Abstract - With the increased industrialization more and more number of industries are setting up all over the world. For a developing country like India the number of industries setting up is overwhelming. The use of electricity is closely associated with the industrialization; hence to improve the efficiency of the industries which already are into existence seems to get first priority. This paper tries to find the scope available in an industry to use its resources in a proper manner by energy management. The in-depth analysis of a milk and dairy industry is shown in this context and one can use this as the basis to generate such overwhelming results in different sectors. The scope of further improvements in energy utilisation with the latest researches that came to light is also discussed.

Keywords—Cogeneration, SCADA, Tri-generation

I. INTRODUCTION

Currently India produces around 123.7 million tones of milk every year and the same is processed in milk processing plants. (Source: Department of Animal Husbandry, Dairies & Fisheries, Ministry of Agriculture, GOI) Raw milk is collected from almost every part of the country and there is a wide scope for small scale processing plants. Milk can be converted to various dairy products such as cheese, curd, ice creams etc. As the per capita milk consumption in the country is rising the need to produce more amount of milk is gaining priority.

As the milk processing industries extend their production horizons the energy consumption in these and the upcoming industries will tend to rise. In accordance with the alternative and innovative means adopted for the milk processing plants one must also consider various energy conservation techniques in the existing plants in operation.

II. LAYOUT OF MILK PROCESSING PLANT

The layout of a milk processing plant depends upon the operations carried such producing pasteurized milk, cheese, curd, etc.

A typical milk processing plant receives raw milk from a collecting station through trucks and is stored in large tanks at the industry. It is then clarified and homogenized and moved to pasteurization. Milk is chilled uptill 4 degree Celsius and then packed into cartons and dispatched for transportation.

Fig. 1 below shows a typical layout of a plant.

III. TOTAL ELECTRICITY CONSUMPTION

Fig. Sectoral Electrical Consumption [1]

IV. BOILER

The dairy has 1T/h rated low fire boiler which operates on almost full load producing 930Kg/hr steam.

The boiler uses furnace oil. The specification and the flue gas analysis are as shown in Table 1.
### Table 1. Flue gas analysis [2]

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Pressure</td>
<td>9 (kg/cm²)</td>
</tr>
<tr>
<td>Steam Temperature</td>
<td>170°C</td>
</tr>
<tr>
<td>Steam Enthalpy</td>
<td>2776.2 KJ/kg</td>
</tr>
<tr>
<td>Feed Temperature</td>
<td>80 °C</td>
</tr>
<tr>
<td>Steam to Fuel Ratio</td>
<td>14 (kg/kg)</td>
</tr>
<tr>
<td>A/F ratio</td>
<td>14:1</td>
</tr>
<tr>
<td>CO₂</td>
<td>14.5 (%)</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1.7 (%)</td>
</tr>
<tr>
<td>Excess Air</td>
<td>13 (%)</td>
</tr>
<tr>
<td>Flue Gas Temperature</td>
<td>250 °C</td>
</tr>
<tr>
<td>Boiler Efficiency</td>
<td>84 (%)</td>
</tr>
</tbody>
</table>

With the data available from the industry the following energy calculations are made.

**Operating Hours** = 24 Hours

**Production of Milk**

Annual production = 13627071 Litres/month

= 18926.48 Litres/Hour

**Fuel Consumption**

Furnace oil consumption = 66778 L/month

= 92.75 Lit/hr

Density of FO = 950 Kg/m³

Mass of FO = 0.09275 X 950 = 88.11Kg/hr

**Heat carried away by the flue gases**

= (1482.11*1.005*(250-30)/360 = 91 kW

Blow down = 0.04 T/hr

Blowdown losses = 0.014*1.87*(180-30) = 8.79 kW

**Energy input of Fuel**

= 88.11*10300*4.18 = 3793488 kJ/hr

= 1053.75 kW

**Energy output of fuel** = 895.68 kW

**Energy utilised by milk pasteurization**

Specific heat of milk = 3.93 kJ/kgK

Density of milk = 1.03 kg/Litre

**Energy for pasteurization**

= 3.93*1.03*(82-40) = 170 KJ/Litres

= (170*18926.48)/3600 = 893.75kW

**COGENERATION**

Dairy industry requires both electricity and process heat. There is a chance of co-generation.

