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Applying Energy Management in Textile Industry, Case Study: An Egyptian Textile Plant

Dalia M.M. Yacout*[1], M.A. Abd El-Kawi* and M.S. Hassouna*

Abstract – *Textile industry in Egypt is energy intensive and is one of the top energy consumers in the country. Both the global and local energy crisis, in addition to high cost of fuels led to additional activities to conserve and manage energy in the best possible ways. The study aimed to investigate and apply a proper Energy Management System (EMS) for the textile industry and identify potential savings by applying novel approaches. An energy management system was implemented in a local textile plant. According to ISO 50001:2011 the energy management system was built on the ISO quality management system's philosophy of Plan-Do-Check-Act (PDCA) continual improvement framework. A number of improvement actions were identified, related cost savings were calculated and an action plan was developed for the implementation of those improvements. The identified actions which had highest cost savings were: usage of efficient lighting systems, arresting compressed air leaks, replacement of inefficient pumps and recovery of steam condensate. The established system was cost efficient and the applied actions for improvement can be implemented in the different industries.*

Keywords – Cost efficiency, Egyptian textile plant, energy management, energy savings, and textile industry.

1. INTRODUCTION

A number of investigations agreed that the textile industry is energy intensive, the production of textiles often requires high levels of energy consumption and energy usage is inefficient [1]-[4]. Analytical studies have been done on energy auditing and energy conservation in textile industry [5]. There are additional studies that recommend improving energy efficiency with the help of energy conservation techniques and energy management [6] - [10].

Nagaraj [11] declared that the textile industry is one of the major energy consuming industries and retains a record of the lowest efficiency in energy utilization. He assured the increasing necessity for energy management due to the rapid growth of process industries causing substantial energy consumptions in textile operations. This increasing requirement revealed the importance of energy conservation which can be done through process changes, machinery modifications and implementation of novel technologies related to process optimization.

In the same time from a business point of view, energy efficiency is of greater importance as it has direct economic benefits, like increased competitiveness and higher productivity [12] - [13]. It is very important to minimize the energy cost and energy consumption for the textile industry to reduce the cost and to rival [1].

Moreover, Nagesha [14] illustrated that ways to reduce energy input without compromising product quality are being continuously researched. Measuring and monitoring the use of energy and utility resources in textile manufacturing processes are necessary to reduce energy losses and to recover lost energy, which are of great importance to companies for cutting cost and supporting sustainable development.

The current study aimed to investigate and apply a proper energy management system for the textile industry. That was achieved by design an integrated plan for energy utilization and energy conservation. In addition, establish and implement an applicable energy policy for energy conservation and potential savings in a textile plant located at Alexandria Governorate, Egypt.

2. MATERIALS AND METHODS

2.1. *Energy Management Strategy*

According to ISO50001:2011 [15] the energy management system was built on the ISO quality management system's philosophy of Plan-Do-Check-Act (PDCA) continual improvement framework which incorporates energy management in the daily organizational practices. In the energy management context, the outline of the continual improvement framework (PDCA) is:

– Plan: starting by an energy review and accordingly establish organization's energy policy, baseline, energy performance indicators, objectives, targets and action plans to achieve results that will improve energy performance.

– Do: the established objectives and targets within the energy management action plans should be implemented

– Check: monitor and measure processes of the implemented actions, monitor the energy performance indicators and compare them against the energy policy and targets

– Act: based on the monitor and reviews actions should be taken to continually improve energy performance, correct any deviations or abnormalities and improve the energy management system to meet the established targets.

*Environmental Studies Department, Institute of Graduate Studies and Research, Alexandria University, Alexandria, Egypt.

Corresponding author: Mobile: (+2)01221306958.
E-mail: dalia.yacout@gmail.com.

2.2 Auditing

According to ISO50001:2011 [15] internal audits were done on weekly basis to identify any leakages of steam or compressed air, recognize abnormalities or losses in a specific area. In addition, external auditing was done once during the study by an external energy auditing agency.

According to Derashri [16] and William [17] the energy audit was conducted in three stages: preparing for the audit visit; next performing the facility survey and finally implementing the audit recommendations.

