosion. The corrosion will start as a small pit and gradually grow until it is large enough to catch fiber and cause strings and/or lumps in the sheet. For getting best performances following procedures can be followed

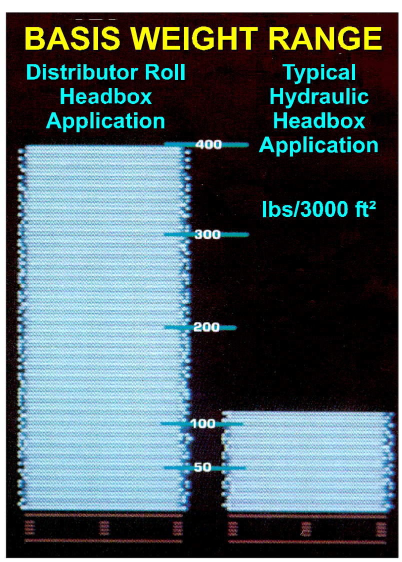
a) Sourcing new head box from Standard manufactures employing international standard manufacturing practices with well established Quality Assurance Plans & Time tested installations.
b) Standard Head box interior maintenance practices like removal of shoes, careful tool handling, employment of soft scrapers of nylon base, use of chemical cleaners & periodic caustic boil outs for avoidance of slight scratches & pitting corrosion in long run.
c) Careful handling and refitting of the clean out and/or inspection ports.

II. Hydraulic Flow rates

Some machines that have been speeded up for increased production, and have lowered consistencies for better quality, still have an old head box designed for yesterday's expectations. The forming tables have been reworked many times to try to address head box flow problems. While it may not be totally typical in all cases, the condition of an "over loaded" or "under loaded" head box exists on many a machines today. In such cases Head box performances would reach their peak level, when Head box is revalidated for targeted production / quality levels as the first step in to Paper machine rebuild itself

I.Basic Selection of Head box





From the graphs, we can observe the limitations of both designs. At high speeds and high flow rates an air padded box may not be ideally suited and conversely at low flows and speeds a hydraulic head box will be difficult to operate. The hydraulic flow rates are related to range of GSM, Slice width, Head box consistencies, FPR, machine speed range etc.

III. Control configurations & Tuning

A new head box performance will benefit from this type of new state of art Automatic Profile Controls. However, installing automatic profile control on an existing, older, head box requires detailed careful adaptation. If the head box is unoptimally loaded and is not stable, or the nozzle has been "blown", the automatic system may not perform as desired. The automatic profile controllers are configured based on profile feed back at the dry end of the machine. Hence if the unstable performance is prevailing from the head box, then hunting phenomenon can occur. Before adaptation of any Automatic Profile Controllers, it is recommended that the machine directional stability is evaluated with the help of six or seven scan sample averages and for repeatable results are prevalent, then adaptation of automatic controllers will reap benefits. Controllers PID tuning also is very critical to head box performances

