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Performance Analysis of Bagasse Based Sugar Cogeneration Power Plant in Grid Electricity Generation

Abstract: - Cogeneration power plants using bagasse in sugar factories simultaneouslyto produce steamand electricity.Electricity in Bagasse cogeneration units is used for captive consumption, bulk of it is supplied to the state grid at a fixed price, depending on the demand and supply situation in the specific area. For the generation of excess power there is continuous analysis required for the economical balance for input and output power. The success of cogeneration depends on efficient use of energy.

This paper focuses on potential of electricity generation from bagasse produced in sugar mills of Pravara Sugar factory (PSF) in Ahmednagar district..This 30 MW operating sugar Plant with total installed capacity of 72000 TCD. The average bagasse produced by this sugar mills is about 233280 MT for 160 to180 days. This indicates a significant potential of electricity generation, which can help in mitigating the power shortage in the province. This paper presents to evaluate the electricity generation potential of Pravara Sugar factory (PSF).

Sugar Plant capacity 30 MW, depending on the crushing capacity and technology used in sugar mills. The analysis shows that, generating electricity from bagasse produced by sugar Plant can contribute its share towards reducing shortfall in the electricity for the nearby province.

Keywords: Cogeneration ,cane sugar production, Bagasse, Electricity, Pravara sugar Mill.

I. INTRODUCTION

Cogeneration is the concept of producing two forms of energy from one fuel. One of the forms of energy must always be heat and the other may be electrical or mechanical energy. In a conventional power plant, fuel is burnt in a boiler to generate high-pressure steam which is used to drive a turbine, which in turn drives an alternator through a steam turbine to produce electrical power. The exhaust steam is generally condensed to water which goes back to the boiler. As the low-pressure steam has a large quantum of heat which is lost in the process of condensing, the efficiency of conventional power plants is only around 35%.

In a cogeneration plant, very high efficiency levels, in the range of 75%–90%, can be reached. This is so, because the low-pressure exhaust steam coming out of the turbine is not condensed, but used for heating purposes in factory or houses.Since, the sugar mills in India consume their own bagasse to run their mills during the season and generate steam to run the boilers and turbines; they generate power to run their plants. Surplus energy can be exported to the grid of distribution licensees.

Bagasse from sugarcane milling has significant energy potential as a combustion fuel for power generation. Sugarcane is generally grown under a wide range of conditions, in tropical and sub-tropical geographical regions in India Sugarcane is generally harvested every 9-24 months, based on variety and growing conditions. A typical sugar factory has average electricity demand of steam generation at a high pressure of 99 bars can generate 130 kWh/tc. An evaluation of bagasse cogeneration shows that the cost of electricity generated within the sugar industry is as competitive as electricity from fossil fuels. This gives the sugar cane industry plays a very important role in the sustainable energy transition.

The company had initial cane milling capacity of 4000 tonnes of cane per day (TCD) which wasincreased to 7200 TCD and obtained optimum sugar production of 884 TPD.

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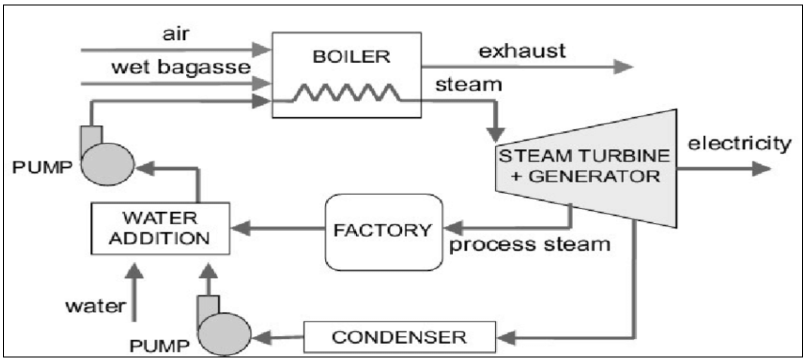


Fig.1 showscogeneration in sugar plant

II . PRAVARA COGENERATION POWER PLANT CAPACITY

The main objectives for establishing the 30 MW bagasse cogeneration plant by Pravara Sugar Company was to make use of excess bagasse fuel to generate extra power for sale to grid and hence earn extra revenue stream in addition to sugar sales. Selling surplus power to the state grid for achieving self-sufficiency in electricity generation and supply. The plant was also to help eliminate the cost of disposing off excess bagasse and its effects to the environment. The 30 MW cogeneration plant was commissioned in April 2018 which led to increased internal electricity demand is 6.5 MW and18 MW excess electricity for sale to the grid.