Within the first stage, energy data was collected to determine the actual energy consumption, efficient energy usage and historical time variation in energy consumption within the last few years. Preliminary data of the facility was collected as well. Next, auditing tools were provided for the audit and a technical in-house team was assigned to assist the external auditors during the audit.

The second stage was a two weeks survey for different areas in the facility and data record for further analysis. Third and last stage was the preparation of an audit report.

2.3 Creation of Action Plan and Goals Setting

According to ISO50001:2011 [15] an action plan was established based on the results of performance assessment, suggestions of the energy management team and recommendations of both internal and external audits. The action plan contained:

- Status of action (Not started, in progress, Completed).
- Goal description
- Actions required to be taken to achieve each goal
- Accountability/responsible of implementing the action
- Date of completion, revised completion and actual completion
- Expected savings (EGP)

Next, a tracking system was developed to review the action plan. Status of actions was being updated on the system by the assigned responsible in coordination with the energy management coordinator and energy manager. The updated track of action plan was reviewed on monthly basis. Consequently, performance assessment was done and new goals were set.

3. RESULTS AND DISCUSSION

In the current study an energy management system was implemented in a local textile plant. The design capacity of the plant in ideal conditions should reach a production of 18,000 ton fiber per year. The main energy sources used in the plant were power and steam.

The system was designed and implemented as continues improvement cycle. According to ISO50001:2011 [15] an action plan for the energy management system was established. The development of EMS started by historical data collection of power and steam consumption, establishing a daily monitoring system for the same, audits in different areas in the plant then analysis of collected data. As following:

3.1. Development of Energy Management System

In accordance to ISO 50001:2011 [15] the planned policy for energy management aimed to achieve at least 15% reduction in energy consumption. By applying the EMS a significant reduction in power consumption happened. The monthly reduction in power consumption within 2013 was 3.9% which achieved a direct saving of 919,500 EGP/year.

3.2. Analysis of Present Status

According to ISO 50001:2011 [15] the organization recorded and maintained energy data. Historical data for monthly power and steam consumption was gathered. The collection and monitoring of daily power and steam data started by the initiation of the program on 2012. Data was collected for: Power consumption by different areas in the plant (material preparation, production and utilities) (kWh/Day), total power consumption of the plant (kWh/Day), total steam consumption of the plant (MT/Day) and total production (TF /Day).

Using these data the consumption ratio for power in different areas was calculated, overall steam consumption ratio was also calculated.

3.2.1. Power Consumption

In order to assess the efficiency of power consumption in the plant, four years data from 2009 to 2012 were collected for power consumption. Data indicated that utility area was the highest power consumer with a percentage of 68.1 % of the total consumption followed by production section (19.7 %) then material preparation (11.4 %). Accordingly utility area was considered the focus area for further improvements.

3.2.2. Steam Consumption

According to process engineering design steam consumption ratio was 9.8 T/TF. Total steam consumption in 2012 was 222,473 ton, consumed for the production of 16,556 ton fiber. Further, steam consumption data was limited due to non-availability of steam flow meters. Only total steam consumption data for all the plant was available. Highest steam consumption ratio was in January as additional steam was required for heating purpose during the cold ambient conditions. Lowest consumption was in August.

3.3. Implementation of Action Plan

According to data collection an action plan was set and the identified actions which had highest cost savings were: usage of efficient lighting systems, arresting compressed air leaks, replacement of inefficient pumps and recovery of steam condensate.

3.3.1. Efficient Lighting System

The lighting system provides many opportunities for cost-effective energy savings with minimum changes. Lighting energy use represents only 5-25% of the total energy in industrial facilities, but it is usually cost-effective to address because lighting improvements are often easier to make than many process upgrades [18].

Results of plant survey are shown in Table 1. Three types of lamps were used in the facility: fluorescent, high pressure mercury vapour (HPMV) and compact fluorescent lamps (CFL). Fluorescent lamps were used in most of the areas, they represent 76.9% of the total lighting used in the plant. HPMV were mainly used in material preparation, production and utilities areas; they represent 21.5% of the total lighting used in the facility. CFL represent 1.5% of the total lighting used in the facility, they were used in the offices and switch gear rooms.

