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OPTIMAL CONTROL OF STEAM AND POWER GENERATION IN SUGAR INDUSTRIES

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Abstract—

The fossil fuels such as coal and petroleum products have only limited reserves and are getting depleted quite fast. Thermal power generation from these resources will last for another 100 years or so and we are left with no other way than looking for alternative resources for power generation. Further, it saves the environment too in terms of lesser emissions if fossil fuels are substituted with other kind of resources. Hydel, wind, solar, tidal and co-generation from the Industries or being thought of as alternative methodologies by the mankind for generating power and exporting it to state grid while providing energy conservation and extra revenue.

This paper presents The steam temperature control in bagasse boilers is extremely difficult owing to the fact that the superheater system and consequently steady state control is reached within ± 10 ^{o}C deviation. The research work aims to reduce the steam temperature deviation from ± 10 ^{o}C to ±2 ^{o}C so that enthalpy of steam can be improved and more power output is delivered by the boiler. The mathematical model of the secondary superheate. The performances of the PID Controller + Kalman filter predictor are compared in simulation mode. It is noticed that the superheater response with the Kalman filter Predictor is 6 times faster than that of PID Controller. Benefit estimation shows that inreal time implementation, the payback period of the system is 18 days for a reduction of ± 5^{o}C in the deviation.

Key words—Sugar plant, Bagasse, Mathematical model, State-space structure, PID Controller, Kalman Filter, White noise, State Estimation Predictive Control,

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Introduction

The conventional energy resources such as fossil fuels are getting depleted and we do not get coal and petroleum products after 100 years. Therefore, we are subjected to mounting pressure to reduce the carbon emissions and identify new and /or renewable energy resources to substitute the fossil fuels our meeting their energy demand at competitive prices. The co-generation of power and steam is a proven method of energy saving and optimization. The main processes that benefit out of this technology are textiles, paper, sugar, food and district heating. The last decade had witnessed a significant momentum in sugar co-generation in India, with many customers are opting for the technology and its modernization. The primary fuel used in sugar plant boilers is bagasse that is obtained during sugar production process. In India, potential power generation from bagasse as fuel is estimated to be about 5000MW and more than 1000MW has already been achieved [1-2].

Bagasse is a useful source of energy with a gross calorific value of about 9200 KJ/Kg but it contains a very high level of moisture of the order of 50% by weight and hence needs specifically designed handling, feeding and combustion systems. Surplus electrical power from the co-generation process can be exported to the state grid, providing the customer with an extra revenue stream.

2. The Energy Flow Process in the Sugar Industry

Production of process steam and generation of electricity are given more importance these days in the sugar industry owing to strict adherence offactors such as optimum energy conservation, minimal industrial emissions and maximum production efficiency. Sugar, the primary product from the plant gives energy to people and the residual biomass (bagasse) is burnt in the boilers for releasing the energy required to allow the sugar factory for generating electricity as well as to generate process steam in order to crystallize the sugar. Further, studies indicate that sugar cane can absorb 22 to 36 tons of Carbon-dioxide per hectare on a continual basis during its lifecycle of five to seven years. Fig.1 gives an overview of the cane to sugar making technology and the energy flow diagram.

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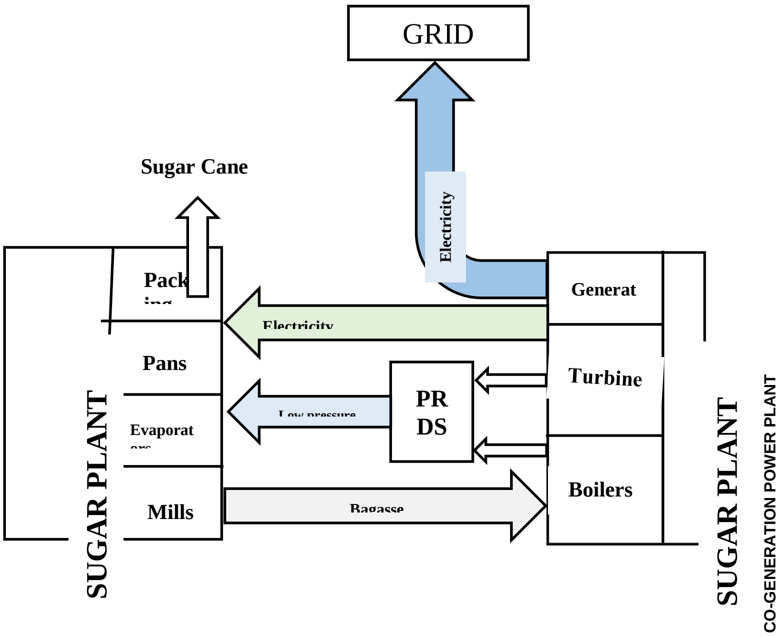

Fig.1 Co-generation power plant in Sugar Industry

Bagasse is the fibre that remains after the sucrose containing juice has been extracted. In the boilers, the combustion of the bagasse heats up water to form steam. In order to increase the efficiency of the boilers the steam is "superheated" and is then passed through a turbine that uses its rotation to generate electricity. This electricity is used to power the mill complex in the plant and different equipments. Depending on the configuration of the mill, it can produce excess electricity for sale to the national electricity gridthereby reducing the use of fossil fuels.

