بسم الله الرحمن الرحيم

SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF GRADUATE STUDIES

Performance Evaluation and Enhancement of Bagasse Based Power Generation

A Case Study: Assalaya Sugar Factory

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دراسة حالة : مصنع سكر عسلاية

A Thesis Submitted in Partial Fulfillment of the Degree of M.Sc. program of Mechatronics Engineering

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May 2016

الآيـــة

قال تعالى :

ٱلرَّحْمَنُ(1)عَلَّمَ ٱلْقُرْءَانَ(2)خَلَقَ ٱلإِنسَانَ(3)عَلَّمَهُ ٱلْبَيَانَ(4)ٱلشَّمْسُ وَٱلْقَمَرُ
بِحُسْبَانَ(5)وَٱلنَّجْمُ وَٱلشُجَرُ يَسَجُدَانِ(6)وَٱلسَّمَآءَ رَفَعَهَا وَوَضَعَ ٱلْمِيزَانَ(7)

صدق الله العظيم

سورة الرحمن الآية من (1-7)

Dedication

To the soul of my kind father and beloved mother

And to my wife for her patience, help and support

Acknowledgment

I would like to thank all those who educated me.

I would like to thank everyone who helped me in this study .

It is my pleasure to acknowledge in particular Dr. Elhadi Badawi Mahgoub for his patience and great help in putting this research in its final form.

Abstract

Electrical power generation by using baggasse as fuel is a profitable by-product in sugar industry.

This research deal with the possibility of getting the maximum output of the power generation during the crushing season and the off-season and hence highlighting the technical problems encountered and doing the required enhancement.

The method used is the data gathered from the operation log book. Based on baggasse ,steam and energy balance, it was found that Assalaya Sugar Factory crushes 290 tons of sugar cane per hour (TCH) that have 18.5% fiber and 39.0% baggasse which is used for generating 17.2 MW (10.9 MW for the 13MW turbo-alternator and 6.3MW for one of the two existing 6.5 MW turbo-alternators) with the other 6.5MWwhich has to give 6.3MW not running due to lack of hardware (because the existing 7.5 MVA transformer connecting between the 3.3KV and 11KV bus bars is under size), adding new transformer of 7.5 MVA capacity will increase the output power to be 23.5 MW.

By increasing the crushing rate to 295 TCH and running the factory for 150 days , this make the 13MW power plant unit running in the off-season for extra 85 days .

المستخلص

يعتبرتوليد الكهرباء باستخدام البقاس كوقود من المنتجات الجانبية المربحة فى صناعة السكر. هذه الدراسة تقوم على الحصول على اقصى خرج من منظومة التوليد فى مصنع سكر عسلاية فى موسم الانتاج وموسم الصيانة وتسليط الضوء على المشاكل الفنية وامكانية اجراء التحسين المناسب بها والاسلوب الذى تم اتباعه فى ذلك هو جمع البيانات من دفتر رصد بيانات التشغيل اعتمادا على توازن البقاس والبخار والطاقة وباخذ البيانات التشغيلية معدل طحن فى الساعة و قدره 290 طنا ونسبة فايبر فى القصب قدره 18.5% ونسبة بقاس فى القصب وقدرها 39% وبالحساب وجد ان الطاقة الكلية المنتجة تساوى 17.2 ميجاواط (منها 10.9ميجاواط تنتجها وحدة المولد البخاري13ميجاواط و6.3 مبجاواط من احد المولدين البخاريين6.5 ميجاواط الموجودة) ووجد ان المولد 6.5ميجاواط والذي من المعول عليه ان يعطى 6.3 ميجاواط لا يعمل (لان المحول الموجود الذى يربط بين البسبارين 3.3 و11 كيلوفولت قاصرالسعة) و باضافة محول اخر سعته 7.5 مبجافولت امبير وجد ان الطاقة المولدة تزيد الى 23.5 ميجاواط . وبرفع معدل الطحن الى 295 طنا فى الساعة وتشغيل المصنع لمدة 150 يوما وجد ان البقاس الذى يتم توفيره يمكن من تشغيل وحدة التوليد 13ميجاواط لمدة 85 يوما اضافية فى موسم توقف الطحن.

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Abbreviations

Co-gen = Co-generation
NEC = National Electricity Corporation
MW = Mega Watt
KV = Kilo Volt
TCD = Tons Crushed Per Day
TPH= Tons Per Hour
DEGC =Degree Centigrade
KW = kilo Watt
AVRs = Automatic Voltage Regulators
EHV = Extra High Voltage
DCS = Distributed Control System
VFD= Variable Frequency Drive
KWh = kilo watt hours
I.D. FAN =Induced Draft Fan
S.D. FAN = Secondary Draft Fan
F.D.FAN = Forced Draft Fan
T/H = Tons Per Hour
TC = Thermo Couple
TT = Temperature Transmitter
PT = Pressure Transmitter
SH = Super-Heated
O2 = Oxygen Analyzer
VT = Voltage Transformer
CT = Current Transformer
PC = Personal Computer
N.D.E = None Drive End
D.E = Drive End
MVA = Mega Volt Ampere
LTR / MIN = LITER PER MINUTE
Q = DISCHARGE
HP = HIGH PRESSURE
LP = LOW PRESSURE

Chapter One

Introduction

CHAPTER ONE

1.1 Background

Power generation based on baggasse as fuel is not new to the sugar industry for the availability and cheapness of this fuel. The boilers used, generate a steam at high pressure and high temperature that is used to drive steam turbine which in turn drives an electric generator (alternator) which produce electrical power and the exhaust steam is condensed to water and returned back to the steam generator. The turbine used is back pressure type.

Nowadays most of the sugar factories produce electricity as by product and the others go further for producing it as main product still the others go further more to use it as renewable source of energy (satisfy the concept year after year and forever). For the factories which intended to increase their power generation, production of two forms of energy from one fuel is introduced (co-generation). One of the forms of energy must always be heat and the other may be electricity or mechanical energy

The generation equipment can be fired by several fuels such as natural gas, wood, agricultural waste, peat moss, baggasse, and a wide variety of other fuels, depending on local availability. 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 co-generation plant, very high efficiency levels, in the range of 75%–90% [1], 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 factories or houses.

1.2 Importance of the Study:

1- Because this is the first new power generation unit erected in one of the factories of the Sudanese sugar company which plan to erect power generation units in its other three factories in order to increase their generation capacity, the unit in Assalaya sugar factory is to be well evaluated to avoid the repetition of technical problems encountered in this unit.

2- Also due to shortage in power generation in Sudan and network problems that lead to load shedding most of the year the, surplus power can be supplied to the (NEC) national electricity corporation.

3- The need of satisfaction of the captive demand of power for supplying the irrigation pump stations which consume 10MW per hour.

4- The de-centeralization of electric generation i.e. less power loss in transmission and distribution systems.

5- The possibility of running the unit in the off-season.

6- How to sell the surplus power.

7- More environment friendly type of power because of low emissions (less burned baggasse).

8- The possibility of supplying the total factory load from the new generation unit alone.

1.3 Problem Formulation:

The necessity of reducing the cost per sugar bag in Assalaya sugar factory lead to the erection of new power generation unit of 13MWcapacity based on the existing boilers which fired by bagggasse. To increase the power generation so as to cope for the consumption of the pump station which consume 10MW per hour and supply the surplus power to NEC (national electricity corporation) grid .Many technical problems encountered during the operation of the unit, one of these problems is the operation in the island mode when the grid is off and therefore no power exported and the pump station lose the supply from the generation unit. In this study the problem will be investigated with regard to load shedding searching for the possibility to supply part or the entire load of the pump stations during this mode of operation.

Another problem is in the load sharing, there are two existing turbo-alternators each of 6.5MW which generate at 3.3KV unlike that of the new power generation one (13MW) which generates at 11kV, here investigation is required to determine additional hardware that enable synchronizing at 11KV level to enable distributing the total power generated.

1.4 Objectives and Scope:

1.4.1 Objectives

1) To get the maximum of the power generation in Assalaya.
2) To get the new power generation unit running in the off-season.

1.4.2 Scope:

(I) Searching for the solution of the problem of high vibration exerted during the island operation mode.

(II) Determination of hardware capacity required for the new power generation unit to supply the whole plant load alone.

1.5 Methodology:

The method used to evaluate the power generation unit is the data gathered from operation log book.

1.6 Thesis Structure:

Chapter one include a historical back ground about the using of baggasse based power generation ,the importance of the study while the scope and objectives are given along with the methodology.

Chapter two includes a background and literature review with reference to boilers, turbines, generators, co-generation and controls in sugar mills.

Chapter three deals with methods used to achieve the objectives Chapter four deals with results and discussions while chapter five deals with conclusions and recommendations.

Chapter Two

Literature Review

CHAPTER TWO

2.1 Introduction:

The baggasse based power generation plants generally consists of a high pressure boiler and a double extraction cum condensing turbine. A power generation cycle is shown in Figure (2.1).

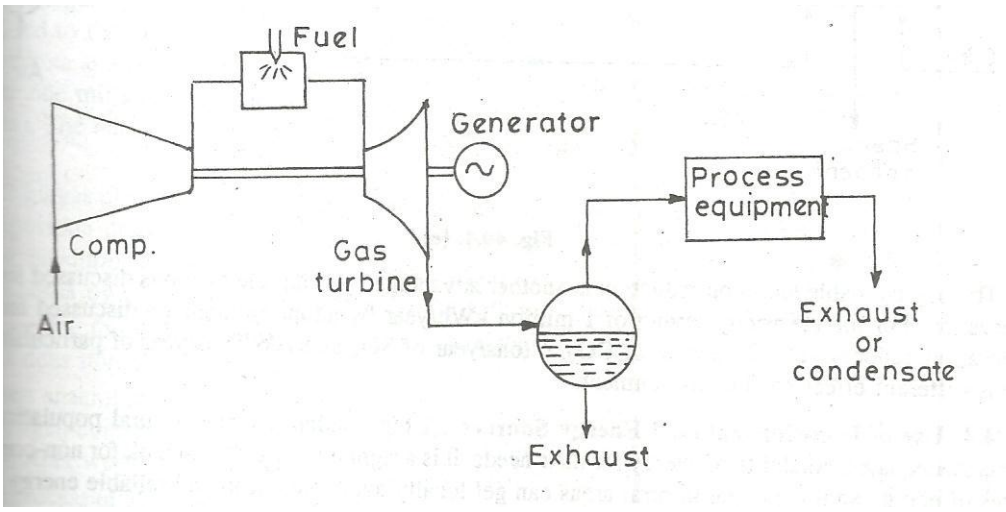


Figure (2.1): A power Generation Cycle [2].

2.1.1 Technical Aspects:

Power generation based on Rankine Cycle is not new to the sugar industry, but however power generation based on high pressure boilers and extraction condensing or straight condensing machines are definitely new to the industry. Power generation, by virtue of the fact that the excess power could be sold to the grid or to a third party for a price. That puts a demand on the sugar industry for modernization, discipline and for energy conservation.

2.1.2 Basic Design of the Co-generation plant:

Basically the power generation plant configuration is site specific, even though some amount of standardization could be made for the baggasse based plants. The Scheme should consider the variations in the baggasse availability, the allowable percentage of the back up using conventional fuels like oil / coal, the process steam requirements and the pressure levels. Considering the variations in the baggasse 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.

2.1.3 Power Cycles:

The co-generation scheme for any sugar plant is plant specific and there is no single scheme applicable for all the plants. A scheme applicable for a baggasse based plant will not fit into an existing operating plant wanting to go for co-generation. 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, and process improvements to reduce steam consumption by judicious vapor bleeding and usage of continuous pass, these steps make more steam available for power generation and improve vastly the viability of the co-generation project [3].

2.1.4 Steam Generating System:

The capability to design, manufacture and install steam generating systems of any capacity with any outlet steam parameters is available nowadays. Baggasse being a fuel not amenable for perfect metering has given some problems with regard to the super heater steam temperatures. Higher temperatures during start-up and at load fluctuations have been experienced, but could be contained because of the de-super heating provided. Some fine tuning is required in the areas of excess air control and un-burnt carbon loss control. Feed water quality control is an area needing attention. In conventional baggasse fired boilers, the baggasse is fed into the boiler directly from the mill. The quantity of baggasse fed into the boiler is controlled manually by opening or closing a gate in the return baggasse carrier. This system cannot have an automatic combustion control. In order to implement an effective combustion control, storage bunkers above the feeders, or a continuous circulation of a large quantum of baggasse, say, about 50% of more baggasse. An effective bunker system for the storage of baggasse, which will store baggasse for the requirement of about 10 to 15 minutes for the boiler, has been successfully tired and implemented.

This system operates well for a baggasse that is well prepared and with 50% moisture. 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 / furnace oil. The availability of a reliable and well proven travelling grate of large size to suit 150 to 200 TPH indigenously is yet to be verified. Capacities in the range of 200 TPH but limited to low steam pressures. The operating experience / feed backs of the large size of grates have to be obtained before selecting boilers of high capacity [4].

2.1.5 Turbo-generator System:

The experience has shown that the turbine for the Sugar plant Co-generation 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

There had been some problems of vibration and failure of bearings. These were due to initial problems in the lube oil system, and these could be resolved by having proper pre-commissioning checks. There had been some problem of exhaust hood spray falling on the blades and causing vibration. This was mainly due to a misdirected spray nozzle in the exhaust hood. 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 other than One or Two, there is none that has set 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 [5].

2.1.6 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 condensate. Efforts should be made to keep this condensate free from contamination the usage of the vapor condensate for the feed water application is not. Recommended as the quality of this condensate varies. Generally the pH is low, the total desolved solids TDS and silica are high and there could be sugar traces.

2.1.7 Baggasse Handling

During the cane crushing season, the cogeneration plant receives the baggasse directly from the mill, and the surplus baggasse is taken to the baggasse storage yard. The baggasse 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 baggasse from the yard to the boiler is required. As the unit size becomes larger the quantum of baggasse 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 baggasse to the storage yard and feed the boiler only through the reclaiming system. For use of other fuels such as cane trash, cotton stalk etc., the collection of the fuels from the farms, bailing, de-bailing / chipping facilities have to be perfected. There are many imported equipment available for collection bailing and shredding of the bio-mass fuels [6].

2.1.8 Baggasse Drying System

The baggasse 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 160 Deg C without any useful contribution. This moisture restricts the efficiency of the boiler to around 70%. If this moisture is removed from the baggasse 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 5% reduction in moisture the boiler efficiency will go up by about 1%. This means that with the same quantity of baggasse available the capacity of the co-generation 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 baggasse 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 baggasse this is a general practice for drying of de-pithed baggasse 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 baggasse 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 baggasse 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 baggasse. The size / capacity of the driers also do not match with the required capacities for a Co-generation Plant. Hence, more feed backs and operating experience on the working of the steam driers with un-depithed baggasse is to be studied before implementation [7].

2.1.9 Electrical Systems

As far as the technology for the design of the electrical systems for the Co-generation plant, right from generation to EHV system and grid paralleling is concerned, enough experience is available. All the electrical equipment required for the Co-generation 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 is properly specified, there is no reason why a cogeneration plant should trip with the grid and not go into island operation. To the extent possible efforts should be made to parallel the cogeneration plant at 110 kV level.

2.2 Controls and 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 and Instrumentation system for the co-generation 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 co-generation plant.