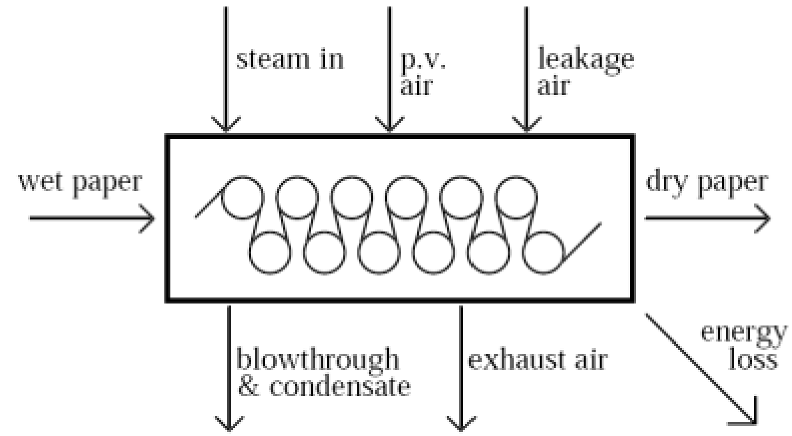


FIGURE 4
Energy flows through the dryer section of the paper machine

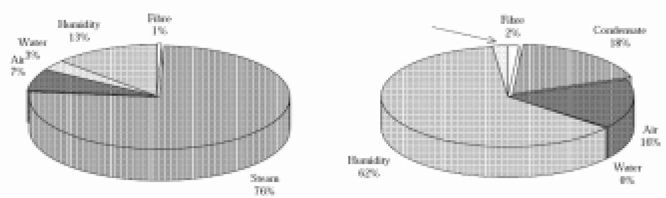
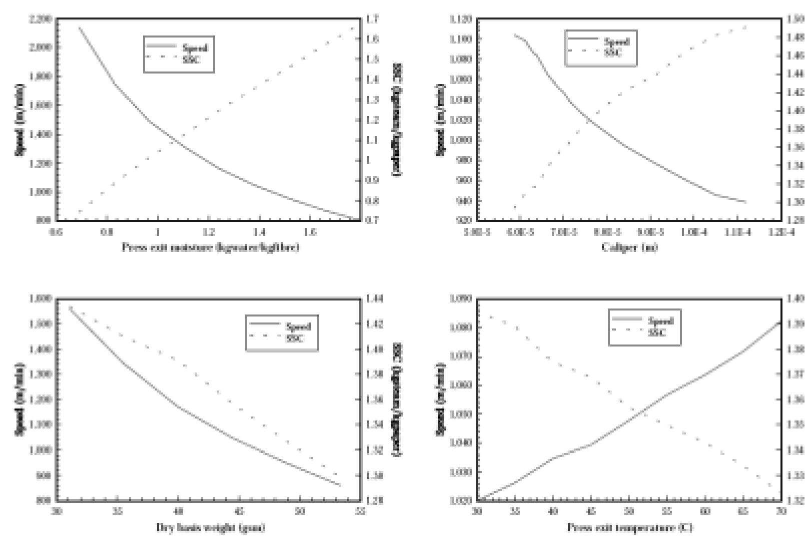


FIGURE 5a Input energy flows

FIGURE 5b Output energy flows



VARIATION OF PAPER SHEET DRYING RATE AND DRYER STEAM CONSUMPTION WITH INITIAL MOSITURE CONTENT, SHEET CALIPER,BASIS WEIGHT AND INITIAL TEMPERATURE

DRYING SECTION STEAM & MOTIVE POWER CONSUMPTION

Water removal in drying section can account for 2/3 of the energy demanded in paper making. Many of the Paper characteristics depend on good control of variables in the drying process. Paper drying is predominantly through steam heated Drying cylinders. Reduction of steam consumption for paper making leads to very healthy economic balancing of the operation.

The following may be observed for effective utilization of steam.

The drying cylinders employed may be checked for uniform wall thickness throughout for achieving even surface temperatures.

The Drying cylinders would perform most efficiently if they have been designed & engineered as per international standards like CE of Europe or ASME of America for obtaining best efficiencies while not compromising on mechanical rigidities related to Steam pressures & Speeds of the machine.

The wall thickness & the material of construction would decide the thermal energy & motive power efficiencies of the total dryer section.

It has been calculated that increase of 4 mm cylinder shell thickness result in increase of motive power by 0.45 Kw per cylinder.

Correct Steam pressure gradient settings as demanded by process standards & as time tested by international practices.

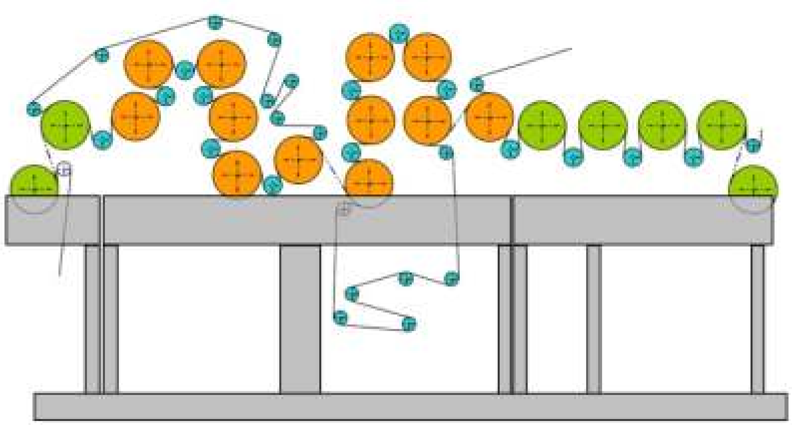
Dryer section geometry is also one of the important factors for the best performances like best drying rates, shrinkage factors etc.

