International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 10, Number 1 (2017), pp. 111-119

http://www.irphouse.com

# Energy Efficiency Improvement in Industrial Pumping Systems

**Prof. S. N. Jani, Mitul Jani and M G Dave**

*Electrical Engineering Deparment, Institute of Technology, Nirma University, Ahmedabad. Accredited Energy Auditor*

**Abstract**

The industrial sector accounts for a major chunk of power consumption in India, it is estimated to be approximately 36.5% of the total power produced. Process industries can be of different domains, but majority of them have a basic requirement of water pumping system. This pumping system accounts for 25-30% of power consumption in industries with basic requirement to fulfill by using pumped water for various applications like process requirements, cooling systems, heat exchange, steam production etc. Due to high power consumption in these motor driven pumps operating at poor efficiency due to wrong pump selection and deviation of operating point from optimum efficiency point led to major losses and there is a good scope of energy savings in such systems. A textile industry consumes huge amount of energy and water in processes like washing, bleaching, dyeing, scouring, finishing etc. The performance study of pumping system in one such textile unit is presented in this paper.

**Keywords:** Pumping system, pump performance, energy efficiency, system characteristics, hydraulic study, techno-economical analysis

## I. INTRODUCTION

*Mitul Jani, Student of M.Tech. Energy System under Dept. of Electrical Engineering, Nirma University, Ahmedabad. (Email : er.mitul@outlook.in)*
*M G Dave, An Accredited Energy Auditor, Bureau of Energy Efficiency (Email:0110dave@gmail.com)*
*Swapnil Jani, Assistant Professor in Dept. of Electrical Engineering, Nirma University, Ahmedabad. (Email : swapnil.jani@nirmauni.ac.in)*

TEXTILE industries are one of the most prominent energy consumers in industrial sector. It not only has a huge requirement of energy, but also consumes a large quantity of water, approximately 250-350 liters of water per kg of cotton fabric processed [2]. As per the data obtained from the historical figures and site measurements, the specific energy consumption of this textile unit was obtained as 2.75 TOE (tonnes of oil equivalent) per ton of product, i.e. ~ 32,000 kWh per ton of product. These figures indicate the extent of energy consumption of such industries in a developing country like India. Improving the energy efficiency of such consumers would make a massive difference in the Indian energy sector, where still many rural areas are un-electrified and lack power for fulfilling basic requirements. Pumping systems of such textile industries offer a good scope of energy saving and they also contribute significantly in reducing the specific energy consumption of the industry.

## II. TEXTILE MANUFACTURING

Textile manufacturing [3] being a very complex process, involves different stages of processing, requires bulk quantity of water, chemicals, steam etc. in different stages of process for variety of purpose.

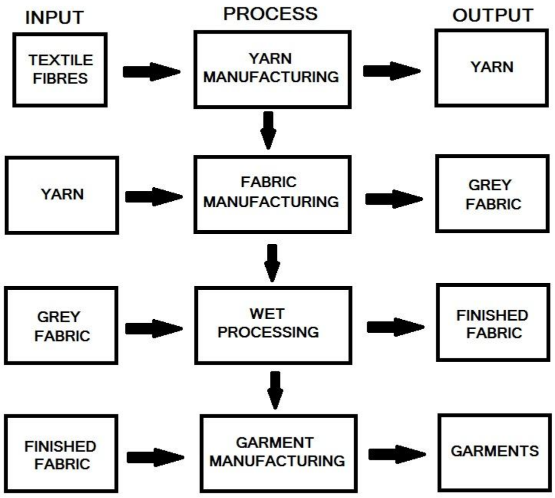


Figure 1. Textile manufacturing process overview

The process begins right from cultivation of basic cotton fiber, which is turned into a yarn by spinning and application of oils to provide cohesion. Then weaving is done in stage of fabric manufacturing with the help of adhesives, binders and solvents. Washing is then carried out using detergents, sizing of fabric takes place with application of sizing enzymes, scouring is then performed to remove wax and other impurities from the fabric. Bleaching is the next step to improve whiteness of the fabric using an oxidizing agent such as hydrogen peroxide. Then comes mercerizing, here the fabric is treated using caustic soda which leads to swelling of fabric, but improves luster and strength of the fiber. The fiber is then ready for printing/dyeing. In dyeing, various dyes, pigments, polymeric resins, acrylates, polyurethane and binders are used. Finally, the printed/dyed fabric is sent for finishing process, where it is applied with different chemicals in order to enhance the fabric properties such as luster, fill, antibacterial, flame retardant, anti-wrinkling etc. Softener agents are applied to the fabric and then it is sent as a final product for conversion into garment. A brief overview of process of textile manufacturing is shown in Fig. 1. These processes require huge quantities of water, mostly obtained from ground water (bore-wells) as a primary source.