A. Characteristics of bagasse

The bagasse that leaves the factory mills as residue is normally made up of fibrous outer part and the underlying prit which is the white, soft, smooth parenchyma ton tissue which is highly hygroscopic. Prit mainly consists of sugars, cellulose, pentosans, hemicellulose and lignin. It also consists of wax and minerals. Properties of bagasse generally depend on the type of cane, its age as well as the method of harvesting used. However, on average, it has been established that bagasse at the point of generation with 49-52% moisture content, 47.4% fiber content and 2.3% solute materials. At 50% moisture content, bagasse has a calorific value (GCV) of 9600Kj/Kg and 7600 Kj/Kg net calorific value. Dry ash free bagasse has GCV of 19400kj/kg . The average fibers content of cane is close to 10-17% by mass, but it generally lies in the region of 12-15% while the quantity of the bagasse varies between 24 and 30% by weight ofsugarcane . Bone dried bagasse has a gross calorific value of 17,632kj/kg. At 50% moisture content it exhibits a net calorific value of 8816kj/kg . The table 1 below shows a typical content composition of mill bagasse.

Table 2.1 Sugar plant bagasse compositions.

Compositions	Percentage	Average composition
Moisture	46-52	50
Fibre	43-52	47.7
Soluble solids	2-6	2.3

From table 1, it is noted that bagasse mainly consists of moisture and fiber and traces of soluble solids. Other physical features of bagasse also have the following physical properties are specified below.

i) It is odorless.

ii) Has specific weight of 250kg/m3

iii.) It is white and light green in color.

Compared to other conventional fuels, bagasse has a relatively lower energy value. However, its availability at the factory and the reduced transport costs involved in ferrying it make bagasse a more suitable source of fuel or energy in sugar factories especially at a lower moisture content level.

B. Sugar manufacturing process

The natural sugar stored in sugar cane is separated from the plant material through sugar manufacturing process. The sugar manufacturing process normally comprises of, juice extraction, juice clarification, evaporation, centrifuging and drying and packaging. These processesinvolve,

• Cane is weighted first, and then it is converted into small pieces by passing through fiberized where cane is turned into small thin fibrous form and then enter into mill set through carrier.

• This prepared cane is now crushed in mill,after passing through mill hot water of temperature 60 °C to 70°C is added to take out as much as possible in leaving Bagasse. The Bagasse is used as fuel in Boiler to produce steam.

• The produced steam is used for prime mover of power turbines, mills and fiberized. The juice is collected at Mills and is called “Mixed Juice”. It is pumped out to auto weighing Tank.

• This “Mixed Juice “is now allowed to pass Juice heater where it is being heated at 60 °C to 70°C for clarification, Juice is mixed with milk of lime and SO2 gas simultaneously. Here PH of juice is maintained at 6.9 to 7.1. This juice is called sulphited juice. This sulphited juice is heated again to 100-105°C and it is pushed to settler vessels called clarifier where all Mud is settled down and clear juice is obtained on upper part of chamber.

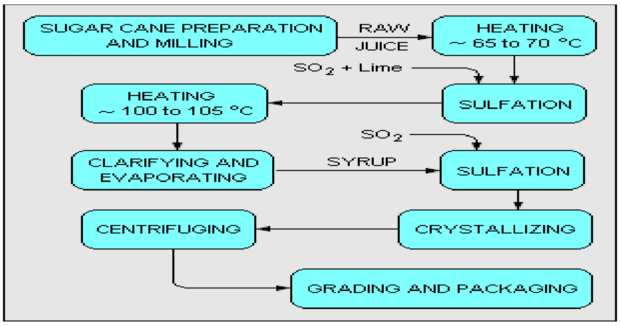


Figure 2. 1: Sugar manufacturing process

• The muddy juice now is pumped to filter where mud is taken out from the juice again sent to “Mixed Juice” and mud separated is known as “Filter Cake” which is used as manure in the syrup is again passed through SO2 gas where PH is maintained at 4.9 to 5.1.

• Now this Sulphited syrup is sent to supply tanks of pan station. After boiling under vacuum at “pan”, small grain is formed with molasses that is called Masscult.

• After dropping from pan, this Massecuite are allowed to cool in crystallizer and then pumped out to centrifugal machines.

• At centrifugal machines sugar and molasses are separated now the sugar is passed through hopper to get it free from moisture and Hot and Cold air is applied through blower.

• The separated molasses is collected in storage tanks.

• This sugar is separated in separate grade by passing through grader of different mesh and finally from grader sugar filled in gunny bags and weighted and sends to go-downs [1].

III. PLANT ENERGY CONSUMPTION PROFILE

A.Energy description of the Plant.

The preliminary data collected from the Plant has been done to determine specific energy consumption of the Plant to analyze energy utilization of the Plant and identify energy efficiency improvements potential through benchmarking strategy with similar industry in the world. (To determine strategy for efficiency improvement for the factory).