2.2.1 Energy Consumption in Sugar Factories

Sugar is a highly energy oriented sector and consumes energy in all its forms viz. heat, mechanical and electrical. Steam consumption ranges from 45% to 60% depending upon technologies and the power consumption ranges from units per ton to 23 units per ton in non-co-gen units and 28 units per ton cane to 32 units per ton cane in cogeneration units with electrical drives for mills and fibrisers. There is considerable loss of energy during the process of conversion from one form to the other and the right selection of the systems; technology, equipments etc. play a vital role in the overall energy conservation. Adoption of modern concepts like automation, V.F.D. drives, energy efficient motors, choosing of transmission gears, high efficiency pumps, correct sizing of all equipments, reducing energy losses due to leakages, radiation, friction and reduction in downtime etc. are the important aspects to be taken care of while aiming at energy conservation

2.2.2 Advantages of power Generation in Sugar Factories:

The economics of co-generation depends on many factors, particularly the availability of cheap source of fuel round the year at site and a purchaser (consumer) of power on a long term basis, paying a reasonable price for the power. All industries like sugar, pulp and paper, fertilizers, textiles, petroleum refineries etc., which require large quantities of steam and electric power, are quite suitable for co-generation. But, the main advantage of the cane sugar industry is the 'on site' availability of biomass fuel like, baggasse. Some of the advantages of co-generation in cane sugar factories, as compared to other industries or as compared to the conventional power plants are as follows:-

Unlike other industries and power stations, which use conventional sources of energy (fossil fuels), in sugar factories, for co-generation, baggasse which is a co-product and a biomass fuel and a non-conventional source of energy is used as fuel for generation of steam, which in turn can generate electric power. In addition to baggasse, trash (dried leaves of sugar cane) is also available, as fuel.

Baggasse is a renewable source of energy, as sugar cane from which it is derived is grown year after year, perhaps forever, unlike the fossil fuels like, coal and petroleum products, which are non-renewable sources of energy.

Co-generation in sugar factories leads to installation of high pressure boilers and special types of turbo-alternators, which means, better and efficient utilization of baggasse and the efficient generation of electric power

1. The technical personnel in the sugar factories are conversant with the work relating to generation of electric power.
2. As sugar factories are located in the rural parts of the country, the demand for electric power to run the irrigation pumping sets is more in these areas. Generation and supply of electric power from sugar factories

means, generation of power on the spot, without requiring transmission of power over long distances (as in the case of hydro-electric or thermal power stations) and hence, power loss in the line is reduced considerably.

3.Baggasse, being a sulphur free fuel (unlike coal or petroleum fuels, which contain lot of sulphur), burning baggasse as fuel is an environmentally friendly technology. Even the comparatively less polluting gases emitted through the chimney are in the rural part of the country, far away from urban areas. By installing suitable air pollution control equipment, like cyclones and wet scrubbers, it is possible to achieve emission of only white stream from the chimney and not dark smoke, un-burnt carbon particles.

4.Co-generation in sugar factories will improve the economics of sugar production. Fixed for the power sold to the grid, the sugar factories will earn a reasonable amount by adopting co-generation.

5.The capital cost of power generation in sugar factories is much lower than power generation in conventional power stations [8].

2.2.3 Equipment for Co-generation:-

The main equipment requirement of co-generation are boilers, power generator and distribution equipment. Whatever may be scheme for co-generation whether a single sugar factories desires to generate power only during grinding season or round the year or central sugar propose to generate power round the year making use of surplus baggasse from neighboring sugar factories the type of boilers preferable for co-generation is the same experience has shown that high pressure boilers with steam pressure varying from 450 psig (32kgs/cm2) to 850 psig (60kgs/cm2) are considered to be most suitable for co-generation. The temperature of steam may vary from 600F to 850F experience of Hawaiian sugar factories ideal steam pressure and temperature is 850 psig and 850F respectively.

Unlike boiler, the type of power generator suitable for different schemes, vary depending on various factors. If the scheme is to generate power and supply to the public utility only during the grinding season the steam turbine driving the alternator may be back pressure type as back-pressure steam may be required in the sugar factory, distillery, baggasse based paper factory or any other ancillary industries. However the exact requirement of back pressure steam in the complex has to be calculated and the only much back pressure steam has to be generated; otherwise lot of back pressure steam may have to be blown out to the atmosphere which is an uneconomic practice.

However if scheme is to generate power round the year when there is no demand for back pressure steam then it is most economical to generate electric power by using a condensing type of steam turbine coupled to an alternator it is very well know that with condensing turbine the quantity of steam requirement to generate a unit of power is much lower than the quantity of steam required with back pressure as shown in table No 24 in therefore in order to enable sugar factories which are mostly seasonal to generate power during the grinding season as well as during the off-season most economically, a combination of back pressure and condensing steam turbines coupled to alternator are most suitable equipment. These are known as extraction-cum-condensing turbo-alternators. When back pressure steam is meant only for process steam to heat and concentrate the cane juice extraction at a single back pressure of about 1 kg/cm2 is sufficient. This type of steam turbine is known as single extraction –cum-condensing turbine. But in some sugar factories as the existing prime movers (driving the mills and power generators) are quite new cannot be replaced, it is advisable to go in for a steam turbine, which can extract back pressure steam in two stages the first extraction at a pressure of existing prime movers and the second extraction at pressure of process steam and the turbine will work as condensing turbine during the off-season. This type of turbine is known as double extraction-cum- condensing turbine. When these extractions are automatically controlled, turbine is known as automatic double extraction-cum- condensing turbine. These are quite common in Hawaiian sugar factories. Which went in a big way for co-generation from the year 1980 onwards? the advantage derived by the Hawaiian sugar factories by going in for high pressure boilers and special type of turbo alternator is that the power generation is of the order of 60 to 100 KW/hr per ton of sugar cane crushed, as compared to about 25 KW/hr per ton of sugar cane while using steam at 225 psig (16kgs/cm2) and the usual back pressure turbo alternators [9].

2.2.4 Power Generation in Assalaya Sugar Factory:

The power generation system in Assalaya Sugar Factory consist of two old turbo-alternators each of 6.5MW capacity driven by two back pressure turbines each of 6.5MW capacity and anew power generation unit of 13MW turbo-alternator driven by automatic condensing –cum -double extraction steam turbine of 13 MW capacity.

The start of the anew power generation unit project was in 2006 -2007 the tables (2.1) and (2.2) highlight the power generation in new power generation unit in Assalaya Sugar Factory .

Table (2.1) Power Generation in Assalaya Sugar Factory

Year	Power Generated in MW	Remark
2006 – 2007	15152	
2007 – 2008	32554	
2008 – 2009	19363	
2009 – 2010	18610	
2011 – 2012	0	No fuel
2012 - 2013	0	No fuel
2013 - 2014	12961	
2014 - 2015	2243	
2015 – 2016	5069	
2016	200	No fuel

Total MW generated since the start of the project = 1106152 MW which run for 9 years.

Average generated power = 11794 MW

The main problem is cane supply.

Minimum crushing rate to enable exporting of power= 5000 ton per day.

Maximum generated co-gen power till now was in the season 2007-2008 which equal to 32554 MW.

Table (2.2) Exported Power in Assalaya Sugar Factory

Year	Power exported in MW	remark
2007	11376.8	
2008	266803.2	
2009	16806	
2010	16224	
2011	0	No fuel
2012	0	No fuel
2013	6809	
2014	483	
2015	2185	
2016	100	

Maximum exported power till now was in the season 2008 which equal to 266803.2MW.

2.2.4.1 Assalaya Sugar Factory production Steps:

The design capacity for Assalaya Sugar Factory is 300t/h after the rehabilitation of the cane preparation by replacing the cutters by shredder system. The production reaches 95000 t/ year. Sugar manufacturing is a highly seasonal industry, with season length of about 20 to 32 weeks, (from October to June); this has make variation in annual production.

The production steps in Assalaya Sugar Factory are as follows

2.2.4.2 The Cane Cultivation:

The cane maturity period ranges from 10 month to 16 month; it is harvested by chopping down the stems, but leaving the roots, so that it re-grows with time for the next crop (ratooning). Raton maturity ranges from 10 month to 13 month and plant ranges from 15 to 16 month. Harvesting is done either manually or by harvester. The cane is burned in the field before harvesting to release the leaves and associated weeds and the top of the stalk, which has poor sugar content.

2.2.4.3 Cane Transport:

The factory takes delivery of cane by means of trailers. And transportation should be as quickly as possible to avoid deterioration of the cane.

2.2.4.4 Cane Weighing

The cane is weighed before processing so as to adjust the operating condition for the amount of cane delivered. An electronic cane weight bridge of capacity 60 tons is used to weigh the Trailer with its cane load entering the factory.

2.2.4.5 Cane Washing:

Cane is unloaded on the feeding table and usually washed with water in order to remove the soil particles and attached ash and other impurities that may hindered the sugar gaining process.

2.2.4.6 Cane preparation in Assalaya Sugar Factory:

The cane carried by belts to be prepared for grinding by revolving shredder which driven by electricity. The shredder system facilitates the juice extraction by the mills .Some sugar factories use shedders in combination with knives.

2.2.4.7 Milling:

In Assalaya Sugar Factory juice is gained by milling which is the process used by most cane sugar factories in the world. Now the milling plant is capable of achieving higher extraction of the order from 91-93% sucrose extraction with higher crushing rate and reduction in power consumption by flowing modern milling techniques .The milling plant consist of 6 mills, having three rollers mills Figure (2.3) .

The roller is made of cast iron cylindrical material with circumferential "V" grooves are helpful in two ways, to provide the passage for the juice extracted by compression and to facilitate further extraction. Mills consist of multiple units of three –roller combination though which the crushed cane or baggasse passes successively. To aid the extraction of the juice, sprays of water or thin juice are directed on the blanket of baggasse as it emerges from each mill unit to leach out the sugar. The process termed imbibitions and has many modifications. In best milling practice, more than 95% of the sugar in the cane goes into the juice. A typical mixed from extraction will contain approximately 15% sugar, and the residual fiber after juice extraction is called baggasse. A typical cane might contain 12- 14% fiber that, gives about 25 to 30 tons of baggasse of 50 % moisture content per 100 tons of cane. This material usually goes to the boilers as fuel for energy generation or other commercial by products.

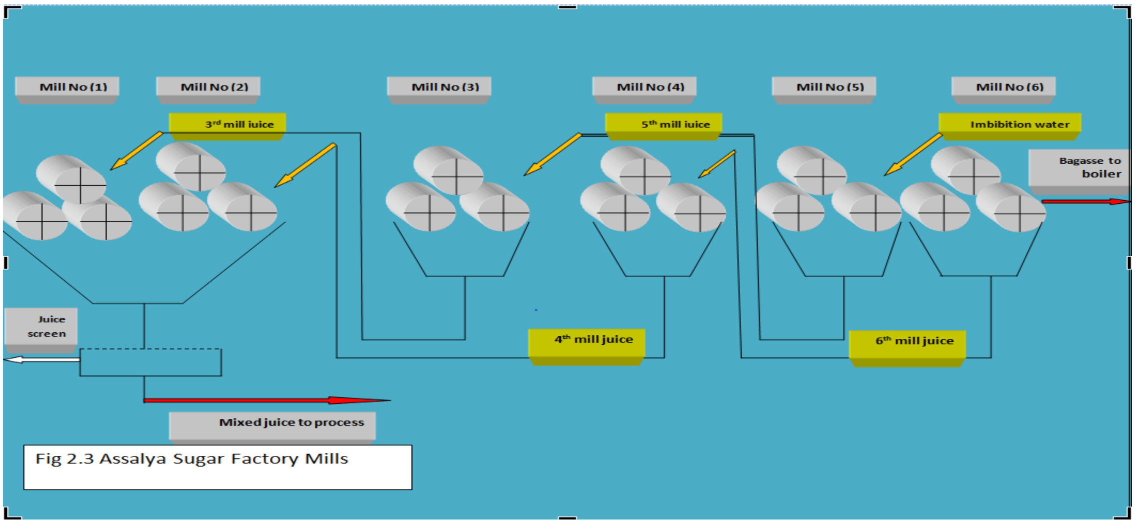


Figure (2.2): Assalaya Sugar Factory Mills

Table (2.3): Power Requirement during Season

Station	Range[KW/TCH]	Average	Power %
Cane preparation	3.5 – 6	4.5	15.5%
Cane milling	5 – 7	6	20.7%
Boilers	3 – 5	4	13.8%
Condensate and cooling	2 -5	3.5	12.1%
Centrifugal machines	2.5 – 3.5	3	10.3%
Pumping….etc	6 – 10	8	27.6%
Total	26 – 32	29	100%

2.3 Power Requirement for Boilers and Baggasse Handling During Off-season:

During off season boilers and turbine are operated for generation of power, this will consume energy along with requirement for injection water pumping for condenser(for condensing type turbine), vacuum pumps , injection water cooling system (for spray pond or cooling tower) and power for baggasse handling system. All this is about 10 to 15%of the total power generation.

2.3.1 Boilers Steam (Live steam) and Boiler house:

In Assalaya there are five boilers, each boiler consist of two drums ;(steam drum & lower drum); three fans (I.D fan, F.D fan, S.D fan) stocker, super heater, chimney, and baggasse burning tools. The basic function is to produce live steam with a total design capacity of 200 ton/h (for four boilers on line); the actual capacity is 160 t/h, at350°C and 23-25 bar. Baggasse is used as fuel and is supplemented with furnace oil. Feed water (100-105°C) consists of condensates of the process steam and treated water make up.

The boilers produce live steam with a total design capacity of 56 (t/h) steams. The actual capacity is (40-50) (t/h) at 350 °C and (23-25) bar. Four boilers give steam to the header while the fifth is kept standby. Each boiler will distribute the main live steam or the common steam header .Thereafter steam will be separated at several points for being directly consumed or conditioned before being used. So live steam goes to:

1- Power turbine No 1.

2- Power turbine No 2.

3- Mill turbine.

4- Steam conditioner station for process steam.

5 –A part of live steam is lost during steam line venting.

Assalaya Sugar Factory boilers are high pressure boilers with sufficient capacity to burn practically all the factory's baggasse during crop time , with provision for an off- crop alternative fuel to guarantee continuous energy supply.

The fiber in cane contains energy of about 640 to 800 KWh / t of cane. About 120 to 135 KWh/ t baggasse, electrical energy generation is possible with conventional system of high pressure boilers and turbines.

In Assalaya Sugar Factory for the crushing capacity of 250 t/h canes 135.65 t/h of steam are needed. Boiler's steam distribution is given in Table (2.5):-

Table (2.4): Live Steam Distribution in Assalaya Sugar Factory:

1- Mills	83 t/h -33.6% cane
2- Turbine	67 t/h - 26.8% cane
3- reducing station	0.12 t/h - 0.05% cane.
4- sugar dryers and sulphur station	12.5 t/ h - 5% cane.
5- losses	2.37 t/h - 1.01% cane
6- Makeup	14 t/h – 5.6% cane
7- total amount of	179.99t/h - 72 %cane.

Exhaust steam from power turbine is at 1.7 kg/cm 2 or 2.3bar design operating conditions and 160 °C. The actual value is 1.4 kg/cm 2 and 160°C. That means it is superheated steam because saturated steam is at 1.4 kg/cm2 has a temperature of 127 °C. To get the max utilization of the latent heat at 2.3 bar it is exposed to conditioner so as to reduce its temperature to 130 0C by using a de super heater. Exhaust steam from the mill which is at 0.9 kg/Cm2 140 °C is also conditioned to 125 °C. Live steam at 3.0 kg /cm 2 is conditioned to 144 °C which is used in dryers – centrifugal machine.