As per General Electric Company's technical pamphlet (TP-105, 2010) the replacement of 40W fluorescent lamps with 40W energy efficient fluorescent light (EEL) can be done with a monitory saving of 3390 EGP/year. Table 2 presents related saving calculation data. The replacement of 250W HPMV lamps with a 150W high pressure metal halide (HID) had a potential saving of 87869 EGP/year when replacing all lamps. In the same way, the replacement of 400W HPMV lamps with a 200W high pressure sodium lamp (HPS) had monitory saving of 47174 EGP/year [18], [19].

Table 1. Lighting data.

Location	Type and number of fittings							
	Fluorescent				CFL	HPMV		
	1*11W	1*28W	2*28W	2*40W	1*18 W	1*125 W	1*250 W	1*400 W
Material preparation	5	27	126	21			28	8
Production area	33	54	550				311	60
Utility units	1		42	21				
Cooling tower				4				
Effluent treatment plant				43				16
Water treatment plant				44				7
Storage area	3	33	25					
Workshop	2		62					
Office building	5	4	81		20			
Switch gear rooms	17	154	134	85	12	10		
Total	66	272	1020	218	32	10	339	91

Table 2. Saving calculation data for lighting change.

Present Lamp	Substitute lamp	Energy Saving per lamp		Fittings	Total Saving*	
		W	%	No.	W	EGP/year
Fluorescent,40 W	EEL, 40 W	7	15	218	1526	3955
HPMV,250 W	HID, 150 W	100	26	339	33900	87869
HPMV, 400 W	HPS, 200 W	200	50	91	18200	47174
Total savings		307			53626	138999

* Electrical tariff is 0.3 EGP/kWh, Egyptian Electrical Utility and Consumer Protection agency, 2014.

Total saving of lighting change

= Energy saving per lamp (kW) x Number of fittings x Cost of power consumption (EGP/kWh) x Lighting duration within the year (8 hr per day x 365 days per year) (1)

3.3.2 Arresting Compressed Air Leaks

Compressed air is a very expensive energy resource, approximately 75% of compressor's production costs are on energy [20]. In the same time, air leaks are the major reason of compressed air losses. Air leakage rate varies between 20% and 40% of the total air usage [21]. According to Dudić [22] eliminating air leaks is the simplest and cheapest way to minimize and improve energy efficiency of compressed air. In order to do so it is necessary to detect air leaks and eliminate their causes.

During the study several audits were conducted for inspection of compressed air leakages: internal audits were conducted on weekly basis by members of the energy management committee, each week in a specific area and an external audit was conducted as well once during the implementation period of the study. A total number of 65 compressed air leaks were identified in the circuit. Table 3 presents a sample of the major air leakages identified during the inspection, their location, pressure, leak rate and cost savings.

Leaks were detected by an ultrasonic detector, the digital reading of the detector was converted into leak rate using detector's system chart "Guess-Timator chart" Table 5 [19], [23]. Monitory saving from elimination of compressed air leakages was approximately 97500 EGP/year. Cost saving calculations were done using the below Equation 2. Cost saving was calculated for each leak separately, operating hours were assumed to be 8000 hours per year and compressed air generation requirement 18 kW/100 cfm [24].

Cost saving = Leakage rate (cfm)
x compressed air generation requirement (kW/cfm)
x Operating hours (hr/year)
x power consumption cost (EGP/kWh) (2)

Table 3. Major compressed air leakages in the steam circuit.

Location	Pressure (kg/cm^2)	Pressure (psig)	leakage extent (dB)	Leak rate (CFM)	Cost saving (EGP/year)
Tow baler	4.5	66.15	75	6.6	2851.2
Panel breaker N.1	4.5	66.15	75	6.6	2851.2
Panel of breaker N.2	4.5	66.15	75	6.6	2851.2
Tow dryer platter joint	5	73.5	75	6.7	2894.4
Tow dryer platter piston	5	73.5	75	6.7	2894.4

* dB : Decibel Reading, cfm: Cubic Feet per Minute, psig: pound per square inch (1 atm. = 14.7 cfm)
** All readings should be taken at 40 Hz at distance 12-15 inch from leakage

Table 4. Guess -Timator chart for dB verses cfm.