The factory major energy consumption is electricity and steam (for process) which is generated from bagasse (by product from sugar manufacturing process) and Heavy furnace fuel (HFO). The energy data (electricity generated, steam produced, electricity imported and exported from/to national grid), cane crashed and sugar produced for the year 2021-22 is collected from the factory using developed data collection worksheet for the purpose of energy utilization analysis and efficiency improvement potential.

B. Energy consumption profile

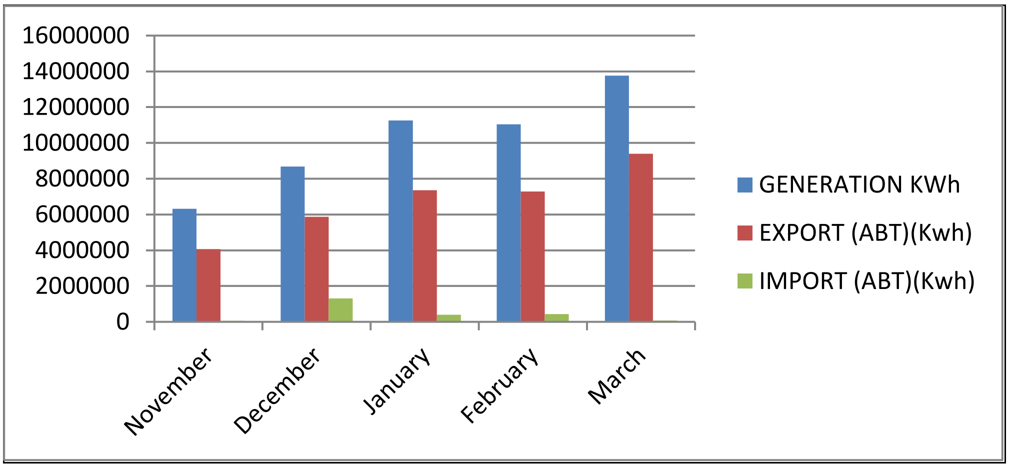
The major source of energy in the plant for sugar manufacturing process is electricity and steam. The factory has one steam turbine generators (cogeneration power plant) 30MW capacity out of that 3MW electricity used for sugar process,1MW used for distillery ,0.5 MW for colony and 2 MW for auxiliary drives such as DC motors, pumps,coolingfan, and VFDs etc.The month wise electricity generated from the plant, electricity imported and exported to the grid on 2021-22 during production period of the factory from October 2021 to June 2022 is given on the following table.

Table3.1:-2021-22 production period electricity profile of the factory

Month 2021-22	**GENERATION KWh**	**EXPORT (ABT)(Kwh)**	**IMPORT (ABT)(Kwh)**	**COGEN (Kwh)**	**SUGAR Process (Kwh)**
November	6320206	4062600	55800	746006	1564771
December	8687261	5869800	1315800	1284592	2808421
January	11261689	7358400	392400	1362412	2866998
February	11034827	7286400	433800	1292463	2797817
March	13755435	9403200	70200	1427518	2973003

Generally total electricity formula as,

Generation+ Import=Electricity in Cogeneration + Electricity Sugar process+ Electricity export



Above graph shows electricity generation and export / import of energy profile .

The import and export balance of electricity indicated on above table is electricity consumed by the plant. The trend of the electricity consumption of the plant is indicated below on the following graph (figure 3.2)

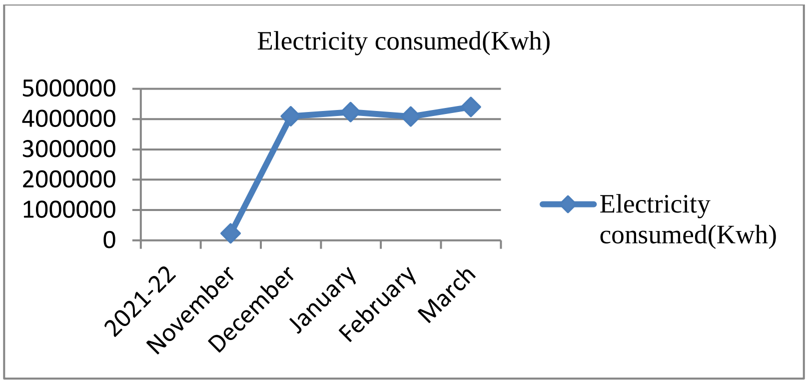


Figure3.2: PSF Electricity consumption profile (Oct.2021-22)

Table 3.2 showsbagasse produced,Sugar produced,steam produced and electricity consumed in Mwh per month during production Period of the factory is indicated in the following table.