An existing boiler is replaced with the new high pressure boiler (η = 85%) and a back pressure turbine which strictly caters the process heat load.

m₀ = 930 kg/hr

= 0.258 kg/s

Enthalpy at 40 bar 300°C = 2962 KJ/Kg [3]

Enthalpy at 10 bar saturated = 2776.2 KJ/Kg[3]

(Power of turbine) P = 0.258 × (2962-2776.2)

(Electrical power output) Pₑ = 47.936 × 0.98(ƞgenerator)

= 47KW

Fuel consumption with cogeneration

F_C = 0.258 × (2962- 251.22)/10300×4.18×0.85

F_C = 76.76 Kg/hr

Fuel consumption without cogeneration

F_NC = 0.258× (2776.2-251.22)/ 10300× 4.18×0.85

= 71.25 Kg/hr

F_PP = 47/10300× 4.18×0.85

F_PP = 10 Kg/hr

Relative Fuel saving (R_f) = (71.25 +10) – 76.76/(71.25 +10) = 5.54%

FCP (fuel chargeable to power) = 0.1147 Kg/KWh

Heat rate of Co-generation =0.1147×10300×4.18 KJ/KWh

= 4946.56 KJ/KWh

Heat Rate of power plant = 3600/0.4

= 9000KJ/KWh

The co-generation system shows relative fuel saving and heat rate of co-generation is less than the heat rate of power plant. Hence cogeneration is seen to be feasible but it has following limitation:

The Power generation is so small hence it is difficult to get the generator of such a small capacity. Even if we get the generator then scale of pay is very high hence it is not that affordable.
VI. WASTE HEAT RECOVERY

Since there are several limitations associated with the co-generation system. Hence we can also use the option of WHR (waste heat recovery) because exhaust gases are at high temperature (250°C). Hence by retrofitting the economizer that can extract heat from flue gases which can be used for the preheating the boiler feed water. The proper calculations are as follows:

Boiler uses furnace oil which has A/F ratio = 14
Fuel rate = 71.25 Kg/hr
Excess air = 13%
Air rate = (1+0.13) × 14×71.25Kg/hr = 1188.45Kg/hr
So, 1188.45×1.005×(250-160) = 930 × 4.18 × ΔT
ΔT = 27.64°C
Fuel saving
mT ×10300 ×0.84 = 930×27.64
mT = 3.2Kg/hr

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommended Measures</th>
<th>Fuel saved (Litre/Month)</th>
<th>Capital Cost (Rs)</th>
<th>Savings (Rs/Month)</th>
<th>Simple Payback Period (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Retrofit Economizer for the Waste Heat Recovery from Boiler</td>
<td>2422</td>
<td>19,00,000</td>
<td>96870</td>
<td>20</td>
</tr>
</tbody>
</table>

VII. REFRIGERATION

Energy for chilling = 3.93*1.03*(40-6)
= 137.63 kJ/Litres
= (137.63*18926.48)/3600
= 723.57 kW
Refrigeration load = 270TR
Electrical load = 270×3.5 = 945kW
For Storage = 945-723.57 = 221.43kW

The dairy has refrigeration load of 270 TR. It uses 3 screw compressors and 1 reciprocating compressor with ammonia (NH3) as refrigerant. About 35% of the electrical load is utilised in refrigeration. The plant incorporates an ice-bank maintained at 0°C by controlling the compressor load. Presently, there is no integration between the process plant and refrigeration plant and the controlling is done manually. This variation is clearly seen from this given graph:

Using the SCADA system we can integrate the process and refrigeration systems this will tend to reduced variation.