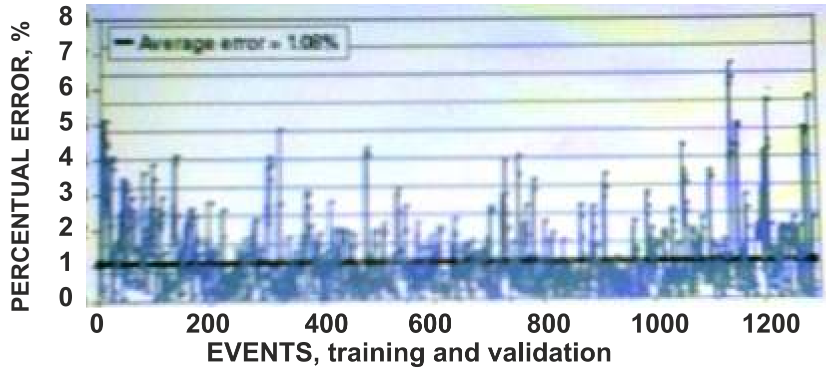
Deployment Pocket ventilation

- boxes & Vacuum Turning rolls in High speed Unirun dryer section improves the machine runnability
- Modeling drying process thru Neural networks are useful to help control moisture content & increase dryer efficiency
- Engineered Hood & Pocket ventilation systems are deployed.
- Best application engineered Steam & Condensate system to be deployed
- In case machine operating speeds beyond 500 mpm use of spoiler bars is recommended for achieving best thermal evaporation rates.
- **Paper machine production speeds may be designed to obtain constant draw characteristics throughout gsm range of production.** This avoids demands for lower steam pressures due to over drying phenomenon.
- Employing Silent drives in dryer section improves drive efficiency.
- Employing industry standard screens & felts, Stretchers & Auto Guides optimally designed & engineered suiting to machine speeds

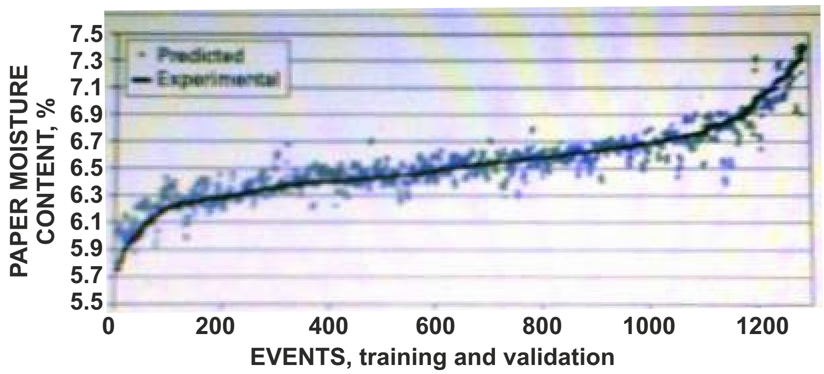
CASE STUDY - ASSIDOMÄN FRÖVIFORS KM5

This carrier board machine had an MG cylinder in the dryer section to provide the required surface properties. The installation of soft calendars made the MG redundant, and the mill was looking to fit the maximum number of dryers into the space left. The installation was entirely above the soleplates. By using a vertical single-tier design it was possible to fit 12 cylinders into the space. A two-tier section in the same space would not have given shrinkage restraint. Here the vertical concept is fully established. The installation consists of two separate vertical sections, drying alternate sides of the sheet. The first section (on the right) has the vacuum rolls to the outside; the second section has them on the inside. In both cases, broke falls directly to the floor. This is a major advantage of vertical single-tier. In other designs (apart from top-felted horizontal single-tier) broke will be trapped within the section.





3. Percent error, experimental and predicted (neural network) average moisture content.



2. Experimental and predicted (neural network) average moisture content (dry basis).

CASE STUDY KLABIN PR MP-7 paper machine

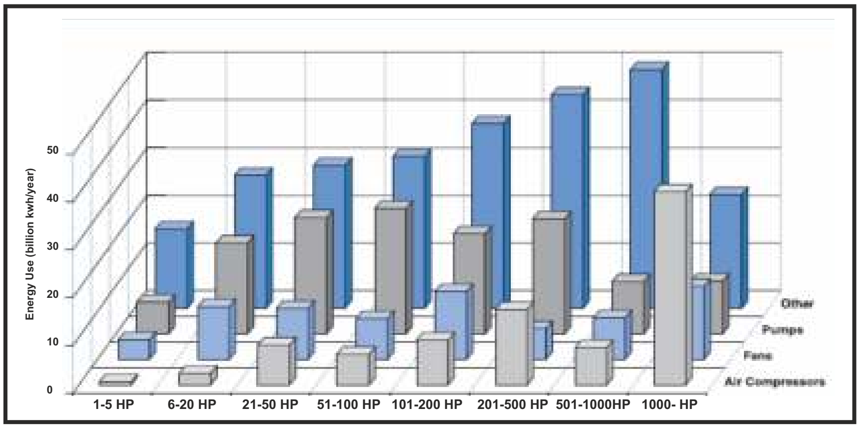
Identification of an dryer section operational behavior by the use of Neural networks in the simulation of the final moisture content was taken up in Klabin Parna Papeis S.A, (Klabin PR), MP 7 paper machine. For this study operational data related directly and indirectly to the drying process composing a database with 110 preselected variables were collected. These data were analysed with the help of a Statistics based Neural Network software and the results were found to be within 2% inaccuracy as compared to actual physical results.

