

Energy Conservation in Co-generation in Sugar Mills

Introduction

All the industries centres around Cost Reduction, Quality, Customer satisfaction and Environment awareness for its growth and survival. In the Processing Industry, Energy cost is one of the major components of the production cost. So Production cost can be reduced by controlling energy cost. But as Sugar Industry has self-sufficiency in fuel and power, primary importance is being given to operational convenience and Secondary importance to Energy conservation. Sugarcane is an Energy Crop and contains about 4500 MJ energy per ton cane in which about 1800 MJ is lost in the boiler flue gas and about 750 MJ heat energy is dissipated to atmosphere through the cooling tower / spray pond. Energy spend for the production of sugar is about three times of energy in sugar.

Thermal and Electrical Energy

Combined heat and power cycle system is being followed in Sugar Industry where Steam is used for dual purpose. In the conventional Sugar Mills, Steam production and consumption % Cane are about 50% and Power Production and consumption are about 30 kw per ton can whereas in Co-Generation Sugar Mills, Live Steam % Cane, Exhaust Steam % Cane, Power Generation per ton Cane are 60%, 50% and 108 units respectively.

Need for Co-Generation

India, being a developing country, face the daunting task of ensuring a decent standard of living for their burgeoning population. Industrialization can provide goods and services and employment opportunities to boost the GDP and per capital income. Rapid industrialization has thrown up new challenges for Indian Industry. Available energy infrastructure is inadequate to meet the growing power demand. Overall Electricity shortage is nine per cent. The peak shortage of electricity at the all-India level is 30%. Fossil fuel reserves are fast depleting. So further energy infrastructure development is the need of day. Bio-mass is the most promising alternative fuel. Agro-waste and agro industrial products have today been recognized as 'modern' bio-mass material which can be converted directly into useful forms of energy. Bio-mass has the crucial advantage of being environment friendly. Bagasse is a captive bio-mass. In India, there are 478 sugar mills of varying crushing capacity ranging from a critical period because of over-production, low sugar price, low international market, etc., can enhance revenue by co-generation. So Co-Generation would benefit both the nation and the industry. It is estimated that Indian Sugar Industry can export 3600 MWe power by adopting bagasse based co-generation units. In the Co-Generation Sugar Mills, Power generation and consumption per ton can is about 108 and 36 units. So power Revenue of Co-Generation Sugar Mills is around Rs. 210 per ton cane.

Need for Energy Conservation in Co-Generation Sugar Mills

In Co-Generation Sugar Mills, Specific Power export to the grid is equal to Specific Power generation minus Specific Power consumption. It can be increased either by reducing the Specific Electric Energy consumption or Specific Energy Generation or both. Profitability increases by about Rs. 12000 per season for every unit increase in Specific Power Export to the grid. So Electrical and Thermal Energy Efficient Equipment enhances the power export and profitability of the Co-Generation Sugar Mills and reduces the Pay Back Period.

Enhancing Specific Electric Energy Generation

Specific Energy Conservation in Non-Co-Generation and Co-Generation Sugar Mills are about 30 and 125 units per ton can respectively. The factors which determine Specific Power Generation and the methods by which it can be enhanced are discussed here.

I. Fiber % Cane

Fibre % cane varies between 12 and 16 % depending upon the variety of the cane, cultural practice, age of the cane, etc. Generally Fiber-rich variety has low Sugar % which is more detrimental for the profitability of the factory. So developing Fiber rich variety for the sake of enhancing the power output is

not profitable. Immature cane has less Fiber % and Sugar %. So immature cane reduces both power and sugar revenue and affects the profitability of the factory. Over-matured cane has more Fiber % but less Sugar %. So the overall profitability is not in favour of Over-mature cane. Having maximum Sugar % and optimum Fiber %, Matured Cane maximizes the profitability of the factory. Under identical conditions, Specific Power Generation with 12% Fiber Cane is 94.5 and that of 16% Cane is 138.5% kw.

II Input Steam Pressure and Temperature

In Co-Generation Sugar Mills, at present there are different pressure boilers- 42, 66 and 84 ata specific power generation for the different steam pressure are 73,100 and 123 kw respectively. So in the present available high pressure boiler of 84 ata, the specific power generation is the highest.