De super heaters

At the outlet of the compressors the temperature is around 85°C to 95°C which is very high as compared to R-22 refrigeration system. This system can be utilized to heat boiler feed water. This gives the saving in terms of fuel. The calculation is given as follows:

270 x 210 = mR x (h1 – h3)
or, 180 x 210 = mR x (1457.81 – 350)
or, mR = 51.18 kg/min
or, mT = 3071 kg/hr

mR C_P x (95-60) = m_w x C_Pw x (ΔT)
or, 3071 x 2.176 x (95 – 60) = 10^3 x 4.187 x (ΔT)
or, ΔT = 56°C

saving:
10300 x 4.18 x 0.84 x mT = 10^3 x 4.187 x 56
or, mT = 6.48 kg/hr
or, mT = 4665.6 kg/month
saving = 186624 Rs/month (fuel cost = 40 Rs/kg)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Recommended Measures</th>
<th>Fuel saved (Litre/Month)</th>
<th>Capital Cost (Rs)</th>
<th>Savings (Rs/Month)</th>
<th>Simple Payback Period (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Condenser heat can be recovered in the Heat Exchanger to preheat the water (ΔT – 56°C)</td>
<td>4665.6</td>
<td>15,00,000</td>
<td>1,86,624</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3. Refrigerator Energy management

Partition in the cold Storage:

<table>
<thead>
<tr>
<th>Month</th>
<th>Milk processed (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 12</td>
<td>15183797</td>
</tr>
<tr>
<td>Sep 12</td>
<td>13851051</td>
</tr>
<tr>
<td>Oct 12</td>
<td>14191597</td>
</tr>
<tr>
<td>Nov 12</td>
<td>11843581</td>
</tr>
<tr>
<td>Dec 12</td>
<td>12975300</td>
</tr>
<tr>
<td>Jan 13</td>
<td>13717100</td>
</tr>
</tbody>
</table>

Table 4. Monthly milk production [5]
Energy Management In A Dairy Industry

6 months average
= 13627071/month
= 439583/day
= 14652.65 litres/shift
~ 146528 litres/shift (10% less in product)
~ 131875 litres/shift (storage required)

Without partition

60 TR x 3.5 = 210 KW
= 5040 KWh (24 hrs operation)

With partition

37.5 x 3.5 x 8 hrs = 840 kWh/day
60 x 3.5 x 16 hrs = 3360 kWh/day

Total = 4200 kWh/day
Savings = 630 kWh/day
= 630 x 30 x 6.3 kWh/month
= 119070 Rs/month

Table 5. Cold storage Energy Management

VIII. ELECTRICAL

Motors
During inspection we found that the motors on the condenser 2 and 3 are working on the part load condition and after discussing with their staff we noticed that even pumps are not operating up to the mark.

Motors/Pumps

<table>
<thead>
<tr>
<th>Motors/Pumps</th>
<th>Rated Power(hp)</th>
<th>Actual Power(kw)</th>
<th>% Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump-3 on Condensor-2</td>
<td>12.5</td>
<td>5.4</td>
<td>52.1</td>
</tr>
<tr>
<td>Pump-2 on Condensor-3</td>
<td>5.0</td>
<td>2.5</td>
<td>57</td>
</tr>
<tr>
<td>Pump-1 on Condensor-3</td>
<td>12.5</td>
<td>7.4</td>
<td>71.4</td>
</tr>
</tbody>
</table>

Table 6. Specifications of motors

These motors can be replaced by small capacity motors depending on their individual maximum demands or they can be retrofitted with the VFDs.

Lighting

The dairy has around 95 number of tube lights which have magnetic ballast. They can be replaced by electronic ballasts which give greater energy savings.

Table 7.1 Electrical energy management (Tubelights)

The dairy has certain numbers of mercury vapour lamps which can be replaced by a metal halide lamp. Thus, about 40% saving is possible.

Table 7.2 Electrical energy management (Lamps)

Compressor

The dairy requires compressing air for actuating valves blowers etc. the specifications of compressor are followed:

Table 7.3 Compressor Specifications

The operations of compressor are as followed:

Table 7.4 Loading Unloading of Compressor
This power loss can be saved by retrofitting VFD (variable frequency drive) on compressor.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>On loading period Hour/day</th>
<th>Unloading Power kWh/month</th>
<th>Total Saving Rs/month</th>
<th>Capital Cost Rs</th>
<th>SPP Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>5313</td>
<td>34317</td>
<td>300000</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 7.5 Electrical energy management (Compressor)

IX. RENEWABLES

The plant has 25 flat plate collectors installed to preheat the boiler feed water. During our inspection we found that the outlet temperature of outlet is 45°C. The actual claimed temperature at outlet is around 80°C. The reasons for poor efficiency can be poor maintenance. It is hereby recommended that the collectors should properly clean regularly. Also the installation of collectors away from the boiler house which causes loss through the pipes. Hence it’s recommended to have good insulation on delivery side and if possible then to install collectors on boiler house itself.