The blow tanks collect all the drains and deliver as feed water to the boiler drum. Portion of the steam from the SSH is taken in to the Pressure Reducing and Desuperheating System (PRDS) and goes as "process steam" to the sugar plant at required pressure ranges. Remaining steam is considered as "power generating steam" and is directed to turbine and generators for generating power and transportation to the state Grid.

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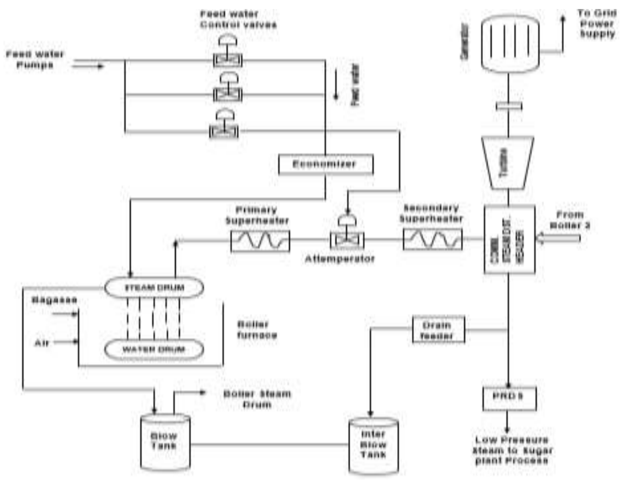

Fig.2 Steam and Power generation in a bagasse fired

2. Problems in Steam Temperature Control

The following problems exist while controlling the steam temperature in the sugar plant with conventional methods using PID Controllers:

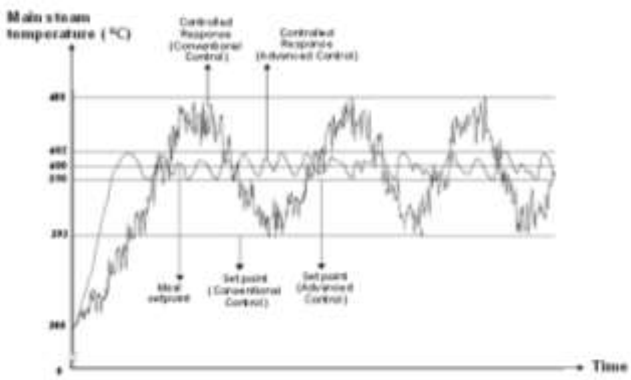

Fig. 4 Temperature deviation of minimum ±8°C exists in closed loop control

4. Proposed optimal Control System

The proposed control system consists of six important components namely, (1) Conventional PI steam temperature control system (2) Boiler plant model in state space form (3) Kalman Filter based stochastic state estimator (4) Adaptive Process Identification (5) N-step Kalman filter state predictor and (6) Adaptive Predictive controller as shown in Fig.7. The conventional PI steam temperature control system depicted in Fig. 6 is a proven control system and has been

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accepted by the boiler power plants since many years. Due to this reason, this control system is chosen as the basic building block for the predictive control system. Building blocks 2 to 6 are used to enhance and optimize the performance of Building block1 in order to obtain minimum possible steam temperature deviation from the setpoint in close loop control.