III Exhaust Pressure

In Sugar Mills, Exhaust Pressure varies between 1.7 and 2.5 ata. In the beginning of the run, exhaust pressure is very low and at the end of the run exhaust pressure is high. Under identical operational conditions, Specific power generation for 1.7 and 2.5 ata back pressure are 100 and 109 kw respectively. Similarly depending upon the exhaust steam temperature, Specific power generation varies.

IV Thermal Efficiency of the Boiler

Bagasse fired boiler efficiency ranges between 55 and 68%. The factors which determine Steam-Bagasse ratio are excess air, flue gas temperature, particulate in the flue gas, temperature of the feed water, fouling of the boiler tubes, Fines and uniformity of the bagasse, Moisture % bagasse, temperature of the bagasse, etc. Under identical operational conditions, fines and uniformity of bagasse reduces fuel-air ratio under the controlled draft and this increases Steam production per ton bagasse. Similarly Steam-fuel ratio increases with increase in bagasse temperature. In the milling plant, the co-generation of variation of bagasse size is more. Bagasse Powder is more. This causes more particulate in the flue gas. In Diffuser Plant, Preparative Index-fines of bagasse and uniformity of bagasse size is given more importance to maximize the sugar extraction in the Juice Extraction plant. This increases the boiler efficiency, steam-fuel ratio and power-ratio. In the Diffuser, Diffuser bagasse temperature is raised to 65 Degree C by the circulating Scalding Juice which is heated by Quint. III or IV Vapour. So in the Diffuser Plant, Final Bagasse Temperature is around 50 degree C and that of milling plant is 30 Degree C. Higher bagasse temperature reduces the heat energy to be taken by the bagasse from the burnt gas to vaporize the moisture in the bagasse. This increases the Fuel value of bagasse. If bagasse temperature is increased from 30 to 50 Degree C, the fuel value increases by about 19.5 Kcal per kg bagasse which is equal to 0.88%. This increases Steam fuel ratio by 0.01 Power production per ton cane increases by 1 kw. This is to state that in the diffuser plant, size of bagasse is small and uniform and the bagasse temperature is more than that of mills which increases the fuel value of bagasse.

V Power Generation and Fuel Conservation

In Sugar Mills, about 0.75% bagacillo is used as Filter aid. This reduces steam production and power production by 16.5 kg and 4.1 kw per ton cane. In the cane Diffuser plant, the circulating juice is limed and heated. So most of the organic coagulating compounds are coagulated and the mud is filtered off in the Diffuser bagasse blanket. Bagacillo requirement is reduced from 0.75 % to 0.25%. Extra Steam Production due to bagacillo conservation and power production per ton cane are 11 kg and 2.75 units respectively. In 2500 tcd Co-Generation Sugar Mills, this increases Power export and revenue by 1.18 million units and Rs. 3.67 million respectively. Moreover in Milling plant, opened to atmosphere causing fuel windage loss. In the diffuser plant, the complete system is closed. So there is less flying of bagasse powder. This conserves fuel and enhances specific power generation.

VI Processing Steam % Cane

Power-Stem ratio can be increased if the quality of steam going to condensing mode is increased by decreasing the Processing Steam. If processing steam % on Cane is reduced by adopting the thermal energy conserving measures to 40% Cane from 50%, Specific power generation and power export to the grid can be increased by 8.3 kw. In 2500 tcd Co-Generation Sugar Mills, power export and revenue per

season can be enhanced by 3.569 million units and Rs. 11.06 million respectively. So Co-Generation Sugar Mills can enhance the specific power generation by reducing the process Steam % Cane. The factors which determine the Steam % on Cane are discussed here.

(i) Bleeding System

Maximum Steam economy can be achieved by optimizing vapour bleeding to Juice heaters and Pans. Vapour required for each Juice Heater is almost fixed in conventional sugar mills. Differential Juice Heating System-heating in stages, improves steam economy. In the diffuser plant, Diffuser juice heating can be done in two states to improve the later body bleeding. This reduce vapour going to the condenser which reduces the Evaporator Injection water power consumption also.

