MODERN TRENDS IN SUGAR PLANT HIGH PRESSURE COGENERATION SYSTEM

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SYNOPSIS

Cogeneration in sugar industry to produce surplus power and export to the Utility Distribution grid has gained momentum and is the order of the day. In Indian sugar industry it has been estimated that the sugar plants can export and export about 5000 MW of power to the national grid. The successful operation of more than 76 projects designed by Avant-Garde and a few more projects designed by others have given the required confidence in the Indian sugar industry to implement high pressure cogeneration and look for avenues to further improve the cogeneration plant revenues. In fact, under today's condition, the profitability of a sugar plant is centered on the revenue from export of power. The encouragement being given by the central and state government for promoting the use of bio-mass / non-conventional, Eco-friendly energy further encourages the implementation of cogeneration plants in sugar industries. Today the catch word in the industry is "to maximize the export of power". In the non crushing season the sugar plants in India produce power in the condensing mode with saved bagasse and coal as fuel and strengthen the power grid helping to reduce power shortage. The concept of high pressure cogeneration has caught up in East Africa and the first 34.2 MW, 87 ata, 515˚C cogeneration plant is successfully running at M/s. Mumias Sugar Company Ltd., Kenya for the past two years which was engineered by Avant-Garde as EPCM consultant. A few more projects in Kenya have completed the techno economic feasibility report and are awaiting financial closure for implementation.

INTRODUCTION

The bagasse based cogeneration plants generally consist of a high pressure boiler and a double extraction cum condensing turbine. The terminology high pressure has a floating value today as the power cycle parameters adopted are undergoing fast changes. Since, the first plant was installed with a capacity of 18.68 MW and was commissioned and stabilized in November 1995 there were a flurry of activities for preparation of Detailed Project Reports and implementation of Cogeneration programs. The Progressive minded changes in a State Electricity Board power purchase policies such as allowing certain percentage of pass through of power using conventional fuels is resulting in the increase of the Cogeneration Plant capacities.

The increasing sizes offer options on selection of higher parameters for the power cycle which are in turn related to the capacities of the steam generators and turbo generators. The modern trends in technologies and the related issues are briefly discussed in this paper.

TECHNICAL ASPECTS

Cogeneration based on Rankine Cycle is not new to the sugar industry, however Cogeneration based on High pressure boilers and extraction condensing or straight condensing machines are definitely new to the industry. In olden days, the power cycle adopted was based on 14 kg/cm^2(g) and 21 kg/cm^2 (g). This has been gradually increasing to 32 kg/cm^2 (g), 45 kg/cm^2.(g), 66 kg/cm^2.(g), 86 kg/cm^2.(g), 110 kg/cm^2.(g) and now stabilized at 124 kg/cm^2 (g) and 540°C. With the sizes of the cogeneration plant going above 40 MW the use of 135 kg/cm^2 (g) pressure cycle and reheat cycle are being explored. The following highlights a few of the technical issues for designing of the Cogeneration projects.

BASIC DESIGN OF THE COGENERATION PLANT

This stage of Project is where the configuration of the Cogeneration plant gets finalized. What is important is that the configuration conceptualized is appropriate for the specific project. Basically the Cogeneration plant configuration is site specific, even though some amount of standardization could be made for the grass root plants. The Scheme should consider the available bagasse, the variations in the bagasse availability, the allowable percentage of the pass through using conventional fuels like oil / coal, the process steam requirements and the pressure levels. Considering the variations in the bagasse availability and the possible variations in the process steam consumption and the number of days of operation, maybe it is better to down size the plant and ensure maximum plant load factors. The plant cycle should be optimized to give the best efficiency.

Even though there is no limit to the achievable steam pressures and temperatures with bagasse firing, it is essential a cost benefit study is made before deciding on the steam cycle parameters. In such a study proper consideration should be given to the cost aspects of the higher grade metallurgy of both the turbine and the boiler, specifically the superheater and the piping. With the industry almost voting now for one boiler concept as against multiple boilers, with the process steam consumption coming below 38% on cane and with the size of the sugar mills in India, use of single drum boilers and capacities exceeding 100 TPH is gaining momentum. It is now well established that there are no specific problems in adopting a single boiler configuration with single drum concept in the sugar industries. With boiler capacities above 100 TPH and the optimum cycle parameter could be 125 ata and 540˚C.