2.3.2 Power house turbo – alternators:

The power house contains 2 x 6.5 MW turbo- alternator driven by back pressure steam turbine Peter Brotherhood make and two standby diesel generators each of 0.6 MW run in parallel when the NEC(national electricity corporation) supply is not available during off crop and in pre-starting to supply power for starting one boiler to provide steam to the power turbine.

2.4 Boiler Control Objectives

For proper control application, it is necessary to understand the objective of the control system. In the case of steam boiler, there are three basic objectives:-

1- To cause the boiler to provide a continuous supply of steam at the desired condition of pressure and temperature.

2- To continuously operate the boiler at the lowest cost for fuel and other boiler inputs, consistent with high levels of safety and full boiler design life.

3- To safely start up, shut down, monitor on-line operation, detect unsafe condition, and take appropriate actions for safe operation at all times.

The second objective translates into "improving boiler efficiency," since achieving the lowest fuel cost involves operation with the most efficiency combustion. For the proper under-standing of combustion efficiency and how it is achieved, the text includes material that covers the combustion process. This material includes discussion of the measurements that are used to determine combustion and boiler efficiency and the techniques and methods used in determining those efficiency values

The third objective is specifically supported by the included sections on interlocking, burner management, and flame safety system. Other digital logic functions that relate to the third objective and are more integrated with the modulating logic function are covered as parts of varies other sections.

There are multitudes of design of boiler system. Built into the design may be heat recovery features that enable operation at a particular level of cost for fuel and other inputs. Since the automatic control system actually operates the boiler, whether or not the boiler achieves its economic potential is a function of the boiler control system.

Generally, control system of greater sophistication can control more precisely and some closer to meeting all of the system design objectives; but greater sophistication of a control system usually means a higher initial It is necessary when applying boiler control systems to understand the trade-offs between increased cost for control sophistication (including a higher level of maintenance) and the savings that result from its application .investment in control sophistication, as with other investments, usually is layered **[10]**.

2.4.1 Boilers Control Systems

2.4.1.1 General :-

Control systems may be pneumatic, analog, digital, or a combination of the three. Older designs utilized pneumatic control for local control loops. Analog control systems were an industry standard for a short time before quickly being replaced by digital control systems. The present industry standard is for a distributed control system (DCS), a programmable logic controller (PLC), supervisory control and data aquisition SCADA or a direct digital controller (DDC) to provide digital control logic based on information gathered from electronic sensor inputs and responding with electronic control of pneumatic or electric powered valves and dampers.

2.4.1.2 Control Selection:

Choose the type of control that will do the job most economically. This includes total cost over the lifetime of the equipment. Also consider compatibility with controls used in the existing plant, ease of operation and maintenance, and plant personnel familiarity and training. Consider unique situations such as a high EMF (electric magnetic field) where either EMF shielding, fibre optic data transmission or pneumatic controls are required. Obtaining the latest technology should not be used as the main criteria in the selection of controls.

Use the following as a guideline in selecting the type of control.

Microprocessor digital type of controls (e.g. PLC, DDC, or DCS) should be used for most new designs and in particular where a large number of control loops are involved. Consideration should also be given to using microprocessor digital type controls to replace pneumatic control systems that have exceeded their life expectancy.

Pneumatic control devices should be used in hazardous areas. They may also be used in the expansion of existing designs or as actuators for the final control elements in the design. In general, the pneumatic actuation of larger valves and large number of valves is more cost effective than using electric actuation.

Analog logic devices (e.g. pneumatic receiver-controllers or electric potentiometer controllers) should not be considered for new designs.

Consider the environmental conditions (e.g. temperature and humidity) in which the controls will be installed.

2.4.1.3 Pneumatic Characteristics:

Pneumatic characteristics are included primarily for the pneumatic power requirements of valves and dampers. In most cases, new designs should incorporate electronic control signals. Standard operating and supply pressures for pneumatic instruments are defined by ANSI/ISA-S7.0.01, Quality Standard for Instrument Air.

Air Supply Pressure Plant and instrument air is typically available at 6.21 bar (90 psig) pressure. Instruments typically operate from a 1.38 bar (20 psig) supply. A standard pneumatic control signal is 0.21-1.03 bar (3-15 psig).

Design Considerations. Piston operators are used for dampers and control valves. Size pneumatic devices operating on a nominal 6.21 bar (90 psig) air supply so that they will operate with a minimum pressure of 4.14 bar (60 psig) and will withstand a maximum pressure of 7.58 bar (110 psig)

Service Tubing Size .Use 9.53 millimetre (3/8-inch) outside diameter (OD) copper or stainless steel tubing for signal transmissions of 60.96 meter (200 feet) and over. For shorter lines, use 6.35 millimetre (1/4 -inch) OD copper or stainless steel tubing.

Control Distance. Pneumatic control can be used for up to 60.96 meter (200 feet) without any special provisions and up to 91.44 meter (300 feet) if the valve has a positioner. A volume booster must be used for distances between 60.96 and 91.44 meters (200 and 300 feet) if the valve does not have a positioner. Use electronic signals for valve control in lieu of pneumatic for distances greater than 91.44 meter (300 feet).

Instrument Air Regulation. Furnish pneumatic instruments requiring an instrument air supply with individual combination filter-regulators and an output gauge. Instrument air should be supplied by an oiliness compressor to help eliminate control instrument and device contamination.

2.4.1.4 Electrical Characteristics:

Electrical Interface. The electrical interface between instruments and a digital controller varies depending upon application. Typical analog signal ranges and levels include the following:

MA direct current (DC) (4-20 mA, 10-50 mA, or 0-100 mA)

Volts DC (0-10 millivolts, 0 -100 millivolts, or 0-5 volts)

Temperature (thermocouple in millivolts, or RTD)

Volts alternating current (AC) (120 volts)

Transmitters and control valves commonly use a range of 4-20 mA DC.

Switches and solenoid control commonly use a switched level of 120 volts AC. For signal requirements for instrument loops refer to ANSI/ISA-S50.1, Compatibility of Analog Signals for Electronic Industrial Process Instruments.

Communication Data Bus. Complex boiler control systems may involve multiple digital control systems (e.g. DCS, PLC, or computer controlled smart instruments) linked together by a communication data bus. The communication data bus passes significant data between the digital control systems in a serial format. There are numerous bus architectures available. One commonly used is the RS-485 hardware bus with Modbus software protocol

2.4.2 Turbine

A steam turbine is a mechanical device that extracts thermal energy from high steam pressure and converts it into rotary motion.

2.4.2.1 Assalaya 13MW Power Generation Turbine :-

The 13MW steam turbine Skoda is a single-casing, impulse-type condensing turbine, equipped with one controlled and one non-controlled steam extraction.

Turbine technical data

- Make & Serial no. SKODA, 4574
- Normal output 13 MW
- Normal speed 5484 rpm
- Normal Steam pressure 23 bar
- Normal Steam temperature 360 ^{0}C
- Lufkin speed reducing gear box ratio 3.6563
- Normal generator speed 1500 rpm
- Startup pump Q:540 ltr/min & P: 3.9bar
- Main oil pump Q:774 ltr/min & P: 7bar
- Emergency oil pump (DC) Q:490 ltr/min & P: 1.7 bar
- Jacking oil pumps 2 nos.
- Auxiliary oil pump Q:16.5 ltr/min & P:1 bar
- Overhead tank flow by gravity

- Collecting oil Tank 30ltr cap
- Oil mist separator remove vapor/air
- Oil coolers   2nos, 1working & 1stand by
- Three way coupled valves 2nos
- Duplex filter2nos, 25microns
- Oil cleaning unit (Centrifuge)   remove moisture& impurities

Lubrication oil pressure control valve

- Lube oil header pressure   1.5 to 2.5 bar
- Lube oil operating temperature : 38 to 45^{0}C
- Lube oil to journal bearing : 1.4 to 2
- Lube oil to thrust bearing 1.4 to 2
- Lube oil to turning gear   : 0.7 to 1.5 bar
- Lube oil to gear box :1.4 to 2
- Lube oil to generator front & rear journal bearings 1.5
- Differential pressure across filter: 0.8 bar maximum (Change filter)
- Cooling water to oil cooler 1.5 to 3 bar, Q:60m3/hr

- Working pressure   160 bar
- Oil Quintolubric 888- 68

  (Temp range 40^{0}C – 50^{0}C)

- Gear pump 11 ltr/min

- Accumulators: It ensure sufficient momentary amount of working fluid, in case of sudden increase of its consumption and also stabilize pressure in the system when the standby pump start up.
- Pressure filters – 10 microns
- Circulation filters – 3 microns
- Safety relief valves – 200 bar
- Cut off valves 160 bar unloading, 140bar loading
- Volume of tank 160 Liters
- HP Hydraulic system for Actuator of stop flap valve

ABB – electronic microprocessor control system (TCS) it ensures governing and protection function of steam turbine. TCS consists of 3 cabinets,

1. Relays and auxiliary contactors.
2. PM 800 processor module of turbine protection, governor and open loop control system at the door placed process panel.
3. Analog out processor and signal multipliers.

Basic control of turbine:

- Speed control
- Electric load control
- Inlet steam pressure control
- Manual valves control, limiting control
- Pressure control in extraction
- Evaluation of thermal stress

- Turbine protections

2.4.2.2 Vacuum System:-

- It is required for correct function of the condenser and maintaining the designed efficiency of the turbine and it is necessary to remove air and non-condensable gases from steam space of the main condenser. The air in the vacuum system causes significant impairment of the heat transfer co-efficient at the heat exchanging surfaces of the condenser and thus reduces the thermal cycle efficiency.
- Startup ejector (one number).
- Jet steam ejector two numbers. (1work and 1standby)

2.4.2.3 Turbine protections

- Turbine protection : system will shut down the mechanic which evaluated in 2 out of 3 measurement

Lubricating oil – low pressure 2/3(alrm:1 bar and trip:0.8 bar)

Control fluid in the HP hydraulic system, low pressure 2/3 (Al:120 bar and trip:100 bar)

Vacuum – high pressure 2/3 (Al:0.75 and trip:0.50bar)

1. Over speed signal – over speed 2/3 (5830el,6050&6080 rpm)
2. Bearing temp – temperature high 1/1(90^0C trip)
3. Rotor vibration high vibration (89 microns trip)
4. Differential expansion of rotor -1.4 , +2.7 alarm, -1.9, +3.2 trip)
5. Displacement of axial wear-0.8, +0.5 trip
6. Emergency push button
7. Control system failure
8. Some of machine protection

9 Some of generator protection

10 Some of fire protection

- As additional device will co-operate with TCS independent electronic over speed protection system. "Woodward protech 203"
- For the vibration and displacement evaluation we are using Philips EPRO MMS 3000 **[11]**.

2.4.2.4 Turbine Start up

- Line up the Cooling water system
- Line up the lube oil system
- Check the protections
- Start the turning gear system
- line up the condensate via CEP, Ejector, VSC and recirculation
- Start the HP Hydraulic control system
- Check the turbine valves mobility
- Pre heating the pipe line up to ESV
- Line up the Drainage system of the turbine
- Line up the gland steam system
- Line up the vacuum system
- Pre-heating the turbine
- Readiness of Generator
- start up to heating speed 2000 rpm
- Start up to synchronizing speed 5484 rpm

- synchronizing

2.4.3 Load Changes Acceptable

2.4.3.1 Nominal Parameters

Nominal output measured at the generator terminals 13 MW

Nominal turbine speed 5500 1/min

Nominal generator speed 1500 1/min

Nominal steam pressure just before the ESV 2,3MPa

Nominal steam temperature just before the ESV 360 °C

Nominal steam throughput 72,3 t/h

Max. Steam throughput 76 t/h

Controlled extraction - pressure 0,25MPa range 0,15 – 0,35 MPa

- Quantity 30,04 t/h range 0 – 46,11 t/h

Pressure in main stream condenser 0,074 – 0,12ata

Cooling water temperature - nominal 32 °C

Cooling water quantity 3750 t/h

A technically pure steam both mechanically and chemically is used **[12].**

2.4.3.2 Control Elements

The regulating functions of the turbine are secured by the electronic control system. The turbine valves are controlled by the electronic system and their position is changed by using high pressure hydraulic driven servomotors (actuators). Figure (2.2) shows the emergency stop flap-valve.

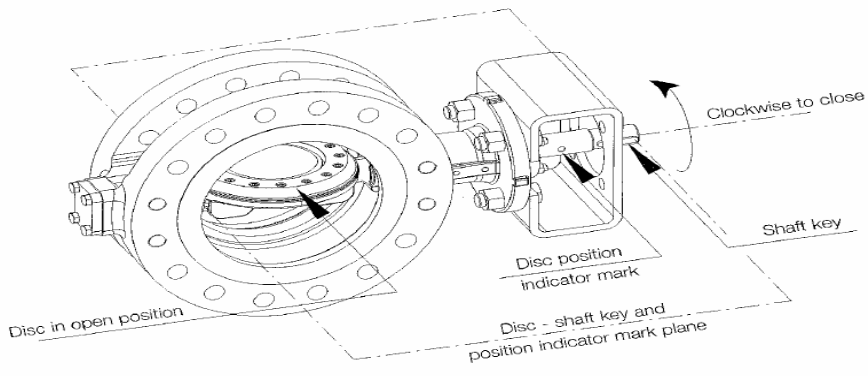


Figure (2.3) : emergency stop flap-valve [6].

There is one emergency stop Flap-valve at the admission steam inlet, bolted down to chamber with the control valves at the topside of the turbine casing's front section. The emergency stop Flap-valve is situated in horizontal position and precedes the control valves. The flap position is managed by the High Pressure Hydraulic servomotor. Opening of the flap is provided by means of hydraulic pressure, closing by force of dish type springs. It assure automatic closing of the flap in case of hydraulic pressure loss as well as during control signal breakdown. Open or closed position of the flap is monitored by means of contact-less pickups. The mobility of the flap is possible test during turbine operation ma means of impulse to appropriate solenoid

2.4.3.3 Control valves

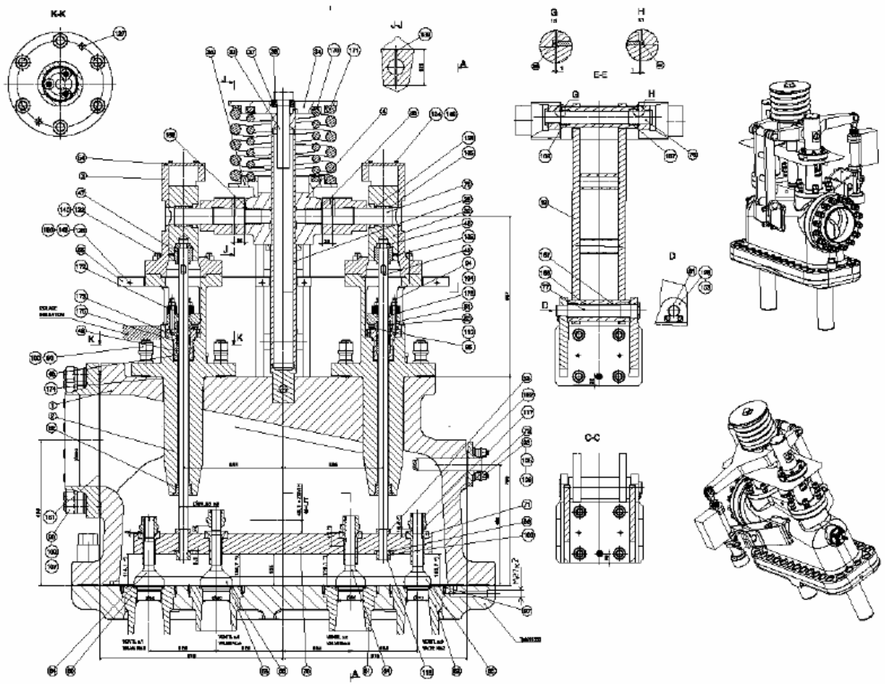


Figure (2.4) : Control Valves [13] .