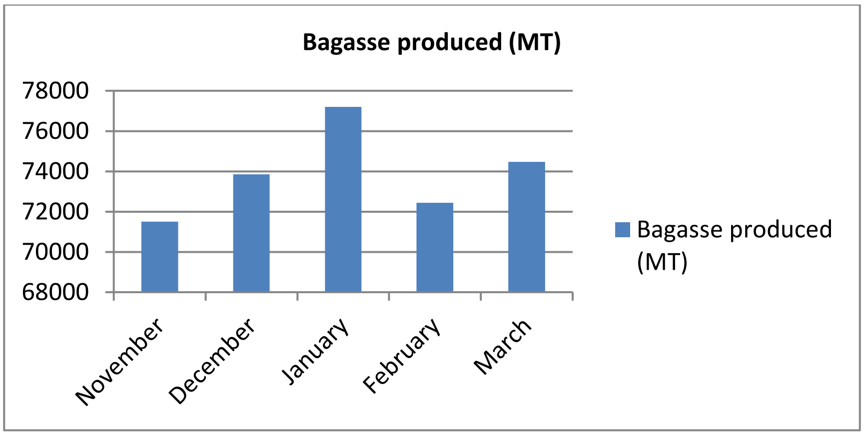
Table**3**.2 as below

Months 2021-22	Cane crashed (MT))	Bagasse produced (MT)	Steam produced (MT)	Electricity consumed (Kwh)	Sugar produced (MT)
November		71500	119400	231077	29870
December		73846	125647	4093013	30855
January		77192	137420	4229410	32550
February		72443	128150	4090280	31776
March		74470	137320	4400521	34310
Yearly/total	**1296000**	**369881**	**648000**	**17044301**	**159361**

The months of October and July are considered as the production months (from October to July) of the factory in a year,but there are no production registered in those months.

IV. BAGASSE SUPPLY AND ELECTRICITY GENERATION

A bar graph showing the total amount of monthly bagasse supplied to the plant.



From figure 4.1 it is noted that enough bagasse was supplied to the plant for electricity generation. The reduction in the amount of bagasse supplied to the plant of courseaffect the electricity generation. The plant was designed to burn more than 100 metric tons of bagasse per hour at its optimum performance. However, due to insufficient supply of bagasse, it could not run at its optimum anymore. Reduced power output led to reduced power exported to the national grid and hence reduced revenue generation from power export to the Company.

The bagasse cogeneration plant is also designed such that it operates on just one, but high-volume boiler that runs on a single-high-capacity furnace. The generated steam is used to drive a single turbine. The turbine is large enough and can generate as high as 30 MW of power. The fact that the massive plant runs on a single furnace, single boiler and a single prime mover makes it very difficult to control the costs involved in its operation.

For example, the costs involved in generating 10 MW or 30 MW are no different since at both low and high output levels the plant operates at constant conditions. It is, therefore, uneconomical running the plant at lower output considering the heavy initial investment involved in setting it up. Whenever there occurs a break down or damage of part, however minor, the entire plant must be shut down for repairs to be done unlike other power plants that are made up of several units. This means that the plant cannot generate power at all during both repair and maintenance periods. The plant is, therefore, unavailable during such times and hence unreliable in supplying power to the national grid.

V. CONCLUSION

This study concludes that Pravara Sugar factory with design cane crushing capacity of 7200 TCD has significant electricity potential of about 30 MW, but this may not be realized because of poor plant availability mainly due to breakdowns and shortage of sugarcane for milling. The plant should increase its availability to about 90% for steady milling and electricity generation. Investment in efficient electric drives as opposed to steam turbine drives and new efficient boilers of greater pressure and efficiency will position in Sugar company for export electricity generation.

Bagasse is Primary fuel used in cogenerationplant therefore plant operation depends upon availability of bagasse in plant.Actually, the bagasse cogeneration Sugar plant operation has ever since suffered a number of challenges that have seen in the plantwhen MSEB Power disconnected electricity supply due to huge electricity bills arising from penalties accrued to the cogeneration plant failure to deliver the terms of the power purchase agreement.

Cogeneration has been seriously affected by shortage of fuel due to supply interruptions caused by strikes and cane shortage leading to long forced outages of the sugar mills and the cogeneration plant. The amount of bagasse produced out of the crushed cane could not sustain the running of the boiler to ensure continuous power generation. It is therefore important that by all means the cane suppliers be motivated to remain on board and continue with cane farming to supply the factory that will guarantee adequate bagasse supply for the operation of the cogeneration plant.

The design of the cogeneration plant to use single fuel is a serious challenge to sustainable cogeneration. Multi-fuel boilers running on more than one fuel could guarantee continuous power generation since can faming and supply to the factory has deteriorated and is no longer sustainable.

The cogeneration plant has capacity of 30 MW and was designed to run on a single high-capacity boiler with a single turbine prime mover. This is causes serious challenge in operation and maintenance in terms ensure consistency in power generation as the whole plant must be shut down altogether whenever there is need to carry out repair or maintenance. The single boiler also requires a lot of fuel to run and whenever there was little bagasse, the entire plant is stopped ultimately affecting cogeneration and sugar production in the factory.

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