PROJECTS UNDER AVANT-GARDE CONSULTANCY

S. No	Cycle Parameters (Bar(A) /^{0} C)	Commissioned	Under Implementation
1	45/440 & < 45/440	16	5
2	67/485	23	1
3	87/515	29	6
4	110/535	23	26
5	125/545	2	6
Total		**93 (2005.21 MW)**	**44 (1195.50 MW)**

34.2 MW COGENERATION PLANT IN KENYA

POWER CYCLES

The Cogeneration scheme for any sugar plant is plant specific and there is no single scheme applicable for all the plants. A scheme applicable for a grass root plant will not fit into an existing operating plant wanting to go for Cogeneration. Even among operating plants, a plant going in for modernization or capacity up gradation can have an economical and power maximizing configuration, than the one where no capacity addition or modernization is planned. The modernization mentioned above includes, changing Mill drives from inefficient single stage steam turbines to Hydraulic/Electric drives, use of variable frequency drives, planetary gear boxes, process improvements to reduce steam consumption by judicious vapor bleeding and usage of continuous pass etc., these steps make more steam available for power generation and improves vastly the viability of the Cogeneration Project.

For a typical 3500 TCD plant with steam consumption 40% on cane the possible maximum steam generation will be around 120 TPH. By adopting difference cycle parameters the indicative figures of the maximum power generation possible are:

Sl.No.	Description	67 ata	87 ata	110 ata	125 ata
A	**Design Data**				
1	Boiler Capacity (TPH)	110	110	110	120
2	Boiler Outlet Parameters (ata)	67	87	110	125
3	Boiler Outlet Steam Temperature (Deg.C)	485	515	540	545
4	Feed Water Inlet Temperature (Deg.C)	150	170	210	240
5	Steam to Bagasse Ratio	2.45	2.49	2.605	2.76
6	TG Capacity (MW)	20	21	22	23
7	Turbine Inlet Steam Pressure (ata)	64	84	105	120
8	Turbine Inlet Steam Temperature (Deg.C)	480	510	538	540
9	No.of HP Heaters	1	1	2	3
10	Condensing System	ACC	ACC	ACC	ACC

The above data indicates that by adopting 125 ata pressure cycle about 15% more power can be generated for the same sugar mill compared to 64 ata power cycle. Thus, the selection of the power cycle and the cost competitiveness depends on the steam generation quantity of the boiler.

Adopting multi stage feed water heating; high pressure deaerator and adopting new technologies for reducing moisture percentage in bagasse will contribute to the overall cycle efficiency increase. The major issues in adopting higher pressure cycles are the selection/availability of proven high capacity boilers and fuel handling/firing system. The availability of servicing facility and spares for imported high capacity turbo generators could also be a specific problem.

STEAM GENERATING SYSTEM

The capability to design, manufacture and install steam generating systems of any capacity with any outlet steam parameters is available in India. Bagasse being a fuel not amenable for perfect metering it has given some problems with regard to the superheater steam temperatures. Higher temperatures during start-up and at load fluctuations have been experienced, but could be contained because of the staged de-superheating provided. Continuous bagasse feeding system with bagasse silos have been developed for maintaining the boiler parameters steady even with the process steam fluctuations.

Some fine tuning is required in the areas of excess air control and un-burnt carbon loss control. The cinder recovery system is now being provided for reducing the carbon loss.

Feed water quality control is an area needing attention and this is separately dealt under the water quality management.

125 ATA, 540˚C BAGASSE FIRED BOILER

In conventional bagasse fired boilers, bagasse is fed into the boiler directly from the mill. The quantity of bagasse fed into the boiler is controlled manually by opening or closing a gate in the return bagasse carrier. This system cannot have an automatic combustion control. In order to implement an effective combustion control, storage silos above the feeders, or a continuous circulation of bagasse, say, through a merry-go-round system is required.