Digital Reading	100 psig	75 psig	50 psig	25 psig	10 psig
10dB	0.5	0.3	0.2	0.1	0.05
20dB	0.8	0.9	0.5	0.3	0.15
30dB	1.4	1.1	0.8	0.5	0.4
40dB	1.7	1.4	1.1	0.8	0.5
50dB	2.0	2.8	2.2	2.0	1.9
60dB	3.6	3.0	2.8	2.6	2.3
70dB	5.2	4.9	3.9	3.4	3.0
80dB	7.7	6.8	5.6	5.1	3.6
90dB	8.4	7.7	7.1	6.3	5.3
100dB	10.6	10.0	9.6	7.3	6.0

psig: pound per square inch

3.3.3. Replacement of Inefficient Pumps

Two operating pumps were used for intake well water and two as a standby. Pump efficiency is calculated according to [19] using the below Equations 3 and 4. Table 5 presents the comparison between design and actual operating data for intake well pumps with both pumps in parallel operation and with each pump in single operation.

Total differential pressure = Discharge pressure - Suction pressure (3)

Both discharge and suction pressures were measured by on site pressure gauges and assuming motor efficiency 0.9. Pump efficiency (%) is:

$$\frac{PumpFlowRate * TotalDifferentialPressure * 9.81}{PowerDrawn * MotorEfficiency} * 100 \quad (4)$$

With both pumps in parallel operation, pump 1 and pump 2 operate at 62% and 70% efficiency, respectively, which is lower than standard design efficiency of 84%. Flow requirement is 400 m^3/h, one pump designed for 400 m^3/h does not deliver as per the design due to piping pressure drop. The pressure drop in piping was high due to pitting corrosion inside and pipes leak. Proactive steps should be taken into consideration for chlorination of water to avoid corrosion due to sulfate reducing bacteria.

Both pumps were replaced by a new energy efficient intake well pump of 500 m^3/h with high efficiency motor to save pumping power. Table 6 presents comparison of performance between present and new status.

Table 5. Comparison between design and actual operating data of intake well pumps (pumps in parallel and single operation).

Particulars	Unit	Design data	Operating data				
			Single		Parallel		
			Pump 1	Pump 2	Pump 1	Pump 2	Combined
Power	kW	110	72.4	89.1	71.9	74.9	146.8
Flow rate	m^3/hr	400	340	362	187	220	407
Speed	rpm	1490	1490	1490	1490	1490	1490
Suction pressure	m	-3	-3	-3	-3	-3	-3
Discharge pressure	m	74	58.7	55.5	74	74	74
Total differential pressure	m	77	61.7	58.5	77	77	77
Efficiency	%	84	89.7	73.6	62	70	66.1

Table 6. Performance of present and suggested operation of intake well pumps.

Parameter	Unit	Old (Two pumps in parallel)	New (One pump only)
Flow	m^3/hr	407	500
Head	m	77	80
Motor efficiency	%	88	93
Power input	kW	146.8	139.5
Pump efficiency	**%**	66.1	84.00
Motor rated power	kW	75	75
Motor speed	rpm	1475	1450

Based on daily water requirements of plant 9000 m^3/day. Monetary cost saving of using one new pump 500 m^3/hr instead of present two parallel pumps (400 m^3/hr) were estimated by almost 79400 EGP/year. Cost savings were calculated using the below Equations 5 to 8. Summary of cost savings is shown in Table 7. Operating time (hr/day) is:

$$\frac{DailyWaterRequirementofPlant(m^3/day)}{PumpFlowRate} \quad (5)$$

Power consumption per day (kW/day) =Operating time (hr/day) x power consumption (kW) (6)

Annual cost of pumps operation (EGP/year)

= Power consumption per day (kW/day) x Operating days per year (day/year) x electrical tariff (EGP/kWh)

(7)

Annual cost saving (EGP/year)

= Annual cost of present two parallel pumps (EGP/year) - Annual cost of one new pump (EGP/year) (8)