The graphs above compare predicted & experimental results. Hence it becomes much more easier & precise to engineer a drying section with modern mathematical tools.

MOTOR SYSTEMS ENERGY CONSUMPTION & EFFICIENCY BETTERMENT

The motor systems consume approximately 20% of all energy used and 59% of all electricity generated. The main objectives can be termed as

- Reduce energy costs
- Improve motor-driven system reliability and efficiency,
- Increase productivity



Minimize unscheduled downtime

Within each sector electric motors consume.

- 78% of electrical energy in industrial systems (>90% in process industries)
- 43% of the electrical energy in commercial buildings
- 37% of the electrical energy in the home

Motor-driven equipments such as pumps, air compressors, and fanscon sume about 16% of all the energy used in industrial applications. Typical energy use of Motor driven equipments is as per illustration below

The Paper mills can reduce their motor energy consumption by an average of 11% to 18% by using energy-efficient technologies and practices. The energy saving can be out of efficient operation of existing technology through strategically planned **Smart Maintenance** or by up gradation of technology with **State of Art Technology** or with **correct mixture of both**. The electrical energy cost especially for Electrical rotating machines can be brought under control in Paper Mills through following few standard procedures:

- Selection of most optimum ratings of motors without over sizing & use of researched & proven control topologies from international standard associations like IEEE Inc etc.
- Optimally rating the power of Motor Drive for obtaining best efficiencies. Increasing the service factors in Power ratings also increases the Energy losses.
- Adopting Automatic Solid State Power Factor Correction equipments.
- Resorting to Conventional or State of Art Motor Drive On Line maintenance management systems.
- Using Rule based systems for prediction of motor drive performance and machine performance.
- In house Maintenance agencies be furnished with mandatory testing equipments for testing new/ rewound motors and internationally standard testing practices be employed.

Selection Procedure for Motor Drives

- Variable Frequency Drives along with premium efficiency inverter grade induction motors are the commonly used high efficient technologies
- Selection of the researched & proven control scheme topologies
- Asynchronous/ Synchronous Servo machine technologies are much more apt for the applications that exhibit **cyclic torque characteristics or High rate of speed of correction requirements**.
- Asynchronous Servo Motor

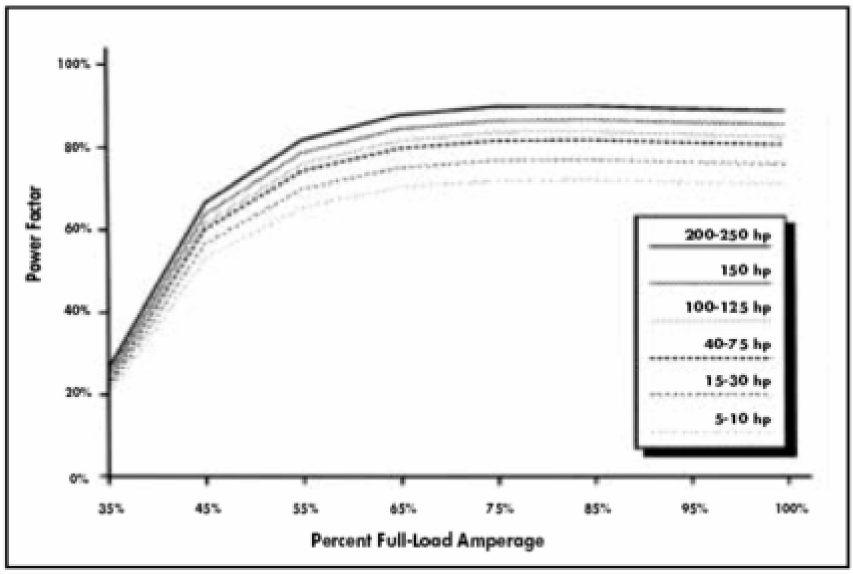


Figure 2 Motor Power Factor (as a Function of % Full-Load Amperage)