The amount of steam entering into the turbine is controlled by means of four control valves. Control valves are placed together with the emergency stop valve in the valves chamber located at the topside of the turbine casing's front section. The drive of these valves is assured by one "Servomotor of Control Valves" which is located at the valves chamber. The control valves are opened over the linkage and traverse by means of the hydraulic fluid pressure inducted upon the piston of "Servomotor of Control Valves" and are closed by the force of springs. The immediate magnitude of the opening of individual valves is given by level of the electric signal transmitted from the turbine governor.

Traverse rods are sealed with graphite rings. Rings are pre-tensioned by dish type springs and their assembly and maintenance abide with special procedure issued by the graphite ring producers. Cones of control valves forms one piece with the valves spindles. Valve seats and cones are fitted with a hardened metal for increasing their life. The steam entrance into nozzle chambers is realized via channels provided in turbine front section casting.

The control valves chamber preheating is made possible via preheating line joint to neck with drilled hole diameter 43 mm in opposite side to steam inlet to chamber. Water that condense in chamber during preheating will be drained via drilled hole diameter 20mm joint to drainage system by screw M27x2-6H at the casing flange of the nozzle chamber.

Controlled extraction diaphragm

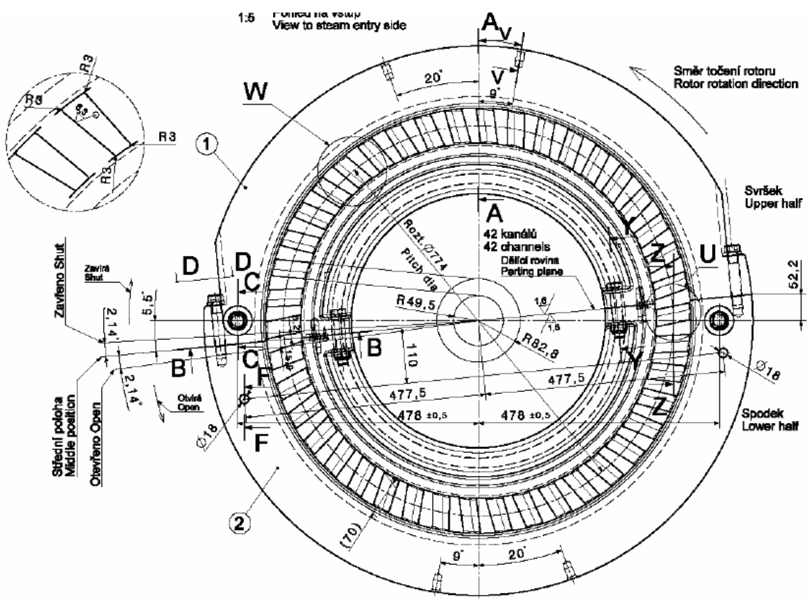


Figure (2.5): Controlled Extraction Diaphragm [14].

The steam pressure in the second extraction is controlled by means of diaphragm provided in both - the lower and in the upper part of stage at the steam inlet side. The diaphragm proper is designed as two half ring shape rotary blade cascade. It can gradually close flow channels of stator part picture of which is shown in figure (2.4).

2.4.4 Assalaya 13MW Generator:-

2.4.4.1 Components

The brushless generator is comprised of a main machine, an exciter with rotating rectifiers and a permanently excited, external auxiliary exciter.

The entire machine can be divided into a range of function units which are described in the following sections.

2.4.4.2 Degree of protection

The machine is designed with the IP 54 degree of protection, complying with EN 60034-5.

2.4.4.3 Ventilation and cooling system

The machine has intrinsic circulation cooling.

It is configured according to cooling system IC 8A1W7 complying to EN 60034-6.

2.4.4.4 Machine Compartment Cooling:

The air cooled by the air/water heat exchanger (intermediate coolant) is circulated by the machine's rotor. The cool air is fed to both sides of the machine interior, to the winding heads and air vents of the segmental rim. In this way, the guided air absorbs the heat from the active parts.

The warm air flows through the heat exchanger area where the heat absorbed from the machine is transferred to the cooling water (main coolant).

2.4.4.5 Air/Water Heat Exchanger:

The machine has an air/water heat exchanger installed in the air hood for intrinsic circulation cooling.

It is installed so that it can be disassembled and is connected to the cool water feed and drainage lines. The heat exchanger has two cooling elements. The cooling elements consist of ribbed pipes, two pipe bases, cool water connection chambers, water reversing chambers, side panels and casing brackets.

The ribbed pipes are rolled into the pipe bases.

The water chambers are equipped with separation profiles corresponding to the number of water channels and screwed, watertight, to the pipe bases by means of rubber seals.

Draining and Dearing equipment is provided to empty the water chambers.

Leakage water chambers sealed by drain plugs are provided in the air hood below the heat exchanger elements installed.

2.4.4.6 Monitoring:

The type and extent of the temperature monitoring of the stator winding are indicated on the circuit diagram. The related feed and derivation lines are laid to the monitoring connection box on the heat exchanger hood.

2.5 Stator winding

2.5.1 Monitoring:

The type and scope of the stator winding temperature monitoring are specified on the circuit diagram and shown in figure (2.5). The temperature monitoring leads are fed to the terminals.

2.5.1.1 Bearing

The machine shaft runs in flange-mounted sliding bearings. Circuit diagram of which is shown in figure (2.6) .

2.5.1.2 Voltage Regulator

The voltage regulator has the task of keeping the generator voltage constant regardless of the load applied. Voltage changes occurring as a result of sudden load changes should be regulated as quickly as possible. This is done by the regulator correspondingly adjusting the excitation of the exciter. The regulator is arranged separate from the machine.

2.5.2 Exciter

2.5.2.1 Exciter Stator

The exciter is a three-phase current, external pole generator. The exciter stator is fixed on the NDE in the stator housing. The iron in the stator is either solid or plated. The projecting poles support the exciter field coils. They are switched in series and the coil ends are fed to terminals.

2.5.2.2 Exciter Rotor

The rotor of the three-phase, external pole generator is attached to the shaft of the main machine. It is always in a plated version. The three-phase winding is accommodated in the core grooves. The neutral point cannot be accessed. A derivative line is fed from each winding branch to the rotating rectifiers arranged on two half shells.

The three-phase winding is accommodated in the grooves of the core and impregnated with epoxy resin as is the main machine rotor.

The rotating diodes are screwed to two half shells of differing polarity and also serve for heat dissipation. The diodes are greatly over dimensioned in respect of their current and voltage requirements and connected to protection elements so as not to put the winding insulation or rotating diodes at risk following faulty synchronization or asynchronous running of synchronous machines, whether due to a fault during the motor run-up or pulling out of synchronism.

2.5.2.3 Auxiliary Exciter Stator

The auxiliary exciter is a three-phase inner pole generator with permanent magnets and externally excited exciter windings. The laminated stator core with three-phase winding is accommodated in its own housing with the NDE shaft end. The energy generated serves to excite the exciter and supply the control unit.

2.5.2.4 Auxiliary Exciter Rotor

The auxiliary exciter rotor is mounted on the exciter rotor hub. The projecting poles consist of screwed-on permanent magnets as pole covers and the pole coils of the load-dependent additional exciter winding, which prevent a voltage drop in the event of increased load. **[15]**.

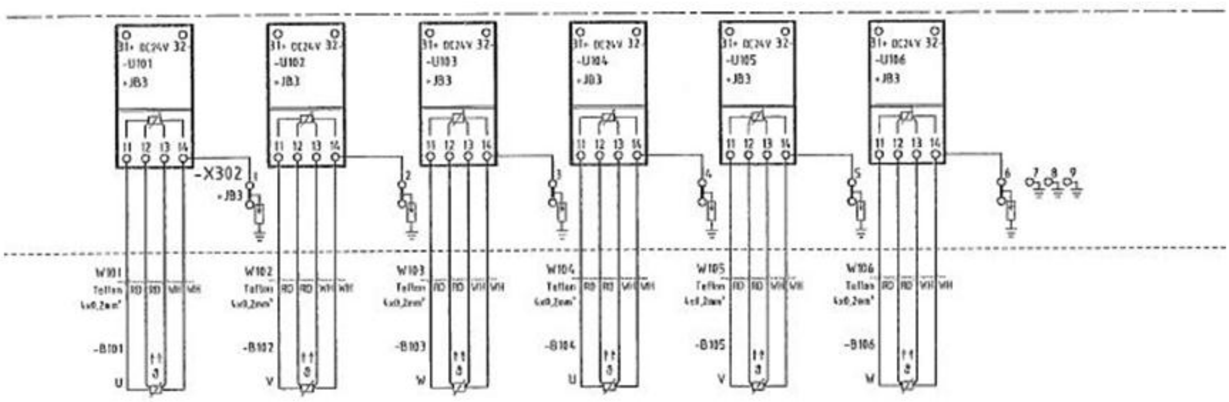


Figure (2.6): Circuit Diagram of Generator Stator Temperature [16].

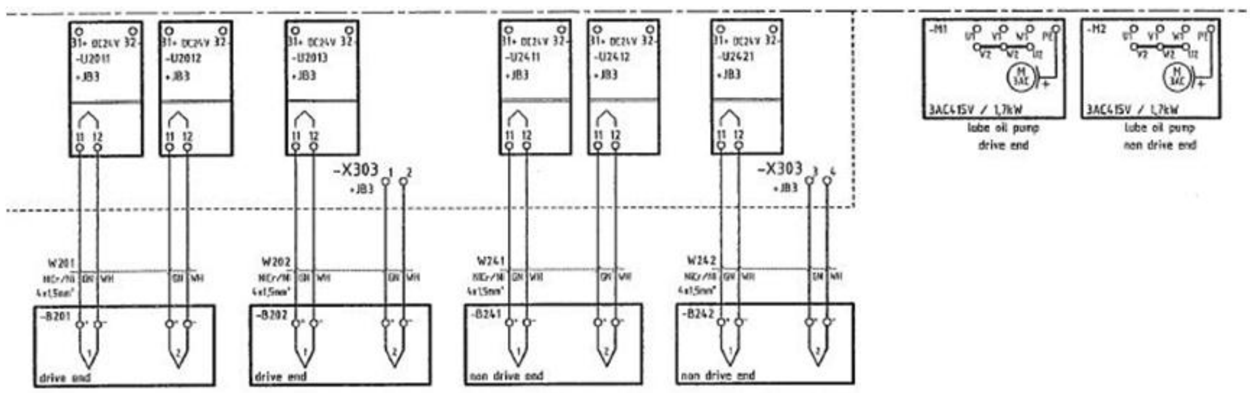


Figure (2.7): Circuit Diagram of Generator Bearing Temperature {17}

Chapter Three

Tools and Methods

CHAPTER THREE

3.1 Background:-

To perform a balance on any system, the system boundaries must first be specified .A total component balance together with energy balance for Assalaya Sugar Factory with the existing working conditions is performed based on data gathered from operation log book, so as to specify these boundaries. Engineers sometimes know the limits and uncertainties from the data, energy and component balance is necessary to provide for full co-generation industrial plant.

3.1.1 Material Balance for Assalaya Sugar Factory:

Material balance is the basis for design and utility consumption.

The mill mass balance is shown in Figure (3.2).

3.1.2 Basis of Calculations:

For basis of 250 Ton cane (the crushing rate is 250 t/h):

Assuming no sugar losses

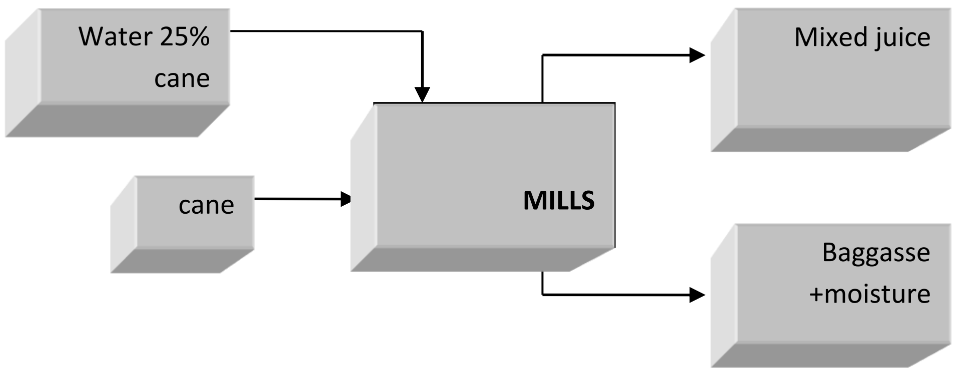


Figure (3.1) the Mills Mass Balance in Assalaya Sugar Factory

The base is 250 t/h (5200 t/d of sugarcane are to be The factory operate for 21 hours per day (the rest of the hours are for mills disinfection and other cessation reasons) Thus 250 t/h of sugarcane has to be processed ,sugar cane content is shown in Table (3.1).

Note: 1. All units unless otherwise mentioned are in tons per

Table (3.1) Sugarcane properties of Assalaya Sugar Factory

Water	66.0%
Sucrose	12.6%
Fiber	19.0%
Impurities	2.4 %

Thus 250 tons cane feed per hour will contain

Water = 0.66x250= 165 Tons

Sucrose=0.126x250= 31.5 Tons

Fibre =0. 19x250= 47.5 Tons

Impurities = 0.024x250= 6Tons

3.1.3 Milling plant

Water used in milling operation is 25- 30 % on sugarcane. Practical value is 25 % as in Assalaya.

Therefore imbibitions water used = 0.25 x 250 = 62.5 t

Milling efficiency 91 % .i.e.91% of sucrose goes into the juice.

Thus sucrose amount in juice = 0.91 x 31.5 =28.665= 28.67t

Un-extracted sucrose = 0.09x31.5 =2.8 35 ≈2.84t

Assuming 80 % of impurities stay in the juice and 20% goes with bagasse.

Impurities in the juice =0.80 x 6 = 4.8 t

Impurities in baggasse =0.20 x 6 = 1.2 t

The final baggasse from last mill contains the un-extracted sucrose and Impurities, fiber and 50 % water.

Thus dry matter amount in baggasse = 47.5 + 2.84 + 1.2 = 51.54 t

Amount of baggasse = 50 % dry matter + 50 % water

= 51.54 dry matter + 51.54 water = 103.08 t

Overall output of mill or mixed juice will have the following composition:

As shown in Table (3.2).

Table (3.2) Overall Output of Mills Juice Compostion

Water	165 + 62.5 – 5754 =175.96 t
Sucrose	28.665 t
Impurities	4.80 t
total juice	= 209.425=209.43t

% of solid in this juice = {(28.67 + 4.8) x 100} /209.43= 15.98 %

Purity of mixed juice = 28.67 / (28.67+ 4.80) = 0.857 i.e. 85.7 %.