## III. PUMPING SYSTEM

A composite textile mill was studied where all the processes mentioned above are carried out including yarn and fabric dyeing /processing. The textile manufacturing unit was having 9 major pumps for supplying water to different point of utilities. There were 3 pumps supplying water to coal handling plant, process division and softening plant with intake from the bore well. These pumps had a rated capacity of 60 H.P. each. The other 4 pumps were installed to cater the requirements of domestic use, one 40 H.P. pump in softening plant, one 40 H.P. pump for thermo pack (Thermic fluid heater) and two 30 H.P. pumps for compressor cooling system. Two 25 H.P. pumps for cooling water as well as chilled water installed for Vapor absorption machine (VAM) refrigeration system. A summary of installed pumps is as given in Table I.

**TABLE I**
**PUMPS IN TEXTILE UNIT**

| Sr. No. | Pump Location | Rated Power (H.P.) |
|---|---|---|
| 1 | Coal handling plant | 60 |
| 2 | Plastic division | 60 |
| 3 | Softening plant | 60 |
| 4 | Softening plant -2 | 40 |
| 5 | Thermo-pack | 40 |
| 6 | Compressor – 1 cooling | 30 |
| 7 | Compressor – 2 cooling | 30 |
| 8 | VAM-CWP (cooling water pump) | 25 |
| 9 | VAM-CHWP (chilled water pump) | 25 |

## IV. ENERGY AUDIT METHODOLOGY

The pumping system of the textile unit was studied for its performance. At initial stage the data was collected, viz. pump and motor rated capacities, pumping duty requirements, piping systems and operational practice. The performance study [4][7][8] was carried out on each pump by measuring its suction and discharge pressure, flow rate, and power consumed for 20 minutes duration individually. The basic idea is to measure the hydraulic power developed by the pump in the given working condition as an output and the input power given to the driver of pump, i.e. motor. For a better system analysis, the study of environmental factors and operating conditions on site is also done.

## V. PUMP HYDRAULIC ANALYSIS

The measurements for hydraulic analysis of pumping system were carried out using digital pressure gauge, non-contact type ultrasonic flow-meter, and 3 phase power analyzer for measuring pressure, fluid flow rate, and power respectively. These measurements were all recorded in the digital instruments. The head-loss inside the suction pipelines in the bore-wells due to frictional losses is calculated with the help of Hazen-Williams (H-W) equation for head-loss [5][6].

### *A. BORE-WELL PUMP ANALYSIS*

The pump performance measurements for the bore-well pumps are as given in Table II. These pumps were having operating efficiencies in the range of 22-25%. This poor efficiency is due to the inability of pump to develop sufficient hydraulic power. The pumps were underperforming mostly due to poor maintenance as well as deteriorated pump impellers. As a result, they were suggested to be replaced with energy efficient pumps having proposed performance parameters as given in the Table II. The techno-economical aspects and their benefits are also included as the part of project study as feasibility of such energy efficiency improvement parameters is also crucial. The weighted average per unit cost of electricity is taken to be as 6.41 in Indian Rupees (INR) from recent electricity bills.

TABLE II
HYDRAULIC STUDY OF BORE-WELL PUMPS

| **Particulars** | **Unit** | **Borewell-1** | **Borewell-2** | **Borewell-3** |
|---|---|---|---|---|
| Location | | Coal handling plant | Process division premises | Softening plant |
| Rated Head | m | 130 | 130 | 130 |
| Rated Power | kW | 45 | 45 | 45 |
| Rated Flow | $m^3$/hr | 60 | 60 | 60 |
| Measured Flow | $m^3$/hr | 38.5 | 39.1 | 36.4 |
| Measured Power | kW | 42.2 | 38.7 | 36.7 |
| Suction Level | m | 76.22 | 76.22 | 76.22 |
| Horizontal pipe length | m | 100.00 | 200.00 | 50.00 |
| Vertical pipe length | m | 6.00 | 5.00 | 5.00 |
| Total Head | m | 77.11 | 77.64 | 76.80 |
| Calculated pump efficiency | % | 22.56 | 25.14 | 24.42 |
| Proposed flow | $m^3$/hr | 60.0 | 60.0 | 60.0 |
| Proposed Head | m | 80.0 | 80.0 | 80.0 |
| Proposed Efficiency | % | 65.0 | 65.0 | 65.0 |
| Proposed Power | kW | 23.7 | 23.7 | 23.7 |
| Present Running Hours | hours | 12.0 | 12.0 | 12.0 |
| Proposed Running Hours | hours | 7.7 | 7.8 | 7.3 |
| Saving Potential | kW | 18.5 | 15.0 | 13.0 |
| Saving Potential | kWh /annum | 106945 | 92163 | 88461 |
| Saving Potential | INR /annum | 686123 | 591287 | 567539 |
| Estimated Investment | INR /annum | 200000 | 200000 | 200000 |
| Payback Period | months | 3 | 4 | 4 |

The head-loss inside suction pipelines is as given in Table III.