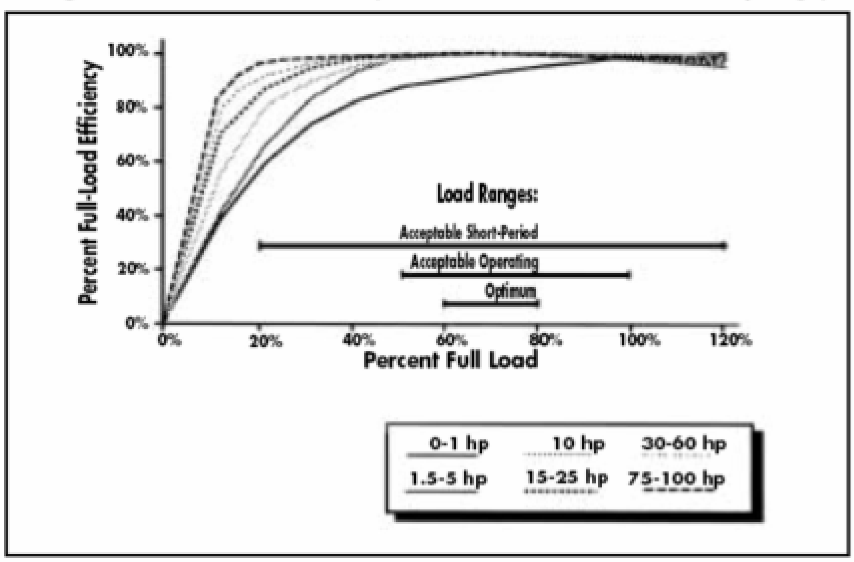


Figure 1 Motor Part-Load Efficiency (as a Function of % Full-Load Efficiency)

Test	Test Condition		Percentage increase in Number of rewinds
	Cooling Fins	Air Intake	
A	CLEAN	0% BLOCKAGE	No Effect (100% Life) 18-25 yrs
B	CLEAN	50% BLOCKAGE	40%
C	LIGHT PULP	0% BLOCKAGE	50%
D	**LIGHT PULP**	**50% BLOCKAGE**	**75% to 85%**
E	HEAVY PULP	0% BLOCKAGE	75% to 82%
F	HEAVY PULP	50% BLOCKAGE	87% to 93%

"Light Pulp about 2/10ths of an inch of pulp " Heavy Pulp cooling fins are completely filled

technologies are commercially cost effective & Synchronous Servo Motor technologies are better suited for High efficiencies, Precise Speed, Torque & Position controls & High speed & High Moment of Inertia load applications

Rating of a Motor Drive on Energy conservation:

Motors & Loads matching is an important criteria for efficient operation. The Electric motors efficiency curve normally peaks at approximately 75% of rated load. Thus, a 10-horsepower (hp) motor has an peak efficiency is at 7.5 hp. A motor's efficiency tends to decrease dramatically below about 50% load. The range of optimum efficiency changes with individual motors type and rating and for larger motors the efficiency tends to extend over a broader range. shown in Figure 1. A motor is considered under loaded when it is in the range where efficiency drops significantly with decreasing load. Figure 2 shows that power factor tends to drop off sooner, but less steeply than efficiency, as load decreases.

Due to such inherent characteristics of Motor drives, it is at times prudential to change/ replace the existing motors with lower sized motors. Also there are Control Topologies designed & engineered by leading Technological associations like IEEE Inc, USA available for reduction of Rated Drive Capacities (RDC) there by Normal Running Loads (NRL) become higher percentage to RDC ultimately resulting in better efficiencies from Motors.

Also Overloaded motors mean loss of energy in the form of heat. An optimum service factor of 15% to 20% is normally acceptable in many applications. If application uses equipment with motors that operate for extended periods under 50% load, mechanical/ control topology modifications may be adapted to achieve better operating conditions. In few applications, motors are intentionally oversized because they must accommodate peak conditions, such as when a pumping system with occasional high demands. Electro Mechanical/ Process options may be deployed to bridge the gap between Peak demands & NRL