Even if the company has bio-gas digester and boiler, it is not in working condition due to the leakage of the tank that can be repaired which will give great saving. Because even the biogas having calorific value up to 5000kcal/kg hence if this plant can bring in to working condition it can be the best feasible alternative for furnace oil.

X. FUTURE SCOPE OF IMPROVEMENT

The Dairy industry is going to grow in the future. It’s a one of the industry which requires process heating, refrigeration cooling and electricity loads. Hence this is an industry which has a huge scope of tri-generation. Here are the some of the feasible options for the tri-generation

Vapor Absorption Refrigeration System:-

The main problem regarding to the cogeneration is its small capacity. The small capacity was due to we were only catering the process heat load now if we install the VARS then the heat required in the generator will be also taken by the turbine outlet steam. The turbine exhaust now will be using for three purposes:-

1) Process Load
2) VARS Generator
3) Bleed of steam can be used for regeneration or in De-aerator.

If we consider a single pass liquid ammonia system having COP=0.7 then to fulfil the total requirement of refrigeration load (270TR) the system will require 1350kW of heat. At 10 bar saturated the steam required will be 1750 hr/kg. The process requirement is 1T/hr. By using high pressure boiler and bleeding of some steam we can produce electricity around 1 MW. Another advantage of this system is the part of heat which is supplied to generator can be recovered from absorber at lower temperature but it can be used for pre heating water or oil.

(Sample calculations)-

Assuming boiler is operating at 40 bar and 700°C

\[ h_{in} = 3904 \text{ kJ/kg} \]
\[ h_{out} = 2776 \text{ kJ/kg} \]

To produce electricity of 1 MW the steam flow rate required = 3257 kg/hr.

…… (Efficiencies of turbine and generator are 75% and 98% resp.)

Mass to be bleed off= 3257-1000-1750= 507 kg/hr

This mass can be used for regeneration or can be used in de-aerator. Since dairy industry has quiet huge amount of waste heat hence option of VARS seems to be feasible in future.

Refrigeration Using Carbon Dioxide:-

Among all the refrigerants the CO₂ is having lowest GWP. The CO₂ refrigeration cycle is a Trans-critical cycle which is capable to fulfill the cooling and heating demands. Since it’s a Trans critical cycle it can give evaporator temperature about 1°C and condenser temperature around 170°C these are the desired temperatures for the process heat and refrigeration in dairy.

The main problem associated with this cycle is the compressor works at higher pressure ratio and high pressure itself. It consumes more power as compared to other refrigeration cycles, but by supplying power at single place we can achieve both heating and cooling unlike other refrigeration cycles.
Instead of using electricity one can use DG sets for the compressors with the direct appropriate coupling which can be helpful to reduce the motor and generator losses. Though the capital cost of this refrigeration system will be high because of high pressure pipe line and compressor it will give the good payback period.

**Safety**

The dairy uses ammonia as a refrigerant but it has no ammonia detector as ammonia is hazardous when its level goes above 1ppm it causes irritation of eyes and nose. If level goes above 25ppm it can cause headaches, nausea, and intense burning of the eyes, nose, throat, and skin. Exposure to high levels of ammonia will lead to permanent damage of eyes and lungs. Also ammonia is inflammable gas. Hence it’s strongly recommended to take safety measures to prevent any catastrophe.

**CONCLUSION**

Dairy industries exist in every corner of the world and they have a considerable share in the country’s economy. The share of electricity consumption in this sector is dominant too. The calculations and results obtained from this study may prove helpful to develop a model based approach to determine the energy saving capabilities in the sector.

**REFERENCES**

[1] Data collected through Industry Visit and data log sheet available with the management.