TABLE III
SUCTION PIPELINE HEAD-LOSSES

| **Particulars** | **Unit** | **Bore well-1** | **Bore well-2** | **Bore well-3** |
|---|---|---|---|---|
| Water level | m | 76.2 | 76.2 | 76.2 |
| Length of pipeline | m | 182.2 | 281.2 | 131.2 |
| Flow rate in pipeline ($m^3$/hr) | $m^3$ /hr | 38.5 | 39.1 | 36.4 |
| Friction factor ( C ) | - | 100 | 100 | 100 |
| Diameter of pipeline | mm | 150 | 150 | 150 |
| Discharge pipeline frictional head-loss | m | 0.892 | 1.416 | 0.579 |
| Frictional head-loss below ground level | m | 0.89 | 1.42 | 0.58 |

### *B. DOMESTIC WATER SUPPLY PUMP ANALYSIS*

The performance parameters and techno-economical aspects efficiency improvement of pumps used for domestic supply are as given in Table IV.

TABLE IV
HYDRAULIC STUDY OF DOMESTIC WATER SUPPLY PUMPS

| Particulars | Unit | Domestic supply | Domestic Supply | Compressor 1 | Compressor 2 |
|---|---|---|---|---|---|
| Location | | Softening plant-2 | Thermo pack side | Atlas Copco Comp Side | IR Comp Side |
| Rated Head | m | 40 | 40 | - | - |
| Rated Power | kW | 30 | 30 | - | - |
| Rated Flow | $m^3$/hr | 180 | 180 | - | - |
| Measured Flow | $m^3$/hr | 64.4 | 57.1 | 67.6 | 108.8 |
| Measured Power | kW | 14.4 | 13.3 | 21.3 | 20.2 |
| Suction Pressure | m | 0 | 0 | 8 | 8 |
| Discharge Pressure | m | 37 | 37 | 32 | 48 |
| Total Head | m | 37 | 37 | 24 | 40 |
| Calculated pump efficiency | % | 53.1 | 50.9 | 24.4 | 69.1 |
| Proposed flow | $m^3$/hr | 65 | 65 | 68 | - |
| Proposed Head | m | 40 | 40 | 28 | - |
| Proposed Efficiency | % | 75 | 75 | 75 | - |
| Proposed Power | kW | 11.1 | 11.1 | 8.1 | - |
| Saving Potential | kW | 3.3 | 2.2 | 13.2 | - |
| Saving Potential | kWh/annum | 26034 | 17322 | 104243 | - |
| Saving Potential | INR/annum | 167025 | 111132 | 668787 | - |
| Estimated Investment | INR/annum | 100000 | 100000 | 100000 | - |
| Payback Period | months | 7 | 11 | 2 | - |

The pumps used for domestic supply are operating at very poor efficiency, in the range of 50-54%. Therefore these pumps are suggested for replacement with energy efficient pumps having performance parameters as given in Table IV. Two pumps used for compressor cooling system, have operating efficiencies of 24% and 69%, the former pump’s poor efficiency is an indication of deteriorated internal condition and hence it is recommended to be replaced with an energy efficient pump having rated efficiency of 75%.

### *C. CHILLED WATER PUMP ANALYSIS*

The pumps used in cooling system (vapor absorption machine), pumping water in cooling and chilling circuits of air compressors and ventilation systems, operated at very poor efficiencies of 29% and 42% respectively. Therefore these pumps are suggested for replacement with energy efficient pumps having performance parameters and their techno-economical aspects as given in Table V. It was also evident from site observations that the flow to the pumps was throttled up to 50% on the suction side, which is wasting of energy and should be avoided. The chilling water pump had un-necessarily a high discharge head, which if reduced, could achieve significant savings in energy consumption. The two pumps in cooling and chilling circuit are recommended to be replaced with energy efficient pumps having rated efficiency of 75%.