(ii) Number of Effect in Multiple Effect Evaporator

In modern Sugar Factories either Quintuple Effect Evaporator or Double Effect Vapour Cell cum Quadruple Effect Evaporator are there. In the Double Effect Vapour Cell cum Quadruple Effect Evaporator, Steam % on Cane is higher by 1.5% compared to Quintuple Effect Evaporator.

(iii) Pan Boiling Scheme

Pans' evaporation rate varies between 17 and 85 kg per Sq. Mt. In A Footing pan, 32 and 72 in A Masecuite Boiling Pan 10.7 and 45 in B Masecuite Boiling and 1.6 and 36 in C Boiling. Care is to be taken to minimize the fluctuation in Pan Vapour demand to achieve maximum steam economy.

(iv) Reducing Vapour and Exhaust steam Venting

During Masecuite dropping, it is a usual practice to let off the heating vapour and this causes loss of thermal energy. In order to minimize this loss, the other pans heating vapour valves are to be opened a little more. But in the Diffuser plant, that vapour can be let into the diffuser to heat the circulating juice by which Diffuser Juice Heating Vapour can be reduced and steam % Cane be reduced indirectly.

(v) Recirculation of molasses and sugar

In order to manufacture the best quality sugar and reduce Sugar loss in Final Molasses Multi Crystallization is being followed. Sugar recirculation index varies between 3.5 and 3.9, Solid recirculation index varies between 3.2 and 3.6 and Non Sugar Recirculation Index varies between 4 to 6 Recirculation of Sugar and molasses are to be optimized to reduce Steam % Cane.

(vi) Pan Washing Steam

In a 2500 tcd, about two tones of steam per day is consumed in Pan washing. Two decades back 3 ata steam were being used for Pan washing. At present Exhaust steam is used for pan washing. Co-Generation Sugar mills can use Quint. I Vapour instead of Exhaust Steam for Pan washings to reduce Steam % Cane.

(vii) Molasses Conditioner Steam

At present 3 ata steam is being used for Molasses conditioning. Approximate consumption of steam is around one ton per hour. The purpose of molasses conditioning is to dissolve the small grains by diluting and raising the temperature. Quint I Vapour can be used instead of 3 ata steam after suitably modifying the molasses conditioners to conserve thermal energy and thereby Specific Power Generation can be enhanced.

(viii) Continuous Melter

About one ton 3 ata steam and 3 tons hot water are being used per hour in the continuous melter. Quint. I Vapour can be used in the melter after suitably modifying the Continuous Melter to reduce water to be evaporated and 3 ata steam consumption.

(ix) Ineffective Imbibition

The object of imbibition is to extract maximum sugar from cane. One per cent ineffective Imbibition % Cane increases in the Steam % on Cane by about 0.4%. In Diffusion plant, the contact time between bagasse and thin imbibition juice and the imbibition stages are more compared to conventional milling. Operation temperature is 75 Deg. C. Hence Imbibition system is effective. So higher Sucrose extraction which can be achieved in milling tandem only with higher imbibition, can be achieved with lower imbibition in Diffuser. In other words, the RME which can be obtained with 300% imbibition in milling plant can be achieved with lesser imbibition in Diffuser. This reduces water to be evaporated in evaporator and Steam % on Cane indirectly without loosing in mill-extraction and increases Specific Power Generation.

(x) Stoppages

Frequent mill stoppages increases Steam % Cane. During the stoppage, the temperature of Juices, storage tank Syrup and molasses, Masecuite in the Pans, heat exchangers, other vessels etc. comes down. During the restarting extra heat energy is required to heat the cooled mass. This increases the Average Steam % on Cane. So stoppages should be as minimum as possible to conserve thermal energy. In the milling Plant, wear and tear due to erosion and corrosion is more because of high pressure squeezing and low juice pH. The percentage crushing stoppage due to mills is about 2%. Crushing stoppages due to Mill break down is more in the later part of the season and when crushing days increases. The break down is due to erosion which is due to rubbing of bagasse with the equipment and corrosion which is due to the low pH of Juice. In the Diffuser plant, erosion is less because of less moving components and less contact between bagasse and the mild steel and corrosion is less as pH of the circulating juice is maintained between 6.2 and 6.8. Stoppages due to Diffuser is almost nil and stoppage in the Diffuser Juice Plant stoppage does not increase even with increase in the crushing days because of less human and machine fatigue. So there is reduction in crushing stoppage in the Diffuser Plant and this improves Steam economy and increases specific power generation indirectly.