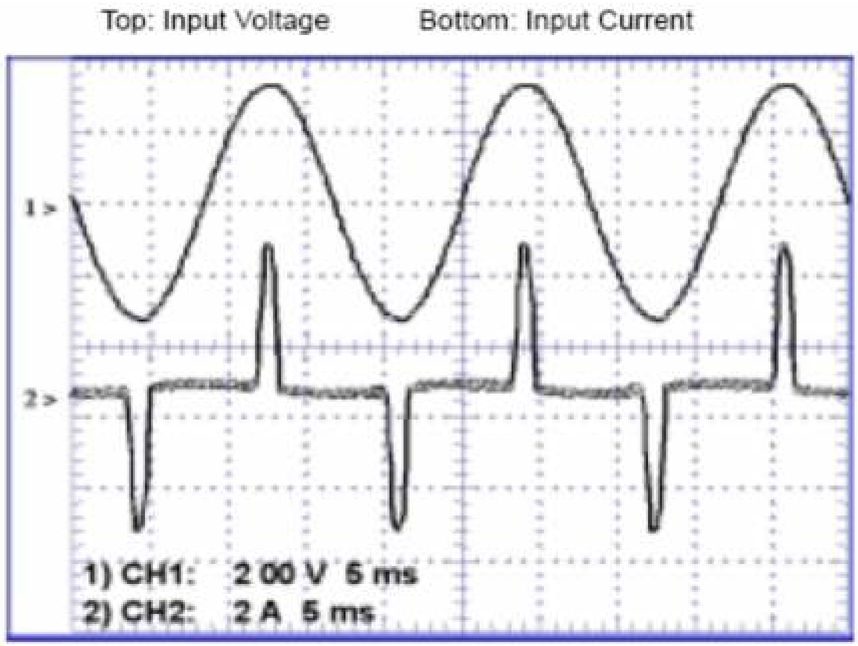
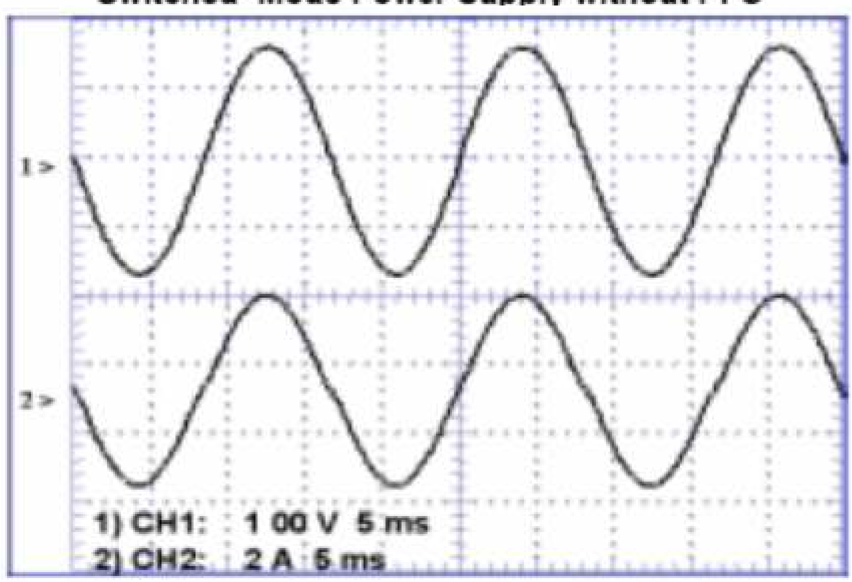


Figure 1. Input Characteristics of a Typical Switched–Mode Power Supply without PFC



Input Characteristics of a Power Supply with Near – Perfect PFC

Energy Conservation by Prevention/ Reduction of Pulp build up on Electric Motors

Another form of energy losses are

reported in Paper mills when pulps build up takes place on Electrical rotating machines. Most pulp and paper mills indicate that the motors see light to heavy coatings of pulp and more than 50% of air intakes blocked. Under these conditions motors experience temperature loss of up to 30°C when operating at 75% to 100% of rated load. This translates directly in to Energy / Efficiency loss in Electrical rotating machines in addition to increase in demand for repeated motor rewinds. This demonstrates the clear need for preventive measures to keep pulp off the motors and to protect the air intakes from blockage. A Motor Cover properly designed to keep pulp off the cooling fins and air intake. The addition of frontal splashguards to the cover face

further reduces blockage of air intakes.

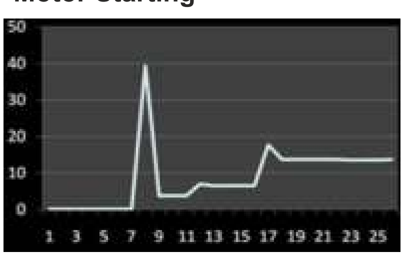
Better Energy utilization through Automatic Power Factor Correction/ Harmonic Reduction devices for motor drive systems

The variable speed drives do generate good amount of harmonics and the generation of these harmonics contribute to lot of reactive power which is unproductive. Reduction of these harmonics as per the international standards shall result in efficient utilization of input power

CASE STUDY OF ENERGY SAVING IN HOMOGENIZER AT FOOD INDUSTRY PLANT

Poliva, a raw material producer for the bakery industry, had introduced Solid State Harmonic reduction equipments

Motor Starting



Smooth motor starting with reduced voltage. The Startup current was only 1.1 times the motor nominal current.

SinuMEC Mode	Save	Bypass	Saving
Volts, RMS	408.7	409.9	-
Currents, RMS	13.68	3.65	73.3%
Line Losses			92.8%
Active Power	2.00	1.27	36.6%
Reactive Power	9.48	2.26	76.2%
Total Power	9.69	2.59	73.3%
Power Factor	0.21	0.49	136.7%

Saved 02.8% in line losses and 36.6% in active power.