TABLE V
HYDRAULIC STUDY OF CHILLED WATER PUMPS

| **Parameters** | **Unit** | **Cooling water pump** | **Chilling water pump** |
|---|---|---|---|
| Existing Flow rate | $m^3$/hr | 145.0 | 68.0 |
| Existing Discharge Pressure | m | 14.5 | 50.0 |
| Existing Suction Pressure | m | 3.0 | 20.0 |
| Total Head | m | 11.5 | 30.0 |
| Pump Power | kW | 18.0 | 15.4 |
| Pump Efficiency | % | 29.7 | 42.5 |
| Proposed Flow | $m^3$/hr | 150 | 68.0 |
| Proposed Head | m | 15 | 30.0 |
| Proposed Efficiency | % | 76 | 75.0 |
| Proposed Power | kW | 7.28 | 8.72 |
| Saving Potential | kW | 10.72 | 6.68 |
| Saving Potential | kWh /annum | 84934 | 52911 |
| Saving Potential | INR /annum | 544911 | 339458 |
| Investment | INR | 200000 | 200000 |
| Payback Period | months | 4 | 7 |

## VI. OBSERVATIONS AND ANALYSIS

From the observations made on site; it was evident that the pumps were quite old and due to poor maintenance, wrong selection, and operation had lead to the poor energy efficiencies. It was also quite clear after analyzing the performance of the bore-well pumps that the impellers of these pumps might have been deteriorated due to poor maintenance and they were not operating as per the desired characteristics of the pumping system.

For efficient operation of pumping systems, it is very important to install the pumps as per the system head characteristics. Every head curve/system curve would have an optimum performance point, on which the pump operating point should be coinciding. If the system curve and pump curve intersect on the point of maximum efficiency, the pumping system is said to be efficient

## VII. SUMMARY

The suggested measures for improvement of efficiency are given and their corresponding saving potential in terms of energy as well as monetary and the estimated investment for implementation of each measure and the corresponding payback period are as summarized in Table VI.

It is quite evident from the given summary that suggested energy saving measures can save up to 5,73,013 kWh of energy annually i.e., approximately 37 lakh INR in monetary terms, after an investment of 13 lakh INR, which resulted in average simple payback period of around 5 months.

TABLE VI
ENERGY AUDIT SUMMARY

| Sr. No. | Energy Saving Measures | Energy Saving (kWh /annum) | Monetary Saving (INR lakh /annum) | Estimated Investment (INR lakh) | Simple Payback Period (months) |
|---|---|---|---|---|---|
| **1** | Replacement of existing bore-well pumps with energy efficient pumps | 2,87,569 | 18.45 | 6.00 | 4 |
| **2** | Replacement of existing domestic supply and Compressor cooling system pumps with energy efficient pumps | 1,47,599 | 9.47 | 3.00 | 4 |
| **3** | Replacement of cooling circuit pump in VAM | 84,934 | 5.45 | 2.00 | 4 |
| **4** | Replacement of chilling circuit pump in VAM | 52,911 | 3.40 | 2.00 | 7 |
| | **Total** | **5,73,013** | **36.77** | **13.00** | **4.75** |

## VIII. CONCLUSION

The textile unit studied for its pumping system's performance, had very poorly operating system in terms of energy efficiency. This performance study developed a huge scope of energy savings in the pumping system alone. This study presents a clear picture of operating conditions of pumps in such energy intensive industries as well as the possible significant impact of energy efficiency improvement in such facilities. Hence it is very crucial to evaluate such systems and their performance should be timely monitored to avoid huge energy losses. The pumps in the system should be regularly maintained and their overhauling should be performed as per a regular schedule. The piping systems are also to be checked for the frictional head-loss they contribute in the system and ultimately degrade pump's performance.

Hydraulic analysis and diagnosis of such systems would definitely provide good scope for improvement in performance of such manufacturing/process units and optimize their specific energy consumption.

## REFERENCES

[1] Pattern of Electricity Consumption (Utilities); Open Government Data Platform, Government of India. [Online]. Available: https://data.gov.in/catalog/pattern-electricity-consumption-utilities

[2] M. I. Kiron. Water Consumption in Textile Industries; [Online]. Available: http://textilelearner.blogspot.in/2014/04/water-consumption-in-textile-industry.html

[3] Textile Manufacturing. Wikipedia. [Online]. Available: https://en.wikipedia.org/wiki/Textile_manufacturing

[4] Pumping System Audit Standard. Energy Management Association of New-Zealand. [Online]. Available: http://www.emanz.org.nz/sites/default/files/data/Directory/Pumping_System_Audit_Standard_v1.pdf

[5] Ray Hardee, Engineered Software Inc.; Calculating head-loss in pipeline [Online]. Available: http://www.pumpsandsystems.com/pumps/april-2015-calculating-head-loss-pipeline

[6] Hazen-Williams equation; [Online]. Available: https://en.wikipedia.org/wiki/Hazen%E2%80%93Williams_equation

[7] Pumps and Pumping Systems. A Guide Book for Energy Managers and Energy Auditors. Bureau of Energy Efficiency. [Online]. Available: http://www.em-ea.org/Guide%20Books/book-3/Chapter%203.6%20Pumps%20%20and%20Pumping%20System.pdf

[8] Performance Assessment of Pumping Systems. Bureau of Energy Efficiency. [Online]. Available:http://www.em-ea.org/Guide%20Books/book-4/4.7.Pumps.pdf