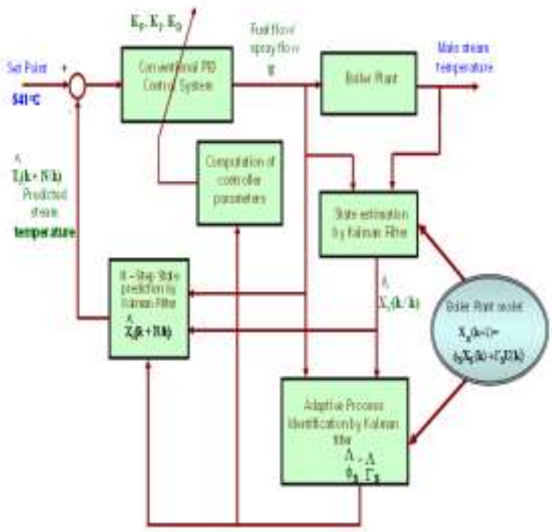

Fig.7 Architecture of Adaptive Predictive Steam Temperature Control System

The sugar plants are investigating the amount of additional power they could generate and export if they used the brown leaf from the cane which is currently burnt prior to harvest. Using the brown leaf technology, we can increase the fuel supply to the boilers significantly and the amount of power can be increased and exported to the grid Fig. 2 explains the steam and power generation operation with bagasse fired boilers in the sugar plant and corresponding steam temperature control Boiler furnace is operated with an air/fuel ratio of 3.5 :1 and the hot gas emanated from it is used as heating source for various heat exchangers such as boiler drum, primary superheater, secondary superheater, reheater, economiser, air pre-heater etc. The boiler furnace is always operated at vacuum pressure in the range of -5mmwcl to +5mmwcl. The feed water is heated in the economiser and delivered to the boiler drum by the boiler feed pumps.Level of water in the drum is maintained constant bythethree-element controller and feed water control valves. The feed water inside the drum is getting heated by the boiler furnace and saturated steam is produced. The saturated steam is further heated with the hot gasses from the furnace in the primary and secondary superheaters and its temperature is controlled

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according to the set point in the attemperators by spraying a portion of boiler feed water in to the steam.

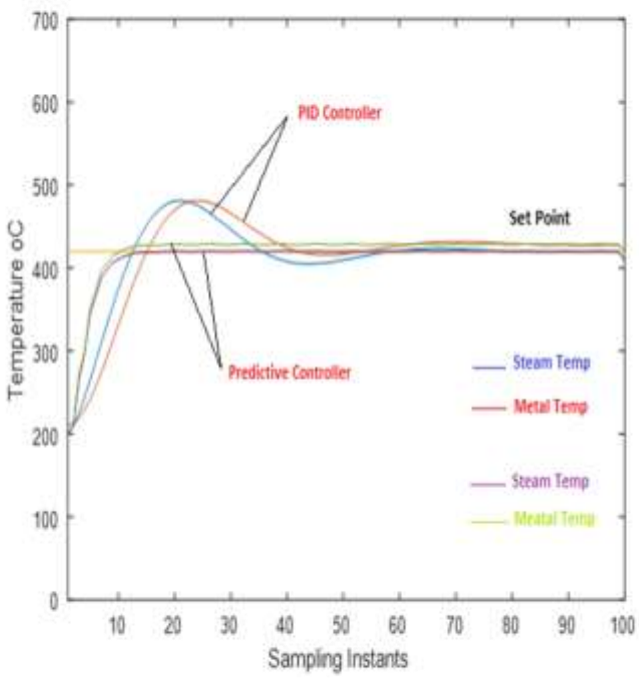

Fig.13 Comparison of Performance of PID and Predictive controllers

6. EXPECTED BENEFITS

A reduction of 5^0 C in the deviation of final steam temperature achieves a payback period of 5.32 Months as shown below:

<u>Tangible Benefits</u>

1. Total steam flow = 100 T/HR
2. Enthalpy of steam at $42Kg/cm^2$, 400^oC= 764.49Kcal/Kg.
3. Enthalpy of steam at $42Kg/cm^2$, 405^oC= 767.32Kcal/Kg.
4. Enthalpy difference for 5^oC raise in temperature= 2.83 Kcal/Kg.
5. 1 Kwhr=860 Kcal
6. Power Generation for 100 T/Hr steam flow

= (2.83x100x1000)/860=329.07 Kwhr.

i.e., if there is 100 T/Hr steam generation at an average higher rise in temperature of 5^oC, there is a gain of equivalent 330Kwhr of additional power generation.

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7. Power generation per day for 5°C rise in temperature

= 329.07x24xRs.4.00 per Kwhr

=Rs. 31,584.00 per day

8.If we assume the plant operon for average **100 days** in a year,

Annual savings= Rs. 31,584x100=Rs. 31,58,400.00

9. Project cost = Rs.6 Lakhs

10. Payback period=14/31.58=0.443 years =0.4433x12=5.32 Months.

Payback period= 18 days

7. CONCLUSIONS

In recent years, Thermal power generation from these resources will last for another 100 years or so and other way than looking for alternative resources for power generation. Further, it saves the environment too in terms of lesser emissions if fossil fuels are substituted with other kind of resources. The research work aims to reduce the steam temperature deviation from ± 10 °C to ±2 °C so that enthalpy of steam can be improved by replacing the conventional controller, and more power output is delivered by the boiler. The mathematical model of the secondary superheated. The performances of the PID Controller + Kalman filter predictor are compared in simulation mode which are shown different conditions results are carried out. It is noticed that the superheater response with the Kalman filter Predictor is 6 times faster than that of PID Controller. Hence, the co-generation in sugar industry using bagasse as the fuel which is obtained as the by-product during the sugar manufacturing process.

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