SinuMEC Mode	Save	Bypass	Improved
Volts, THD	0.9	0.9	1.1%
Currents, THD	8.8	8.2	6.5%
Currents, TDD	2.10	0.52	75.1%
Power Factor	0.21	0.49	136.7%

Does not generate any side effects and does not require any filters. It improved Poliva's power quality by filtering harmonics and improving the power factor.

on Ammonia compressors, chocolate mixers and homogenizers. The ever increasing electricity prices and business demands for increased profitability led Poliva to explore a solution that would provide more functionality than just motor starting. Due to the high starting currents during motor starting and local regulation an advanced energy efficient solution was required. The objective of the project included reduced voltage motor starting, high energy savings and improved power quality.

The homogenizer is used to mix different fluids. Prior to installation, estimations showed that the motor was fully loaded during its entire period of operation. In actuality, the homogenizer was not loaded during 30% of its operating time. The add on system introduced provided harmonics-free motor starting as well as energy savings. It controlled the voltage supplied to the motor, allowing reduced voltage startup, and while the motor runs it adjusts the voltage according to the load. Due to the structure of electric motors, reducing the supplied voltage while partially loading the motor, increases its efficiency and lowers its internal losses without generating harmonics and was EMI/RFI free.

RESULT

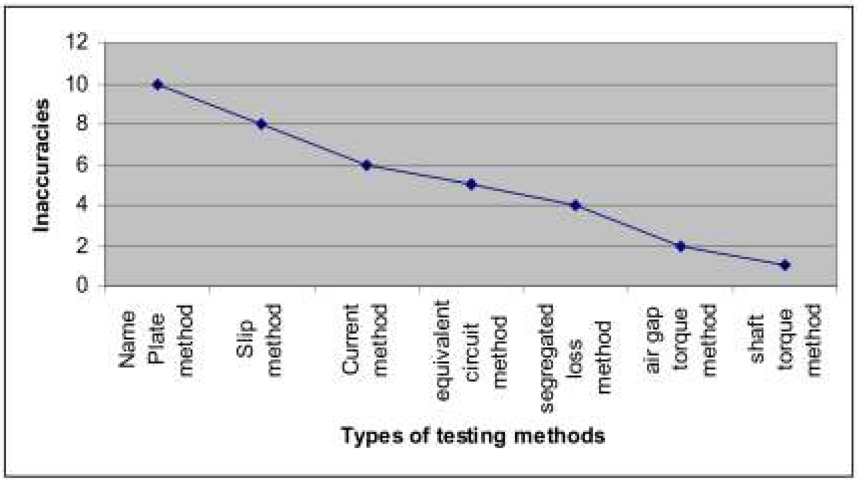
BENEFITS

- Stable and smooth motor starting
- Cuts energy costs
- Reduces motor voltage according to motor load
- Improves motor efficiency and lifetime
- Improves power quality
- Increases reliability, efficiency & profitability

Energy Conservation through Correct & Modern Maintenance Management tools

The correct - standardized maintenance is an investment in the business and not an .expense of doing business. Investment in predictive maintenance practices (PM, TPM, RCM) is an asset and resulted in reduction in energy consumption in plants by as much as 10-14% and additionally, while also reducing unplanned production downtime.

In house Maintenance Partners experienced that the implementation of services combined with Diagnostics and Measurements helps to avoid such acts of surprise, and to reduce the overall spent maintenance costs. The combination of service and diagnostics is a solid tool for the industries to maintain their establishment on the correct course. As maintenance manager you often wished you had a crystal ball to see which machines need overhauling most urgently. In spite of all good preventive cares for production machines, they still are in danger of having a breakdown on any unexpected day. When machines have a condition problem, they also give signals to the environment that there is a problem on the way. Machinery diagnostics helps to detect these signals and estimate the machine health status. Being aware and acknowledging the problem is often the first step in avoiding or even solving the problems. The situation becomes much clearer by taking measurements on the machine such as noise, temperature, vibration, oil-analysis, electrical analysis, visual inspection etc. On line/ Off line data acquisition, analysis and corrective measures create a platform for the maintenance managers to keep the process machines work at highest efficiency. There are few established rule based systems recommended by internationally top research and standards organizations available for effective maintenance management.