The material balance in Assalaya is shown in Table (3.3).

Table (3.3) The Summary of Material Balance Off Assalaya Sugar Factory Mills:

Inlet components t/h		Out let components t/h	
Cane	250	Mixed juice	209.425
Imbibition water	62.5	Baggasse	103.08
Total	312.5	Total	312.5

3.1.4 Steam specification in Assalaya Sugar Factory:

The steam specification in Assalaya Sugar Factory is shown in Table (3.4).

Table (3.4) Steam Specification in Assalaya Sugar Factory

The steam	Pressure kg/cm^2(gauge)	Temp. °C
Live steam	23-25	350
Turbo-alternators exhaust steam	1.7 -1.3	170-150
Mill exhaust steam	0.9	150
Co-generation 13MW exhaust steam	0.2	160

3.1.5 Baggasse, Steam and power balance:-

3.1.5.1 Power Generation During Season:-

Four boilers are in line and one is used as standby during season, only one of the two 6.5MW turbo-alternators running with the new cogen unit ,the layout of Assalaya sugar factory power plant during season is shown in figure (3.2).

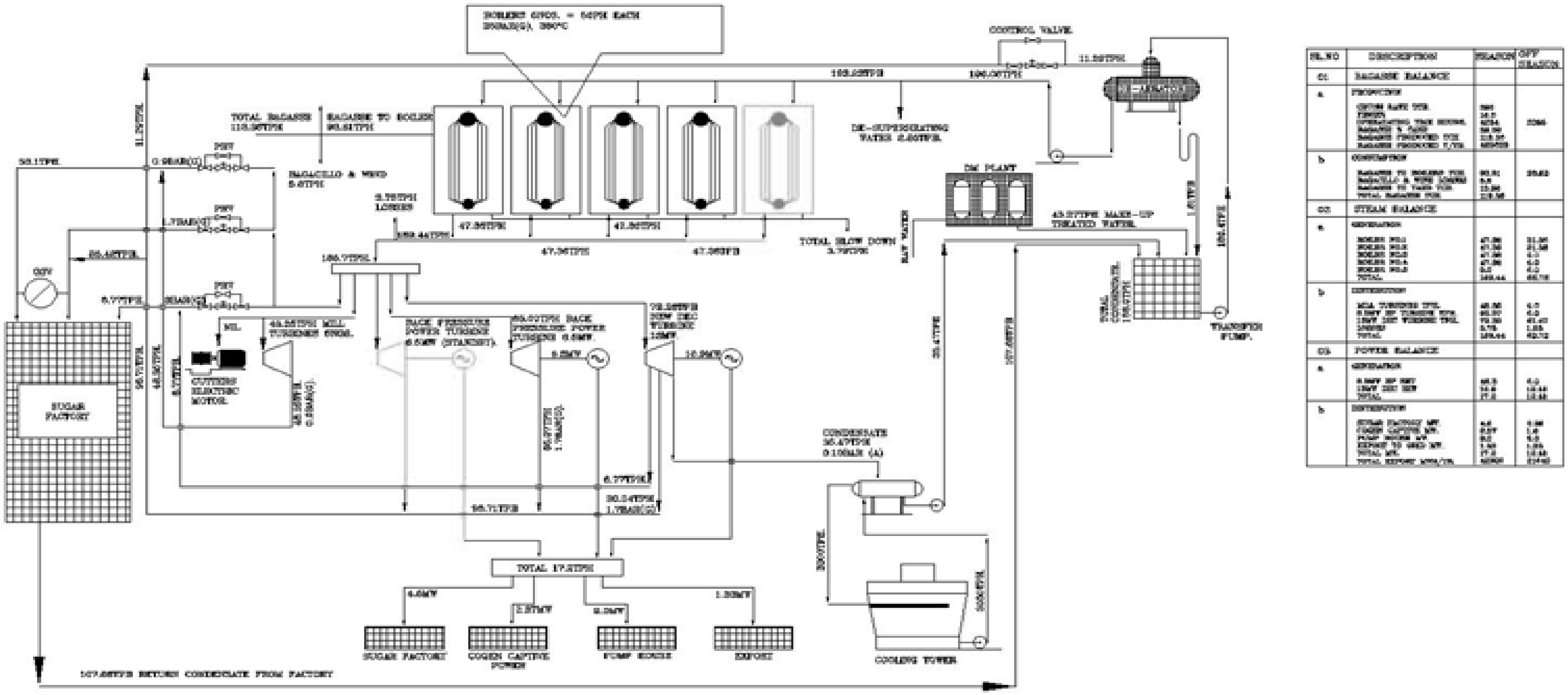


Figure (3.2) : Assalaya Sugar Factory Co-gen power plant [19].

3.1.5.2 Power Generation During Off-season

During off-season only two boilers are in line and the condensing co-gen unit ran alone , the layout of Assalaya sugar factory power plant during off-season is shown in figure (3.3).

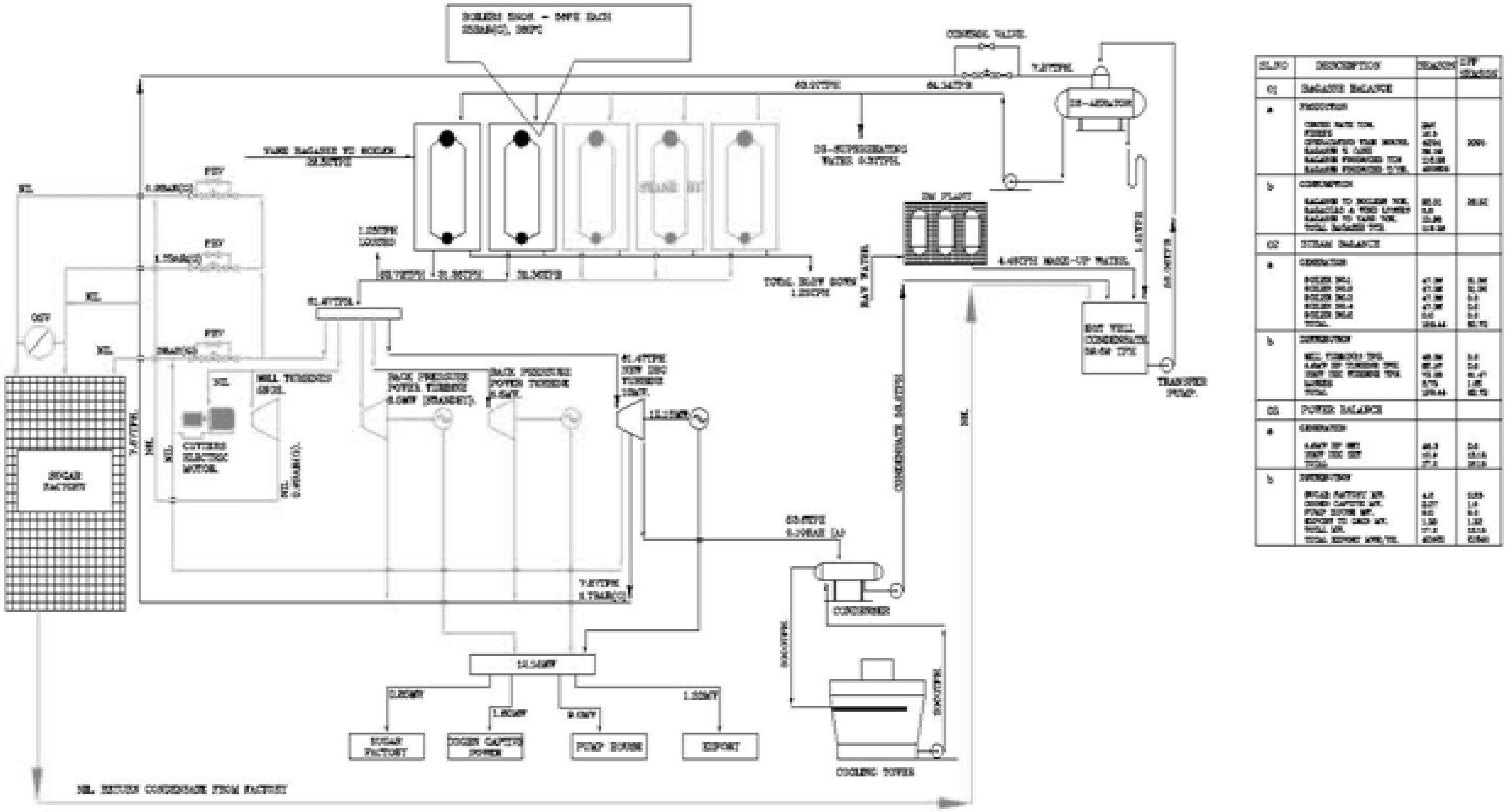


Figure (3.3): Assalaya sugar factory co-gen power plant [20].

All calculation of baggasse, steam ,energy balance is based mainly on the sugar cane contents .

3.1.5.3 Baggasse:-

Rate of crushing = 290 TCH (tons crushing per hour)

Fiber % cane = 18.5

Baggasse % cane = 39.0

Baggasse produced TCH = 290X0.39= 113 Tons/hour

Total cane crushed /year = 800,000 Tons

Baggasse generated/year =800,000 x 0.39 =312,000 Tons

3.1.5.4 Steam Required

1. Mills turbine TPH (Tons per hour) = number of mills x steam consumed per mill = 6 x 8.06 = 48.35
2. 6.5 MW back pressure (BP) turbines(tow turbines) TPH= 2x 32.535= 65.07
3. 13MW DEC(double extraction condensing turbine) TPH=72.28
4. Total steam losses/hour =3.75

Total steam = 189.44 TPH

3.1.5.5 Power Generation:-

1. 6.5 MW B.P(back pressure) hr =6.3MW
2. 6.5MW BP hr =6.3 MW
3. 13MW DEC turbine hr = 6MW

Total = 18.6 MW

3.1.5.6 Power Distribution:-

1. Sugar factory consumption MW =4,5MW
2. Co-generation consumption MW =2.4MW
3. Pump station =9.0MW

Total consumption =15.9MW

Total generation MW =18.6MW

Extra power MW = 3.0 MW

3.1.5.7 Steam Balance:-

Boiler no.1 = 47.36 TPH

Boiler no.2 =47.36 TPH

Boiler no.3 =47.36TPH

Boiler no.4 =47.36 TPH

Boiler no.5 = standby

Total =189.44TPH

3.1.5.8 Boundary:-

Total steam required / hour =189.44

Cane crushing per hour = 295

Total cane crushed / year = 295x24x30x5 = 1062000 m tons

Total baggasse generated = 1062000x0.39 = 414180 m tons

Total steam required Tons / hour = 189.44

Steam required per day= 189.44x24 = 4546.56 tons

Baggasse consumption per day = 4546.56/2 = 2273.28 m tons

Total crushing days = 5x30 =150 days

Baggasse Consumption / year =150x2273.28 =340992 m tons

Extra balance baggasse = 414180-340992 = 73188 m tons

3.1.5.9 Power Generation During Off season:-

Steam required for 10 MW/hour =10X7.2=72 TONS

Steam required /day =72x24 =1728 tons/day

Baggasse consumption /day =1728/2 = 864 m tons

Number of days co-gen running = 73188/864 = 85 days

3.2 Modification required for total plant load up on co-gen

3.2.1 Power Network:-

Total general generation = 26 MW

There exist:-

1) 15 MVA Transformer for export & import 33/11 KV
2) 7.5 MVA Transformer 11/3.3 KV

   The plant load is completely in 3.3 KV for distribution, one more Transformer is required for plant 7.5 MVA (or) 10 MVA 11 /3.3 KV

3) The 11KV bus bar gets extended to enable synchronization between the co- gen and the grid, There exits synchronization & relay panels.

Types of relays used are:-

1) Micon (static)
2) 51V (over current) electromechanical.

And the total network of the power system is shown in figure (3.4).

Additional hardware required to load the factory from the co-gen only

Total available load = 13+6.5+6.5 = 26 MW

Transformers available capacity is 15 MVA + 7.5 MVA = 22.5MVA

So one more either 7.5 MVA or 10 MVA is required to handle the total generated power so 22.5+7.5 = 30MVA or replacing the 7.5 MVA transformer by 16.2 MVA transformer to get 15 + 16.2 =31.2 MVA transformation. We need to select circuit breakers for the 11 KV and 3.3 KV sides of the additional transformer say T9.

Factors for selecting VCB's

1) Voltage 11 KV or 3.3 KV
2) Depending upon load
3) For which purpose

If it is for transformer incoming then transformer protection will be there.

4) Motor protections included breakers
5) C.T & P.T for metering and protection.

The new proposed system appears in below figure (3.5).

The circuit for the synchronization of 13 MW to 11 KV to grid .

.

1) 11 KV switch board should capable of carry 1000 Amps and continuous, and 5000 Amps current for short time to carry fault current.
2) Feeder protection of 11 KV breakers should be adjustable according to total load on 3.3 KV bus.
3) Feeder protection of 11 KV breaker should have transformer protection such as differential, Bochholz, Oil and winding temperature, pressure relief valve, MOG, etc.
4) Feeder TR-8 breaker and CT ratio should be 1000/1 Amps with 2 core per phase.
5) And Transformer TR-8 should be of 16.25 MVA capacities.
6) 11 KV TR-8 breakers to TR-8 16.25 MVA transformer cables should be of 3 runs, 3 core, 300 SQMM. i.e. 3 Runs/ Ph.
7) TR-8 LT side (3.3 KV) cables should be capable of 2843 Amps continuous and 5*2843 Amps for fault current.
8) TR-8 LT breaker (3.3 KV) should be capable of carrying 3000 Amps.

9) 3.3 KV bus including Bus couplers 1 and 2 should be capable of carry 3000 Amps continuously, and 5*3000 Amps for short time (in case of faults E.g. Short circuit, E/F etc.)

10) TR-8 LT side feeder protection should be alerted according to load up on 3.3 KV BUS.