(xi) Cleaning Days

Generally immediate after cleaning, Steam % on Cane is less and bagasse saving is more. As cleaning days approaches, Steam % on Cane increases and Bagasse saving gets reduced. In order to achieve consistent Steam % Cane two sets of evaporator or spare III, IV, and V body can be installed. Moreover as the Cleaning days approaches, exhaust steam pressure increases which decreases the specific power generation also. Similarly Periodical cleaning of the Juice heaters at the regular interval reduces Steam % Cane.

(xii) Continuous Pan

In the batch pans, Pan station vapour demand fluctuation is about 500%. In the Continuous Pans, there is consistency in the boiling mass and boiling height. So there is no fluctuation in pan Vapour demand and continuous pan is useful energy efficient equipment to Co-Generation Sugar Mills.

(xiii) Automation of Batch Pans

In the Batch Pans, by Auto feed systems, the boiling mass consistency can be maintained. By automation, time taken for Masecuite dropping and restarting after dropping and washing can be reduced and this reduces the Steam % on Cane indirectly.

(xiv) Thermal Insulation

All the heat exchangers, pipes, vessels, receiving tanks, storage tanks, etc. are to be lagged with appropriate thickness lagging material. Noel Deer estimates that the loss of heat by radiation and convection is 10kg per ton cane. Webre has estimated the loss in the completely lagged Quintuple Effect evaporator is 2.7%. If the lagging gets wetted, the insulation capacity of the lagging material gets reduced. So the chance of thermal insulation getting wetted should be minimum as possible.

(xv) Optimization of Crushing Rate

Multiple Effect Evaporator is the most thermal energy conserving equipment in Sugar Mills. Utmost care is to be given for its steady working. Any fluctuation in its working effects the overall performance. In order to maintain consistency in the Evaporator working, there should not be any fluctuation in Vacuum, Steam Pressure and Temperature, later body Vapour utilization to Juice Heaters, etc. In the Diffuser Plant, Vapour bleeding is the maximum because of Diffuser Juice heating. This reduces the fluctuation of Evaporator working. Optimization of Crushing rate of suit the Evaporator Brix gives the maximum Steam % on Cane.

(xvi) Thermal Energy Conservation and Filter Cake Washing

In the conventional process, Cake washing water % Cane varies between 2 and 2.5%. In the Diffuser Plant, due to the addition of milk of lime and heating to the Diffuser Re-circulation Juice, most of the organic compounds are precipitated in the diffuser and the precipitate are filtered off in the bagasse blanket and this reduces coagulation in the clarification process. Muddy Juice % Cane, Filter cake % Cane, and Cake washing water are reduced by 75%. This reduces Clear Juice % Cane by 1%, and the Steam % Cane by 0.2%.

(xvii) Light Filterate

In Vacuum Filter, there is heavy and light filterates. Heavy filterate has more suspended particles and brix is equal to Clear Juice. Light filterate has less suspended solids and the brix is less. In the Diffuser plant, the dilute light filterate can be used as imbibition juice after proper accounting by which Imbibition, % Cane can be reduced proportionately without affecting Sugar extraction %. This decreases Steam % Cane and increases Specific Power Generation.

(xviii) Flash Vapour Circulation and U Column

Vapour condensate circulation system and the utilization of flash vapour conserves electrical and thermal energy. Providing U column for condensate withdrawal and transfer of juice from one body to other body arrests the escape of the Vapour.

(xix) Steam and Vapour leakage

Leakage in the steam and vapour pipe lines and flange joints leakage increases the Steam % on Cane. By-passing the Steam traps and excess venting of Ammonia gases increase the loss of Steam and vapour.