An effective silos system for the storage of bagasse, which will store bagasse for the requirement of about 10 to 15 minutes for the boiler MCR, has been successfully tried implemented. This system operates well for a bagasse that is well prepared and with 50% moisture. The system has been implemented by Avant-Garde with auto combustion control at M/s. Lopez Sugar Corporation, Philippines in one of their low pressure boilers.

Travelling grate with pneumatic distributors is best suited for wide variations in the type of bio-mass fuel and additional use of conventional fuels such as coal / lignite. The availability of a reliable and well proven travelling grate of large size to suit 150 to 200 TPH is established. The experience available with the various boiler manufacturers worldwide does not seem to have limitation on the boiler capacity matching with high pressure. Many references are available with boiler capacities in the range of 100 TPH with high pressure in India. The operating experience / feed backs of the large size of grates are good and well established.

CO-GENERATION WITH VINASSE / SPENTWASH INCINERATOR IN DISTILLERY PLANT

TURBOGENERATOR SYSTEM

The experience has shown that the turbine for the Sugar plant Cogeneration application should be rugged and preferably with slow speed. Problems in maintaining the steam purity in the boilers affect the turbine with deposits on the blades. The major contaminant is silica that gets carried over as vapor as the operating pressure of the boiler increases. Modern boilers with primary and secondary steam separators in the boiler drum have improved the quality of steam and the problems of carryover have been overcome.

However there is a specific problem with regard to the servicing and spares availability. There are a number of suppliers who can supply the machines, but it is to be ensured that the supplier sets up an adequately staffed service network and stocks adequate spares. This could pose major problems, specifically after the warranty periods. Most of the suppliers, import the turbine steam path components, generators, AVRs and a few auxiliary equipment, and in such cases spares and servicing could pose serious problems.

TYPICAL COGENERATION PLANT TURBOGENERATOR HALL

WATER QUALITY MANAGEMENT

This is one area that needs more attention. Extraction steam at low pressures is supplied to the sugar plant for processing. About 90% of the steam supplied to the sugar processing is returned as condensate to the steam generator feed water system, at a temperature of around 95˚C. Generally there could be no contamination of this exhaust condensate. Sincere and disciplined efforts should be made to keep this condensate free from contamination.

We are not recommending the usage of the vapor condensate for the boiler feed water application for high pressure units as the quality of this condensate varies. Generally the pH is low, the TDS and silica are high and there could be traces of ammonia and organic compounds. We could use this with a lot of monitoring, but the repercussions could be serious if the monitoring system malfunctions or fails.

This aspect of water management has been mastered and is now well established.

BAGASSE HANDLING

During the cane crushing season, the cogeneration plant receives the bagasse directly from the mill, and the surplus bagasse is taken to the bagasse storage yard. The bagasse thus saved could be used for the off-season operation of the Cogeneration plant, or could be used to run the Cogeneration plant on the cleaning days or when the mill is not running due to some other reasons. Under such occasions back feeding of the bagasse from the yard to the boiler is required. As the unit size becomes larger the quantum of bagasse to be back fed is so high. The feeding becomes non uniform, resulting in the overloading of the conveyors if the feeding is done improperly with bulldozers or pushers. To overcome the back feeding difficulties stacker re-claimers have been designed, but only with limited success. Such systems are successfully in use in Mauritius and Reunion Island. We understand that large storage bins with automatic stacking and reclaiming facilities are in use in Australia, but we also understand that the costs of such systems are prohibitively high. Some operationally effective and also cost effective system of stacking and reclaiming is to be devised. If a good system is developed the best operating procedure will be to delink the Cogeneration plant operation from the mill operation, by taking all the bagasse to the storage yard and feed the boiler only through the reclaiming system.