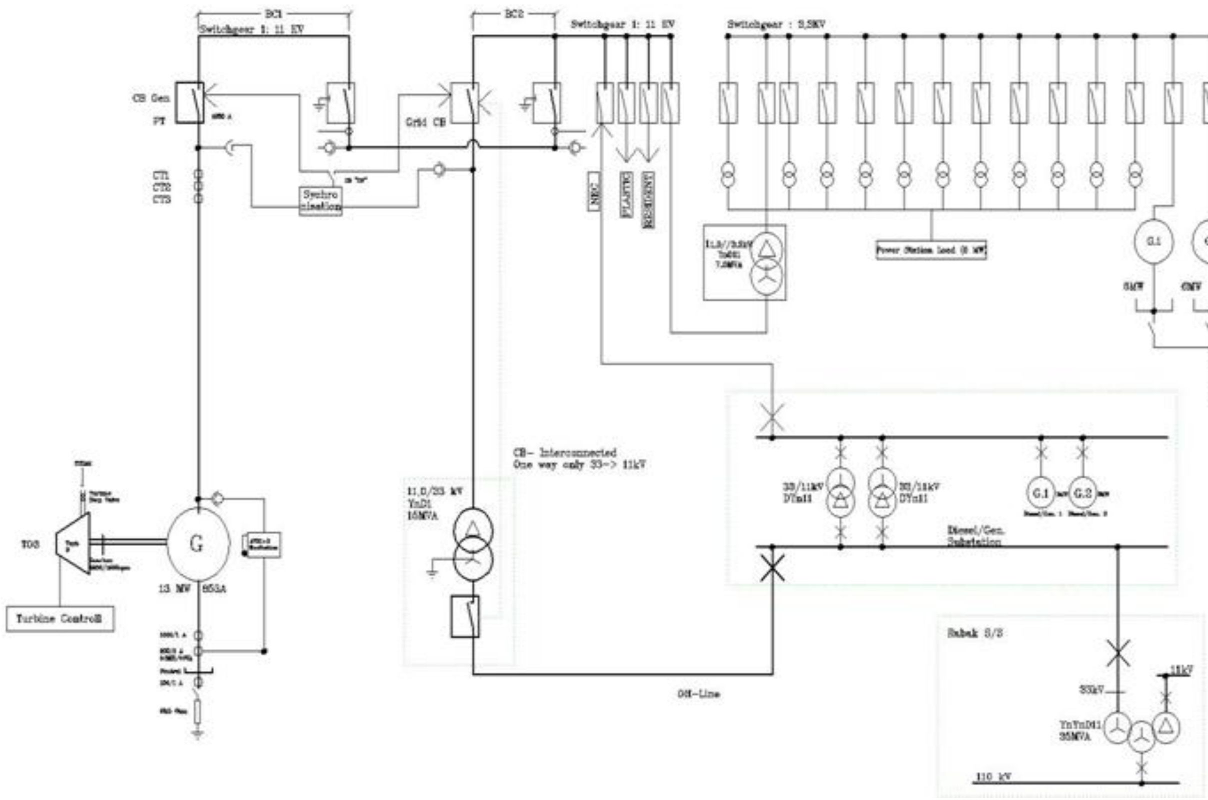


Figure (3.4): Assalaya Existing Network [21].

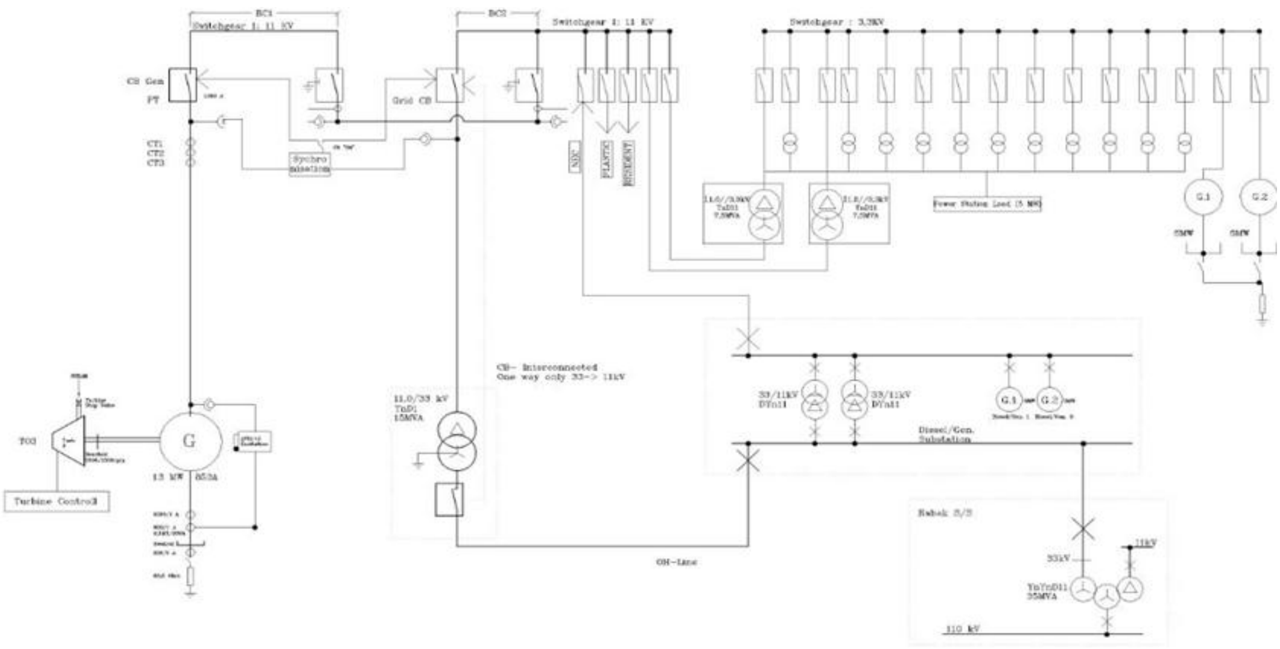


Figure (3.5): Assalaya proposed network

Taking season 2014 to 2015 as a sample , the data taken from operation log book is represented in different format reflecting the contribution of each power generating unit in figure (3.6) it is shown in barmeteric form ,figure (3.7) showing it in percentage while showing in tabular form in Table (3.5).

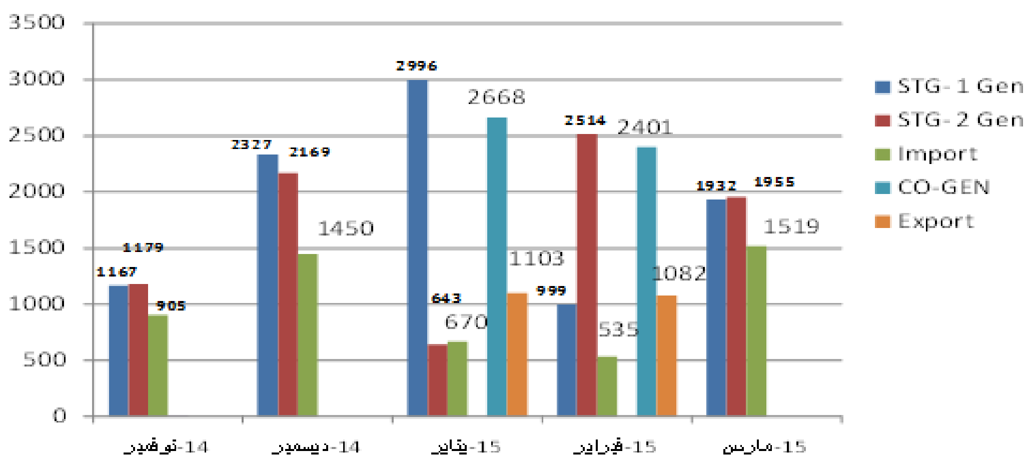


Figure (3.6)   2014 to 2015 Annual Report

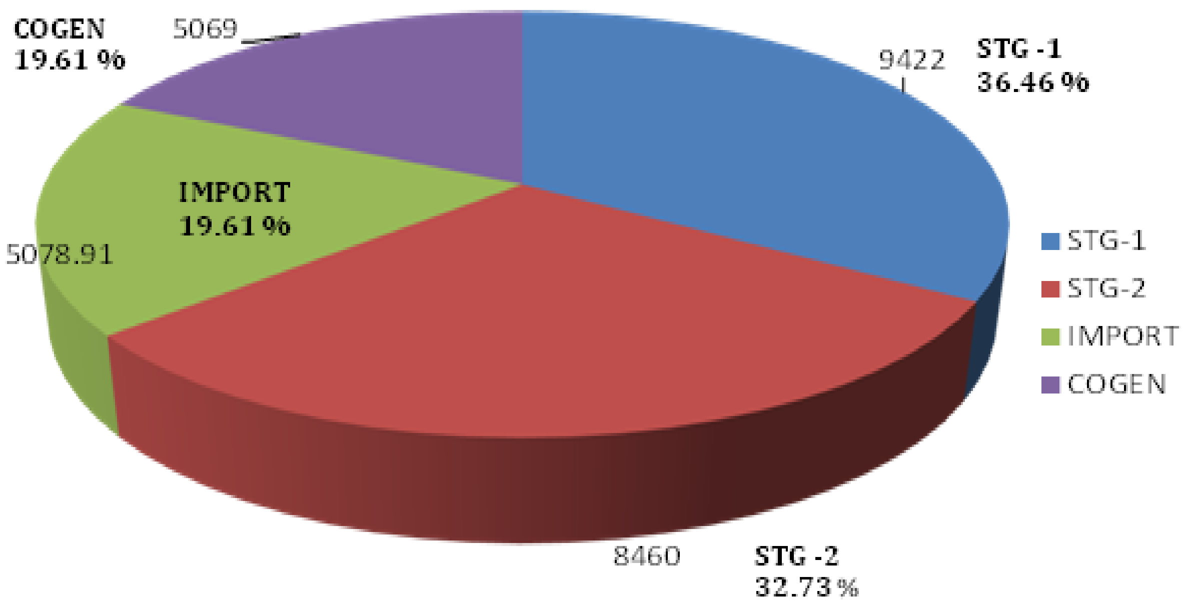


Figure (3.7) : Total Plant Consumption in MWh

Table (3.5) 2014-2015 Season Generation ,Export ,Import

Month	STG- 1 Gen	STG- 2 Gen	Import	CO-GEN	Export	Co-Gen consumption	Plant Consumption
Nov-14	1168	1179	906	0	0	30.1	3252
Dec-14	2327	2169	1450	0	0	86.8	5948
Jan-15	2996	643	670	2668	1103	281.4	5873
Feb-15	999	2514	535	2401	1082	238.8	5366
Mar-15	1953	1955	1647	0	0	70.8	5556
Total	9443	8460	5208	5069	2185	707.9	25995

Chapter Four

Results and Discussion

CHAPTER FOUR

Results and discussion

As per the objectives of this research one of which is to get the maximum of the co-gen. With the existing network, the factory cannot take its full load from the co-gen unit because the transformer TR8 11/3.3 KV of 7.5 MVA is under size and by either extending or using spare VCB in 11 KV and 3.3 KV bus sections to add a new transformer of either 7.5 MVA or 10 MVA to enable the co-gen to handle all the factory load which means putting both 6.5 MW generators in standby and therefore the baggasse consumption will become minimum and the surplus baggasse will be increased for running the co-gen unit in the off season for longer time i.e. almost 85 days as calculated through baggasse, steam & energy balance. This is also lead to make the distribution of all generated power possible and therefore increase the export power to pump station and the surplus power to the NEC grid and it is also make the synchronization of the two conventional 6.5 MW generators at 3.3 KV with that of the co-gen of 11 KV possible.

By increasing the off season co-gen time the bill that paid to NEC for supplying the pump station in the off season will be decreased to minimum that lead to decrease the cost / sugar bag which is the strategic objective of the sugar factory

Using the boundaries i.e. total generated steam (200 T/H) using four boilers out of five boilers and keep one as standby and fiber percent cane (18.5) for Assalaya sugar factory cane and crushing rate (295-300) tons per hours. And additional hardware transformer and circuit breakers, it is possible to run the units together, the two 6.5 MW generators and 13 MW co-gen as shown in Assalaya sugar factory co-gen power plant figure (3.4) in which only one of the 6.5 MW that give 6.3 MW output and the 13 MW co-gen which gives 10.9 MW output with total capacity of 17.2 MW running that is because of the lack of hardware (the transformer 7.5 MVA existed is under size) that make the running of the second unit (6.5 MW) possible and will increase the total generation to23.5 MW and the export will increase from 1.33 MW to 7.63 MW when crushing rate increase from 290 T/H to 300 T/H.

Chapter Five

Conclusion and Recommendation

CHAPTER FIVE

5.1 Conclusion:

Nowadays all factories running after the reduction of total steam consumption. Sugar industry which is a major steam consumer is considered as a high energy production industry. The sugar industry has a potential for generation excess commercial power, which can be sold to the grid. This additional investment is available to low cost where baggasse is used as fuels.

As per the objectives of this research,

1- Output power generated in Assalaya power generation plant will be increased from 17.2MW to 23.5 MW by adding 7.5 MVA transformer.
2- Increasing the crushing rate to 295 tons per hour (T/H) ,lead to save baggasse that enable running the new power generation unit to extra 85 days in the off-season.

5.2 Recommendations:

1- To Study the power supplying of the pump station during island mode
2- To Study the rehabilitation of the existing boilers to enable using more than one fuel.
3- To Study the rehabilitation of the baggasse storage and levelly system.

References

1- Link and reference involving U.N. FAO production figures

2- Arora and Domkundwar, Acourse in Power Plant Engineering, Fifth Revised and Enlarged Edition, Dhanpat Rai & Co. (p) Ltd, Educational & Technical Publishers, 1710, Nai Sarak, Delhi - 110006

3- 7 Avantgrade-india.com/…/modern%20Trends%20in%20…

8-9 P...J..MANOHAR RAO., Industrial Utilization of Sugar Cane and its Co-products, New Delhi, India , 2001

10- SAM G. DUKELOW, the Control of Boilers, 2nd Edition, P. cm., Isbn 1-55617-330-x

11-17 Uttam Sucrotech Limited, Manual for 13 MW Turbine of Assalaya Sugar Factory, India, 2006 .

4- 18 E- Hugot- (1972)-Handbook of sugar engineering - third completely, revised, edition - G. H. Jenkins (Australia)

19-20 Uttam Sucrotech Limited, Lay out for Assalaya sugar Factory Co-generation Plant , India, 2006 .

21- Assalaya Sugar Factory Documents.

Appendixes

Appendex1

Boiler Management System

ELIPSE SCADA:-

Elipse Software is proud to present this powerful tool for creating and developing supervisory and control applications.

Elipse SCADA gives you a great performance and has powerful and innovative features to make the task of developing your application easier. It is completely configurable by the user and the process variables can be shown in a graphic form, allowing an easy understanding of what is going on in real time. To do it you can use any screen object like Bars, Trends, Displays, Gauge, etc. Besides, you can send or receive information to data acquisition equipment using Set points, Sliders and Buttons.

Assalaya Boiler SCADA is divided into five boilers.

Boiler management SCADA covers monitoring, control via tuning faceplates PID, alarm management, logging and customized reporting of all process values i.e.

Feed water flow

Steam flow

Drum level

Drum pressure

Furnace pressure

Oxygen %

De aerator level

De aerator pressure

Air and flue gas system process parameters

Boiler management SCADA system covers eight mimics

1. Boiler Plant Mimic
2. Air and Flue Gas System Mimic

3. De aerator Mimic
4. Real Time Trend Mimics
5. Alarms Mimic
6. Report Mimics
7. Master Control Mimic

Operational Procedure for Boiler Plant System

Boiler SCADA Plant has divided into two parts Master and Slave system via network driver.

Redundancy of both PC's has derived through Ethernet cable specifying IP address for both PC's. On both PC, monitoring and control of tuning process parameters, viewing of process alarms, logged process parameters and reporting through separate PC.

Precaution has to be taken before starting the Elipse SCADA system

1. Check weather all Boiler 5 controllers, RS-485/232 converters, Sharers and both PC are powered on.
2. Check weather all Boiler 5 Shares at one position i.e. either PORT1 or PORT2

When you run Elipse SCADA Boiler system, firstly menu selection mimic appears for selection of MASTER, SLAVE PC. If any wrong selection has occurred, DEACTIVATE selection is provided.

Depending on Sharer PORT position i.e. either connection are for PC1 or PC2, MASTER selection is to be done and another PC should take in SLAVE mode.