(xx) Thermal Energy Conservation and Milk of Lime

If brix of Milk of Lime is low, water to be evaporated in the Evaporator and Steam % on Cane increases. In the conventional sugar mills, Milk of lime % Cane, used in the clarification station is around 2%. In the diffuser plant, about 1% is added in the Diffuser and the balance is added in the Juice Sulphiter. Milk of Lime has about 10% Calcium Hydroxide and 90% water. In other words, 0.9% water is added in the diffuser through Milk of lime which does two functions-maintaining the re-circulation juice pH between 6.2 and 6/8 and acting as imbibition. This increases the imbibition % cane indirectly. This is to state that that the effect of x % imbibition % cane can be achieved with $(x - 0.9)$ % imbibition % cane when 1 % Milk of lime is added to the re-circulation juice. This decreases total water to be evaporated and Steam % on Cane.

(xxi) Thermal Energy Conservation due to Hot Water Imbibition

In the conventional milling process, imbibition water temperature is between 50 and 60 Degree C. Sweet condensate is cooled to the desired temperature and used or Sweet condensate is mixed with fresh water to reduce temperature and used. But in the Diffuser plant, as Second body hot condensate which is around 95 Degree C, is used without cooling, there is thermal energy conservation. Generally Imbibition % Cane is around 37.5%. So the thermal energy conservation is equal to 11250 Kcal per ton Cane. This

reduces the Vapour required for heating the Raw Juice by 2% and improves the Steam % on Cane by 0.8%.

(xxii) Thermal Energy Conservation and Mill Steaming

In the mills, circulating juice is at around 30 degree C which is very conducive for the growth of the micro-organism. Inter carriers, Mill Head stock sides, Roller sides, etc., are steamed with 8/4 ata Steam at regular interval to curb the growth of micro-organism. But in the diffuser, there is only one mill. In the De-water Mill, Diffuser bagasse and squeezed juice temperature are above 60 Degree C. So the chance for the growth of the micro-organism is much less and there is no need for steaming. This decreases the Steam % on Cane indirectly.

(xxiii) Thermal Energy Conservation and Juice Brix

In the milling plant, imbibition stages is about three, Imbibition water and juice circulation is about 120% on Cane, and Imbibition water temperature is around 35 Degree C. So imbibition water and juice circulation is about 750%, bagasse blanket height is about 1.2 metre, distribution of imbibition is uniform throughout the width of the diffuser and Imbibition water temperature is around 65 Degree C and above. So imbibition is effective. Sugar Extraction increases for the same Imbibition % Cane by 2.5%. This increases Brix % Juice by 0.4% for the same Imbibition % Cane. This decreases the percentage of water to be evaporated in the evaporator by 1% and Exhaust Steam demand of the Evaporator by 0.2%.

(xxiv) Heat Loss by radiation in the Juice Extraction Plant

In the milling plant, even with hot water imbibition, Juice and bagasse temperature are not increasing proportionally as the complete system is open. But in the diffuser, the complete system-the bagasse and circulating juice are inside a rectangular enclosed conveyor. The entire shell of diffuser, juice pipes, vessels etc., are lagged. So the loss of heat due to radiation and convection is less. This conserves thermal energy.

(xxv) Cush-Cush in Raw Juice

In the milling plant, more powder bagasse is formed. Dirt % Raw Juice varies between 0.3 and 1% on the cane. Mostly this is fine bagasse. So there is loss of bagasse and reduction of bagasse availability to be used as fuel. But in the diffuser, Diffuser Raw Juice is filtered in the bagasse blanket and free from cush-cush. Dirt % diffuser Juice is much less. This increases the availability of bagasse to be used as fuel.

Electrical Energy Conservation

In Co-Generation Sugar Mills, Reduction in Specific in Power consumption increases Power Revenue by about Rs. 3 per ton cane. Electrical energy consumption can be reduced by installing of Energy Efficient Equipment, correct sizing of the equipment or reducing loss in the energy transmission.

By Installing Energy Efficient Equipment

Some of the Energy Efficient Equipment suitable for Energy Efficient Co-Generation Sugar Mills are discussed here.

1. Cane Diffuser

The major electrical energy consumption section in sugar mill is Juice Extraction Plant. In the standard 2500 tcd milling plant, the power consumption is 1705 kwh whereas in 2500 tcd Diffuser plant power consumption is 1200. The reduction in power consumption is 505 kwh. Reduction in power consumption per season is 2.08 million units for 2500 tcd sugar mills. Extra Power revenue for 2500 tcd Co-Generation Sugar Mills will be Rs. 6.45 million respectively per season.