CLOSED STORAGE BAGASSE STACKING AND RECLAIMING SYSTEM

For use of other fuels such as cane trash, cotton stalk etc., the collection of the fuels from the farms, baling, de-baling / chipping facilities have to be perfected. There are many imported equipment available for collection baling and shredding of the bio-mass fuels. The dependability and performance of this machinery have been successful and is used in various sugar plants in India

BAGASSE DRYING SYSTEM

The bagasse from the mill contains 50% moisture. This moisture is evaporated in the furnace and is let out from the boiler at a temperature of about 150˚C without any useful contribution. This moisture restricts the efficiency of the boiler to around 70%. If this moisture is removed from the bagasse before it is fed into the boiler, the boiler size can be designed to be much smaller in dimensions for the same output or the capacity of the boiler can be increased in an already existing boiler. For every 1% reduction in moisture the boiler efficiency will go up by about 0.55%. This means that with the same quantity of bagasse available the capacity of the cogeneration plant can be increased.

Various methods of drying have been tried. One among them is to tap off the flue gas from the boiler at a higher temperature and use it in a rotary bagasse drier. This method decreases the efficiency of the boiler due to tapping off of the gas at a higher temperature and has added disadvantages of pollution problem due to spreading of the dry pith in the bagasse. In this case, the bagasse is best dried in the furnace.

If alternate heat source of surplus low pressure steam is available then it could be utilized in a rotary steam drier. This is a general practice for drying of de-pithed bagasse to about 5% moisture level in particle board plants. In these driers there is a rotating bundle of tubes through which the steam is passed and the bagasse moves on the outside of the tubes from one side of the bundle to the other. It is possible to reduce the moisture percentage in bagasse from 50% to 20%. The steam for the drying can be bled from the power turbine which will in turn improve the efficiency of the power cycle. The scheme for the system should be properly designed and optimized.

In the operating experience available with steam driers have been more with de pithed bagasse. The size/capacity of the driers also does not match with the required capacities for a Cogeneration Plant. Hence, more feed backs on the cost and operating experience on the working of the steam driers with un-depithed bagasse is to be studied before implementation.

ELECTRICAL SYSTEMS

As far as the technology for the design of the electrical systems for the Cogeneration plant, right from generation to EHV system and grid paralleling is concerned, enough experience is available. All the electrical equipment required for the Cogeneration plant, as well as its grid paralleling are available indigenously. The only problem faced by the Cogeneration plants is the stability of the grid.

There are unfounded fears in the minds of the plant operators with regard to the ability of the cogeneration plant to cope up with the tripping of the grid. If the protections are properly chosen and the equipment are properly specified, there is no reason why a cogeneration plant should trip with the grid and not go into island mode operation. To the extent possible efforts should be made to parallel the cogeneration plant at higher voltage levels.

CONTROLS & INSTRUMENTATION

Being the most important subject from the point of view of operation and maintenance of the cogeneration plant, this subject deserves a lot of attention. Distributed Control System (DCS) is the order of the day. The technology for the planning and designing the complete controls & Instrumentation system for the cogeneration plants is available, but what is required is to create awareness among sugar plant people about the importance of instrumentation in the operation and maintenance of the cogeneration plant.

FUZZY LOGIC BASED CONTROL SYSTEMS

Some of the control loops connected with power plant controls are very complicated in nature and have large time lags, and are not very effective when implemented through conventional PID controls. “Main steam temperature control” with large dead time and lag time is a typical example.

COGENERATION PLANT CONTROL ROOM

Fuzzy logic based control system is found to be useful in such cases. It works with the “data base” of an experienced operator and is able to obtain a tight control over steam temperature. AVANT-GARDE has successfully implemented this feature in one of their Co-Generation based power plants, in which large variation in steam temperature was brought down to an acceptable level using Fuzzy logic based controls. Fan speed control of Air cooled condenser, Drum level control during Swell-Shrink are some areas where Fuzzy logic can be effectively used.

CONCLUSION

The maximization of power generation from bagasse based Cogeneration plant is the thrust factor in implementation of modern high pressure Cogeneration Plants in sugar industries. The basic design of the plant consists of the selection of power cycle parameters, the number of units and capacities of the boiler and turbo generator. The techno economical viability depends on the correct selection of the technology and adopting higher cycle parameters. The issues relating to the selection of the size, the number of units and the design of various other systems such as bagasse handling system, the water system etc., needs careful attention and a more in depth study of the feed backs and operating experience worldwide. There is no technological constraint in adopting high pressure cycles for the sugar plant Cogeneration systems.

If you require any further details or information, please contact us

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