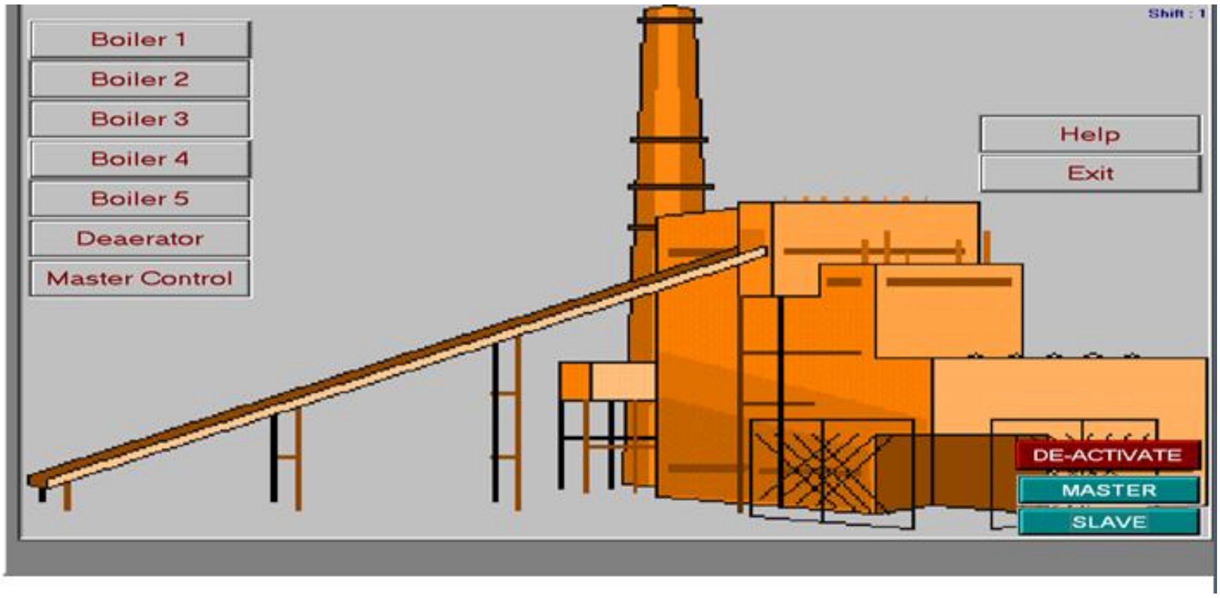
After selection of MASTER/SLAVE mode, SCADA gives feedback indication

1. NOT ACTIVE
2. MASTER
3. ETHERNET.

Operator can go in detail each boiler section through Boiler selections from Menu Mimic to view process parameters, PID facia, alarms and reports with navigation.

Menu Mimic

Menu selection mimic is provided for selection of MASTER/SLAVE and DEACTIVATE, also for viewing and controlling in detail each Boiler process parameters selection for Boilers are provided. To see parameters of Boiler1 select Boiler 1 button similarly for other 4 boilers.



Menu Mimic

Boiler Plant Mimic

Boiler Plant gives monitoring of all main process parameters and selection of PID faceplates and tuning parameters.

Following are the display details

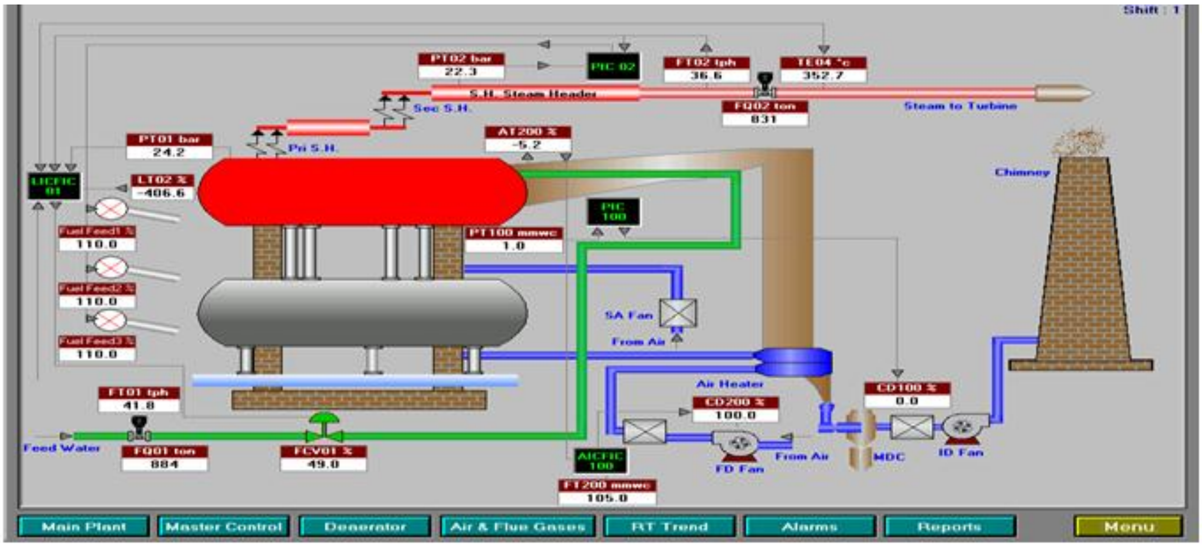
1. Drum Level
2. Drum Pressure
3. Furnace Pressure
4. Feed Water Flow
5. Steam Flow
6. Combustion Steam Pressure
7. Fuel Feed and it’s Speed
8. Oxygen %
9. ID & FD fan damper position

Following are the PID details

1. Three level drum control (LICFIC01)
2. Furnace Press. Control (PIC100)
3. Combustion Control (PIC02)
4. FD Fan Damper Control(AICFIC100)
5. De aerator Level Control(LIC51)

6. De aerator Pressure Control (PIC50)
7. Master Pressure Control (PIC03)

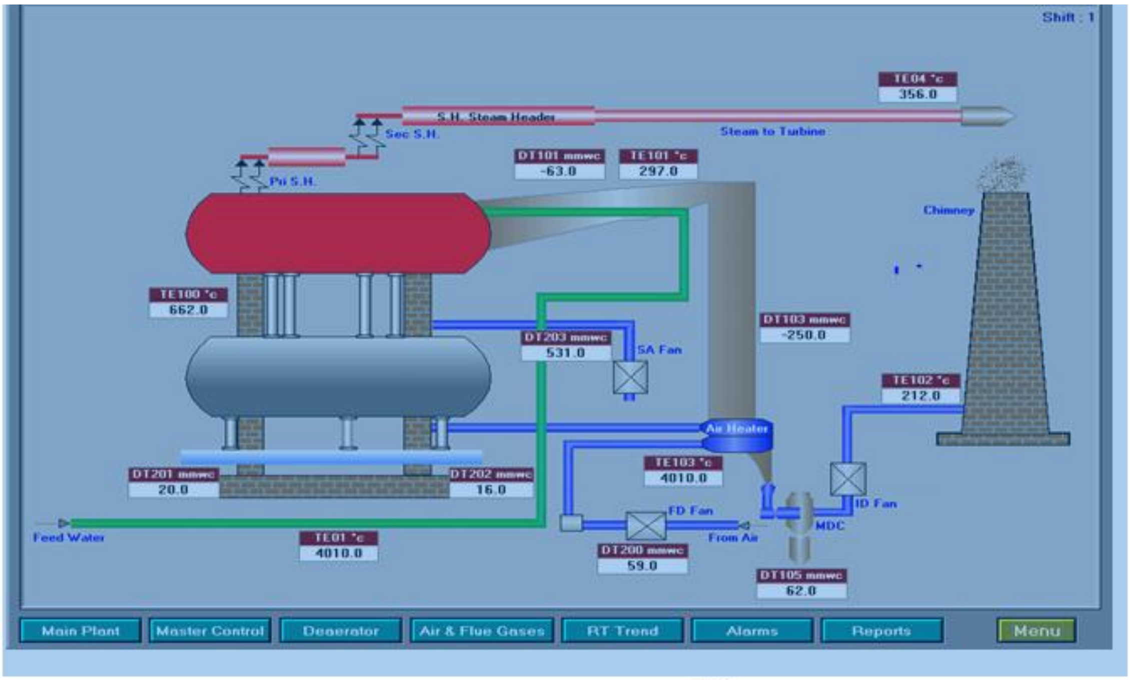
Double click on the "**LICFIC01**" to open PID; similarly you can open other PIDs by double clicking on respective PID. PID screen is useful for tuning parameters. You can set SP, OUT, AUTO/MANUAL & LOCAL/CASCADE facilities.



Boiler plant mimic:-

Air & Flue Gas System Mimic

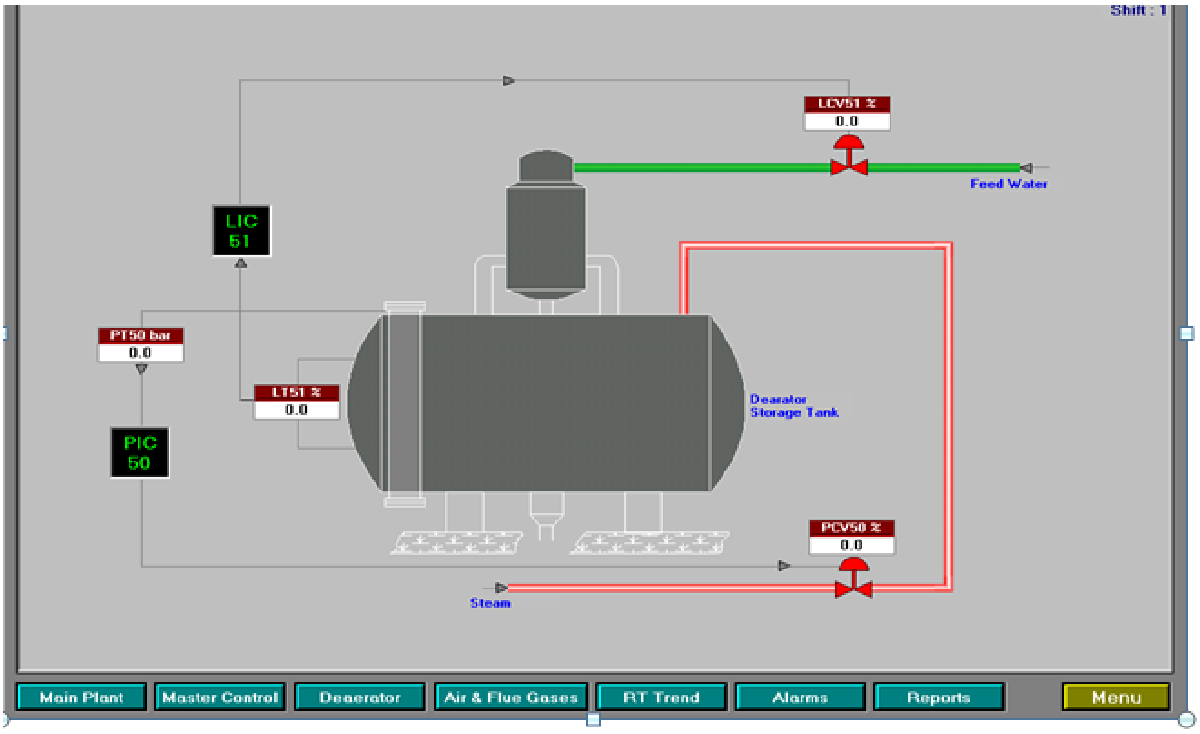
Air & Flue Gas System gives monitoring of all process temperatures and Draught.



Air and Flue Gas System Mimic:-

De aerator Mimic

De aerator System gives monitoring of De aerator Level and pressure and control from tuning faceplates.



De aerator Mimic:-

Real Time Trends

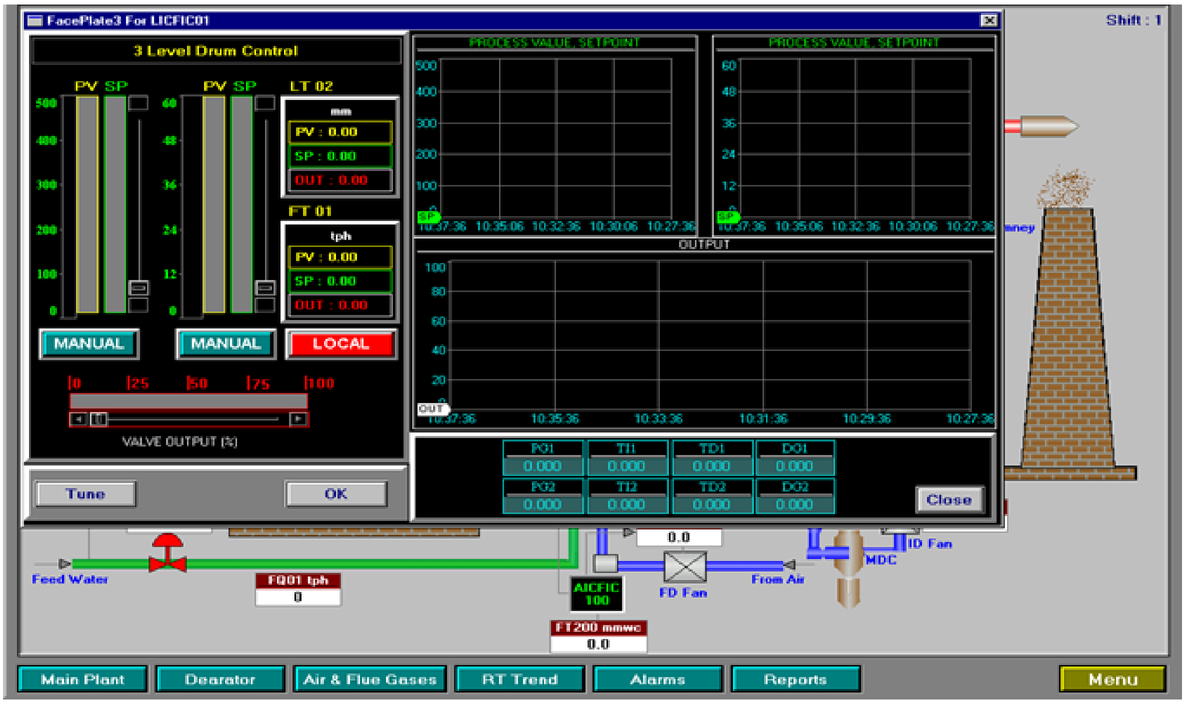
All process values with graphic representation viewed from RT trends. It covers all Boiler process related values and Air & Flue Gas system and all Temperatures.

Graphic Trends are customized with Time Variation and Range Variations with display form. To change Range Variations slider facility provided. Press on slider buttons it will change your Ranges.

Real time trends:-

Control System Tuning Faceplate

PID tuning faceplates are mainly to control the process values with respect to given set points and outputs.