CASE STUDIES OF A DECISION SUPPORT SYSTEM

In an A-Team, there are three types of agents which create and modify solutions:

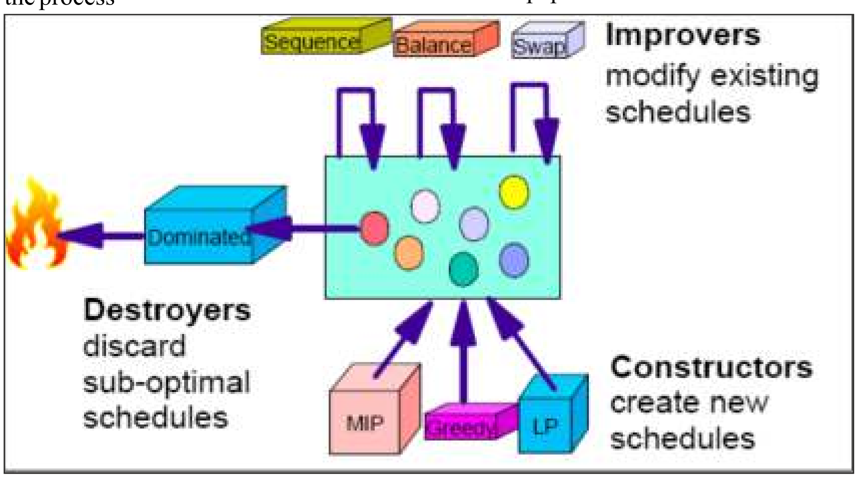
1. *Constructors* that create initial solutions.

2. *Improvers* that take existing solutions and modify them to produce new (improved) solutions.

3. *Destroyers* that keep the size of the population of solutions in check by deleting bad or redundant schedules.

The A-Team architecture does not define the content of the agents, but only their possible roles. This gives complete freedom to use a broad range of algorithms encapsulated as agents. Each agent is independent and can decide for *when* to work and *what* to work on.

The system was successfully deployed at 14 paper mills in North America.



"Computer World" reported that within one year after starting to use the system, Madison Paper Industries saved $2 to $3 million in trim and transportation costs at its one mill (Hoffman 1996).

REWOUND MOTORS EFFICIENCIES & OPERATIONAL GAINS

Rewound Motor efficiency accuracy of measurements is also one important criterion for efficiency optimization / energy conservation in motor management. The inaccuracies graph comparing various testing methods is indicated in the below figures.

The graph indicates that the accuracies of various efficiency measurement methods. It is possible to evaluate the true efficiencies through Shaft Torque methods thereby assisting the mills in their decision making whether to continue with rewound motor or to replace with a new one. By spreading the knowledge base of efficiency bench marks & cost benefits of maintaining such bench marks, the total energy saving in the sector also can be improved considerably.

The Department of Industry along with Technological & Professional institutions in the Paper segment may rope in all their resources together for creating Test facilities in the Paper making hubs in North- East West - South and promote Motor Testing methods as a Non Profit operation for helping the Small & Medium Mills achieve best energy efficiencies. Large corporate mills also may follow the suit of other Core Industrial segment giants like Steel, Power & Defense etc. to put up *Rewound Motor Testing Facilities* in their campuses for achieving Energy efficiency mile stones

For potential energy savings up to 2% improvement in efficiency, the major maintenance components include

- Improved lubrication (vibration)
- Proper alignment and balancing (vibration)
- Correction of circuit unbalances (Motor Circuit Analysis)
- Reduced motor temperatures (MCA, vibration)
- Reduced efficiency losses caused by rewinds (US Department of

Energy estimates one percentage point efficiency reduction per rewind)

Improved drive system performance

It is recommended internationally that one surveys and tests all motors operating over 1000 hours per year. Using the analysis results, one may divide the motors into the following categories:

Motors that are significantly oversized and under loaded replace with more efficient, properly sized models at the next opportunity, such as scheduled plant downtime.

Motors that are moderately oversized and under loaded replace with more efficient, properly sized models when they fail.

Motors that are properly sized but standard efficiency replace most of these with energy-efficient models when they fail. The cost effectiveness of an energy-efficient motor purchase depends on the number of hours the motor is used, the price of electricity, and the price premium of buying an energy-efficient motor.

CONCLUSION

With the present trends in Energy resources availability, Technological developments, Business competition & Environmental aspects, it has become imperative to save energy however small it may be. The Paper Mills, Government & Technological and Professional associations can surely join the hands together to attain best results in Energy savings. The paper mills may also acknowledge the virtues of internationally time tested standard operational practices like selection of vendors, equipments, adapting to impeccable maintenance & housekeeping practices etc. to achieve best efficiencies in business operations. Collective Energy saving of approx. 20% is a distinct possible dream to be achieved by the joint efforts of by the Paper mills & the Professional and Technological associations. It is mandatory at this juncture and in these times to have a main industrial segment operational objective of true "Energy Conservation" policy and work towards implementing this policy for running a very healthy & economically viable operations.

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