3.3.4. Recovery of Steam Condensate

In agreement with Vandana [25], returned condensate from process heat exchangers has a high temperature and consequently an energy value. Significant energy savings can be achieved from the reuse the high temperature condensate. Typical condensate recovery systems collect condensate from the steam system and feed it back into the boiler feed tank

Through the plant survey it was observed that steam headers condensate was sent to drain. Consequently, actions were taken to collect that condensate and send it to the demineralized water (DW) tank in boiler house to preheat water. For the same a separate condensate collection header was provided at the pipe rack. It was connected with all steam trap discharges. Collected condensate was transferred to boiler house by using pressure power pump. This action saved heat content as well as DW, the estimated cost saving was almost 42600 EGY/year. Table 8 presents the collected data for condensate recovery and cost saving. The potential savings for steam recovery were calculated as follows using Equations 9 to 11 [25]:

Quantity of flash steam generation

= (h1- h2)/h3 x 100 (9)

= (144.4 – 99.7)/539.3 x 100 = 8.29 %

where:

h1: Sensible heat of condensate at high pressure
h2: Sensible heat of condensate at low pressure
h3: Latent heat of steam at low pressure

Generated flash steam per hour

= Quantity of flash steam generation x steam consumption of plant (kg/hr) (10)

= 0.008 x 33300 = 2660.4 kg/hr

Annual steam saving

= Generated flash steam per hour (ton/hr) x annual operating hours (hr/year) x steam cost (EGP/ton) (11)

= 2660.4/1000 x 8000 x 20 = 420624 EGP/year

Table 7. Cost saving data for present and new of intake well pumps.

Parameter	Unit	Old (Two pumps in parallel)	New (One pump only)
Flow	m^3/hr	407	500
Operating time	hr/day	22.1	18
Power Consumption	kW	146.8	139.5
Power consumption per day	kW/day	3246.2	2511
Operating days per year	day/year	360	360
Electrical Tariff*	EGP/kWh	0.3	0.3
Annual cost	EGP/year	350589	271188
Cost saving	EGP/year	79400	

***** Egyptian Electrical Utility and Consumer Protection agency, 2013

Table 8. Saving calculation data for usage of steam condensate in boiler house.

Sr.	Parameter	Unit	Value
1	Total enthalpy of steam at 4 bars*	kcal/kg	654
2	Total enthalpy of steam at 1 bars*	kcal/kg	640
3	Condensate quantity	kg/hr	8000
4	Condensate pressure	bar	1
5	Cost of steam	EGP/Ton	20
6	Annual operating hours	hr	8000
7	Sensible heat of condensate at 1 bar*	kcal/kg	99.7
8	Sensible heat of condensate at 4 bar*	kcal/kg	144.4
9	Latent heat of condensate at 1 bar*	kcal/kg	539.3
10	Flash steam generation	%	8.29
11	Steam consumption of plant	kg/hr	33300
12	Generated flash steam per hour	kg/hr	266.4
13	Cost saving	EGP/year	42624

* Steam tables [26]

4. CONCLUSION

The study aimed to investigate and apply a proper energy waste management systems for the textile industry. A number of applications were conducting during the action plan for energy management implementation. The implementation of the action plan was energy efficient and highest cost saving actions were:

- Applying efficient lighting systems, which achieved a monitory saving of 138,999 EGP/year.
- Identifying and arresting compressed air leaks not only improved energy efficiency of compressed air, but also saved approximately 97,500 EGP/year of lost energy.
- Replacement of two inefficient intake well by a more efficient one improves the efficiency and saves 79,400 EGP/year.
- The recovery of steam condensate by collecting the condensate from the steam system and feed it back into the boiler feed tank achieved as estimated saving of 42,624 EGP/year.

The established system was cost efficient, by applying the EMS a significant reduction in power consumption happened. The monthly reduction in power consumption was 3.9% which achieved a direct saving of 919,500 EGP/year. Moreover, the applied actions for improvement can be implemented in the different industries. Application of similar energy management systems is strongly recommended in the textile industry, the textile industry has a large potential for energy saving opportunities.

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