2. Variable Frequency Drive

In the conventional Sugar Mills, various equipment are operated in variable speed. Generally speed variation is by eddy current whose efficiency is around 60% at 80% operating speed. Most of the pumps

are run under reduced capacity by throttling the valves. Here Energy efficient, variable speed equipment- AC-PWM can be installed and this reduces electrical energy consumption at least by 30% VFD can be installed in the following equipment to conserve electrical energy.

- i. Primary Cane Carrier,
- ii. Feeder table,
- iii. Raw Juice/ Diffuser Juice Pumping,
- iv. Sulfur burner Air-Compressors,
- v. Muddy Juice and Filterate Pumps,
- vi. Clear Juice Pumps,
- vii. ID, FD and SA Fans,
- viii. Feed water and Feed water transfer pumps,
- ix. A Centrifugal drives,
- x. Sulfur melt pumping to the Sulfur burners,
- xi. Hot and cold air blowers,
- xii. Dust catcher blowers,
- xiii. Sugar elevators,
- xiv. Vacuum Filter drum drive,
- xv. Vacuum Filter condenser water pumps etc.

3. Energy Efficient Gears

The transmission efficiency of the enclosed worm and worm-wheel gear is about 60% and that of spur worm and worm-wheel drive is about 50%. Replacing the inefficient reduction system with energy efficiency enclosed helical gear, or planetary gear reduces the energy transmission loss. Installed power and power consumption can be reduced. Some of the places in which energy efficient gears, can be installed are given below:

- i. Feeder table,
- ii. Primary Cane Carrier,
- iii. Milk of lime strrrs,
- iv. Crystallizers drives,
- v. Molasses and magma pumps,
- vi. Pug-mills and Magma Mixers, etc.

4. Condensers & Cooling System

Specific Power consumption in the Injection Pumps is about 1.89 kw per ton cane. By installing energy efficient condensers, Specific Power consumption in injection Pump station can be reduced 1.2 kw per ton cane. By installing Energy Efficient cooling system power consumption can be reduced by 33%.

5. Energy efficient Pumps and Motors

In Sugar Mills, there are about 150 centrifugal pumps and 250 motors. By installing energy efficient motors and pumps, installed power and power consumption can be reduced.

6. Juice and Water Flow Meters

By replacing the Automatic Juice and water weighing scales with on line flow meters, Power spent on pumping can be conserved.

By Energy Conservation by Proper Sizing

It is a usual practice to provide higher capacity margin to cope up with the fluctuation in the crushing rate and higher rating motor for avoid tripping. By proper sizing of the equipment and installing less number of higher capacity machines instead of more number of small capacity machines, installed HP and power consumption can be reduced.

Conclusion

By Product Power project improves the profitability of the Sugar Industry. Energy Efficient Equipment improve the profitability of the Co-Generation Sugar Mills. Specific Electrical Energy consumption can be reduced by incorporating various Energy Efficient Equipment like Diffuser, VFD, Energy Efficient Transmission gears, pumps and motors, etc. and thereby power export can be increased. Specific Power Export is an indication of Energy Efficiency. As Diffuser conserves Power directly and fuel indirectly, it is one of the Energy Efficient Equipment. Extra direct tangible increase in Specific Power Export due to Cane-Diffuser is about 8 kw per ton cane. Pay Back Period for the Cane-Diffuser in the Co-Generation Sugar Mills is about three and half seasons only. In the conventional Co-Generation Sugar Plant, Power Export is about 65 kw whereas in the Energy Efficient Co-Generation Sugar Mills it will be about 95 kw per ton cane. Thus Energy Efficient Equipment increases the profitability of the Co-Generation Sugar Mills. In near future, Sugar Mills without Co-Generation will not be viable and after some time Co-Generation Sugar without Energy Efficient Equipment will not be viable. Utilizing the Strength of the organization fully after correcting the internal Weakness, encashing the Opportunity after overcoming the external Threat will improve the profitability of the factory.

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Reference book:

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