Control System Tuning Faceplate

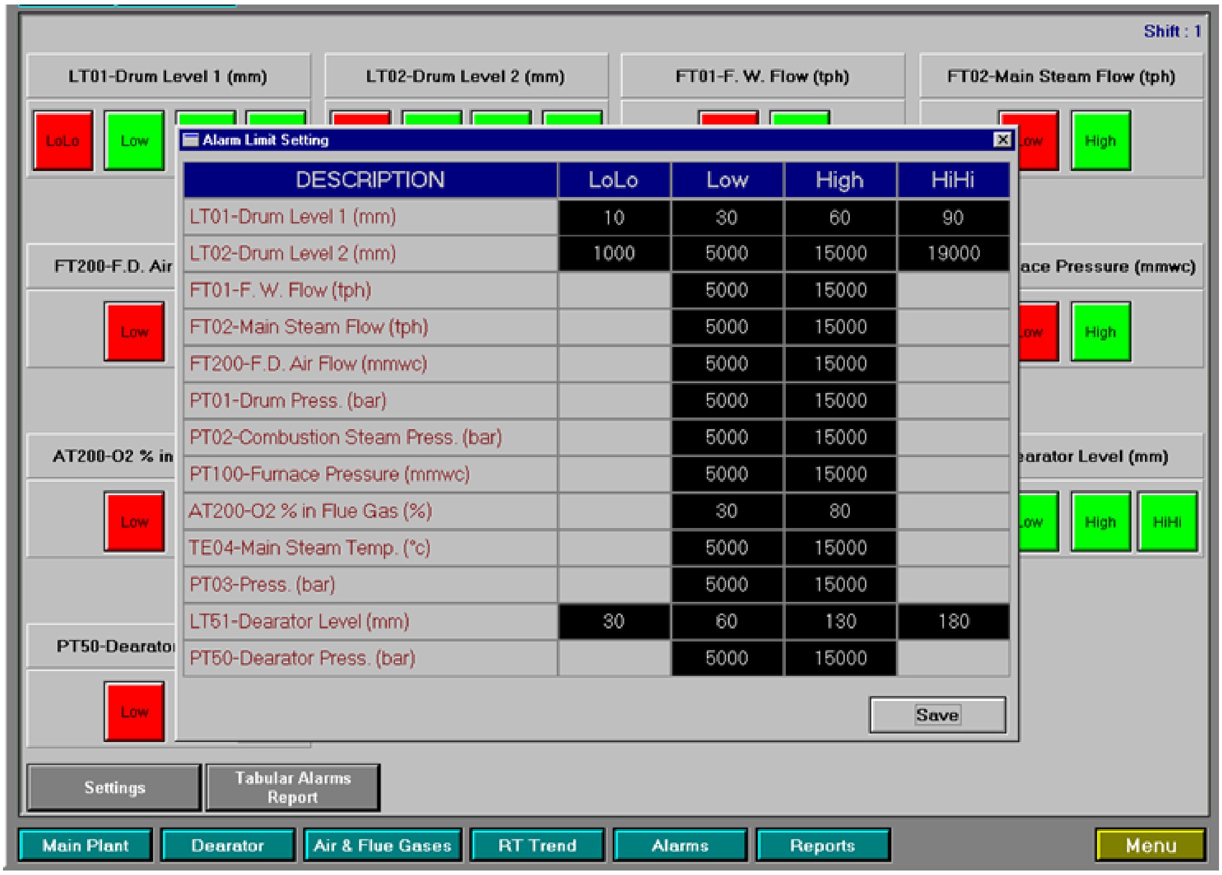
Alarm Management

Good process can be understood from Alarm Management. Basically all process values alarms viewed at one time. Further it can be settable from SCADA and gets logged and make reports facility. If any process values exceeds its limits (defined in Alarm Settings screen) then respective alarm will generated & the window of that alarm becomes red. If there is no alarm then the window will be green colored.

Control System Tuning Faceplate:-

Alarms Settings

You can define your own settings for respective process values. Put Lo-Lo, Low, High, Hi-Hi limits and press **SAVE** button. Changing of alarm settings possible only from the MASTER computer, it will accept settings from SLAVE/ETHERNET computer.



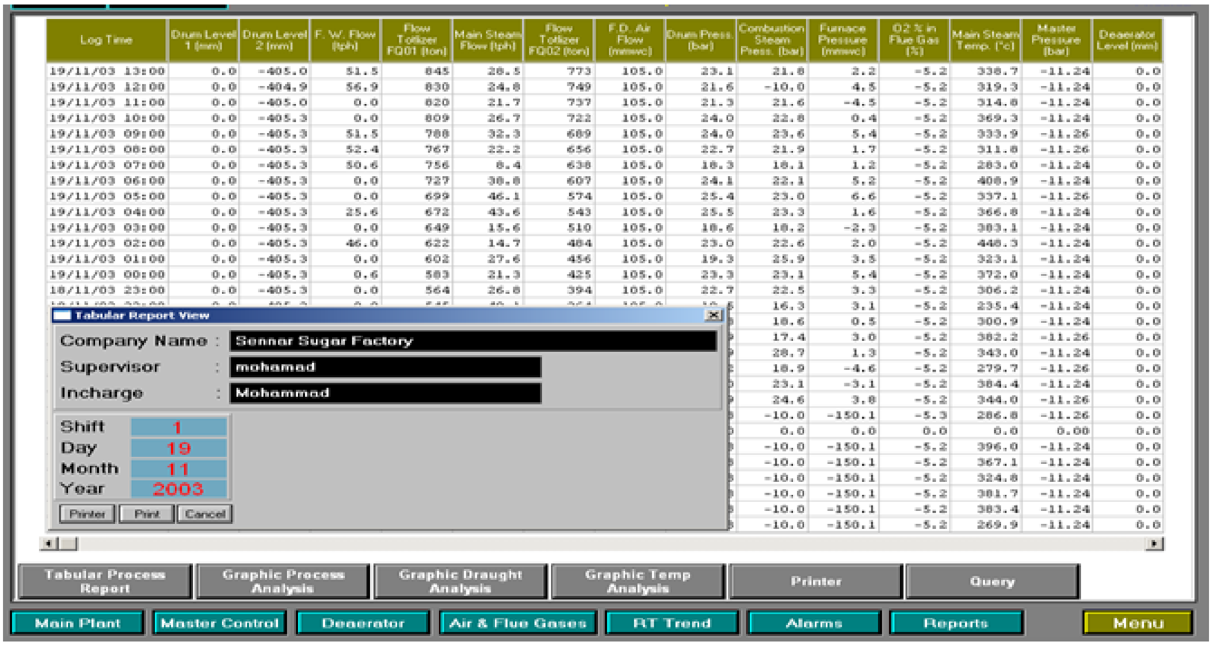
DESCRIPTION	LoLo	Low	High	HiHi
LT01-Drum Level 1 (mm)	10	30	60	90
LT02-Drum Level 2 (mm)	1000	5000	15000	19000
FT01-F. W. Flow (tph)		5000	15000	
FT02-Main Steam Flow (tph)		5000	15000	
FT200-F.D. Air Flow (mmwc)		5000	15000	
PT01-Drum Press. (bar)		5000	15000	
PT02-Combustion Steam Press. (bar)		5000	15000	
PT100-Furnace Pressure (mmwc)		5000	15000	
AT200-O2 % in Flue Gas (%)		30	80	
TE04-Main Steam Temp. (°c)		5000	15000	
PT03-Press. (bar)		5000	15000	
LT51-Dearator Level (mm)	30	60	130	180
PT50-Dearator Press. (bar)		5000	15000	

Alarms Settings:-

DateTime	Comment	Type	Value
06/08/2003 10:26:29	TE_04 Main steam Temp. Low - B5	LOW	0.0
06/08/2003 10:26:29	PT_01 Drum Pressure Low - B5	LOW	0.0
06/08/2003 10:26:29	LT_01 Drum Level LoLo - B5	LOLO	0.0
06/08/2003 10:26:29	FT_02 Main steam Flow Low - B5	LOW	0.0
06/08/2003 10:26:29	PT_100 Furnace Pressure Low - B5	LOW	0.0
06/08/2003 10:26:29	PT_02 Comp.Main Steam Pressure Low - B5	LOW	0.0
06/08/2003 10:26:29	LT_02 Drum Level LoLo - B5	LOLO	0.0
06/08/2003 10:26:29	FT_200 FD Air Flow Low - B5	LOW	0.0
06/08/2003 10:26:29	FT_01 F.W.Flow Low - B5	LOW	0.0
06/08/2003 10:26:29	AT_200 O2% in Flue Gas Low - B5	LOW	0.0
06/08/2003 10:26:29	TE_04 Main steam Temp. Low - B4	LOW	0.0
06/08/2003 10:26:29	PT_01 Drum Pressure Low - B4	LOW	0.0
06/08/2003 10:26:29	LT_01 Drum Level LoLo - B4	LOLO	0.0
06/08/2003 10:26:29	FT_02 Main steam Flow Low - B4	LOW	0.0
06/08/2003 10:26:29	PT_100 Furnace Pressure Low - B4	LOW	0.0
06/08/2003 10:26:29	PT_02 Comp.Main Steam Pressure Low - B4	LOW	0.0
06/08/2003 10:26:29	LT_02 Drum Level LoLo - B4	LOLO	0.0
06/08/2003 10:26:29	FT_200 FD Air Flow Low - B4	LOW	0.0
06/08/2003 10:26:29	FT_01 F.W.Flow Low - B4	LOW	0.0
06/08/2003 10:26:29	AT_200 O2% in Flue Gas Low - B4	LOW	0.0
06/08/2003 10:26:29	TE_04 Main steam Temp. Low - B3	LOW	0.0
06/08/2003 10:26:29	PT_01 Drum Pressure Low - B3	LOW	0.0
06/08/2003 10:26:29	LT_01 Drum Level LoLo - B3	LOLO	0.0
06/08/2003 10:26:29	FT_02 Main steam Flow Low - B3	LOW	0.0
06/08/2003 10:26:29	PT_50 Dearator Pressure Low - B3	LOW	0.0
06/08/2003 10:26:29	PT_100 Furnace Pressure Low - B3	LOW	0.0
06/08/2003 10:26:29	PT_03 Pressure Low - B3	LOW	0.0
06/08/2003 10:26:29	PT_02 Comp.Main Steam Pressure Low - B3	LOW	0.0
06/08/2003 10:26:29	LT_51 Dearator Level LoLo - B3	LOLO	0.0
06/08/2003 10:26:29	LT_02 Drum Level LoLo - B3	LOLO	0.0
06/08/2003 10:26:29	FT_200 FD Air Flow Low - B3	LOW	0.0
06/08/2003 10:26:29	FT_01 F.W.Flow Low - B3	LOW	0.0
06/08/2003 10:26:29	AT_200 O2% in Flue Gas Low - B3	LOW	0.0
06/08/2003 10:26:29	TE_04 Main steam Temp. Low - B2	LOW	0.0

Report Query Return

Alarms Report



Alarms Report

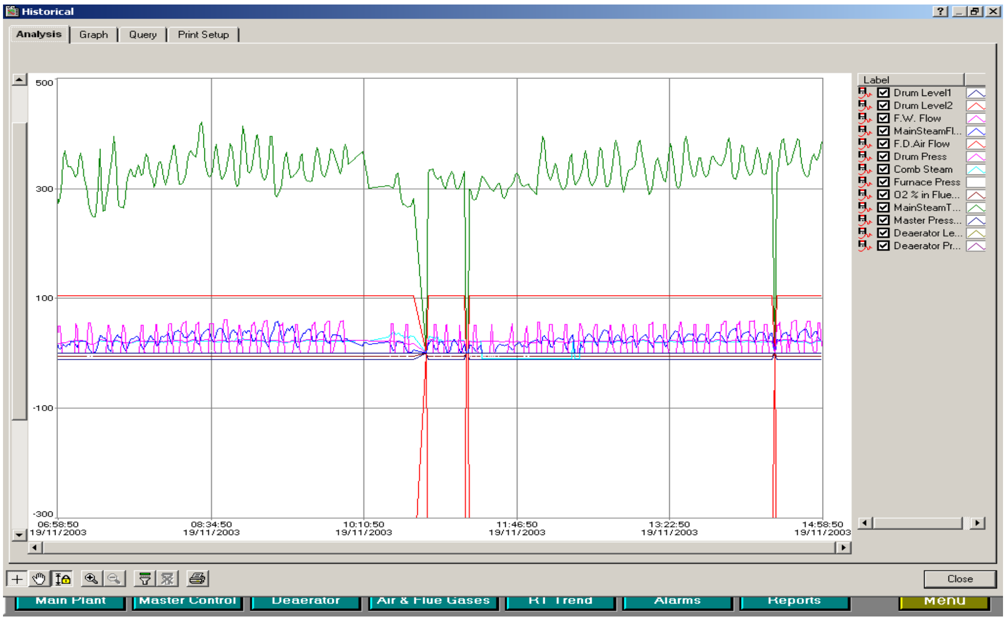
This screen shows no. of alarms came. It is showing date/month/year hour/minute/second, comment (alarm name), its type (low, high…) & its value.

You can print this report using Report button. You can filter data using Query button. Printer button given for printer selection, paper size selection.

Process Values Report Management

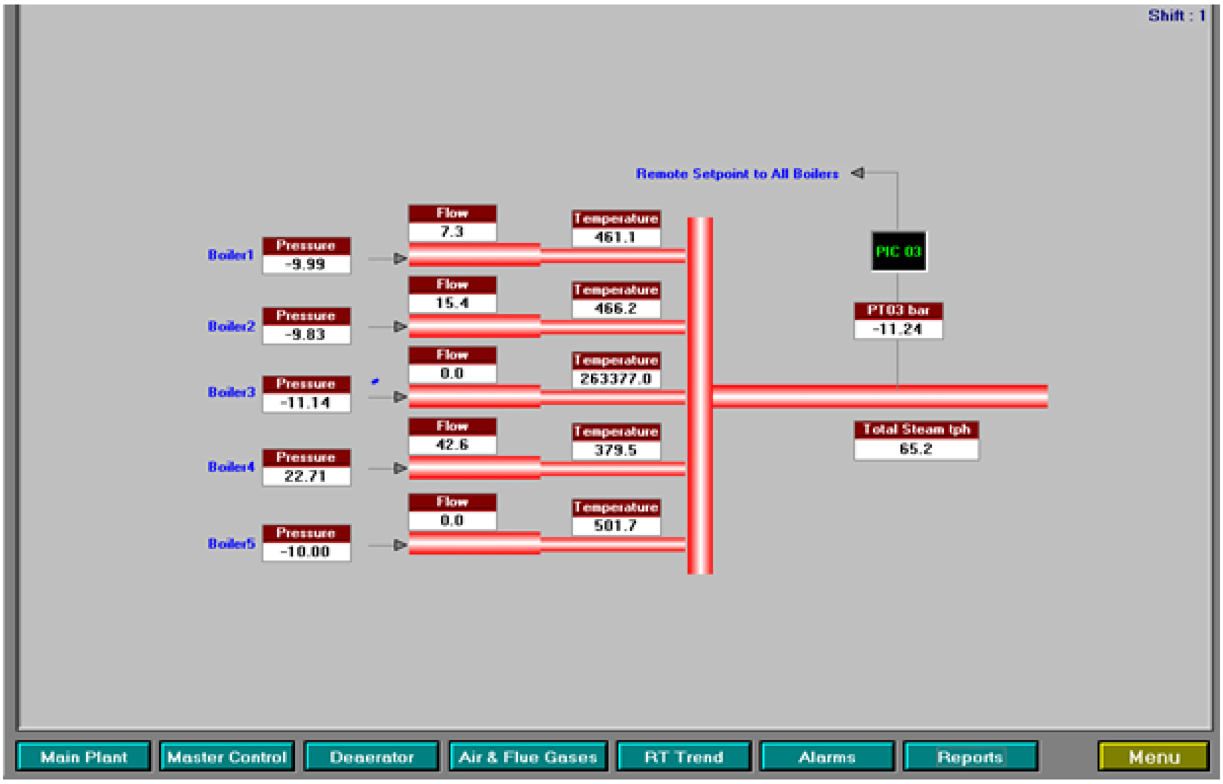
In is screen data is logged for every hour. So it contains every 1-hour reading. If you want to take print out then press Tabular Process Report button, it will show you Tabular Report View screen. Now put your Company name, Supervisor & In charge name. Then choose shift (1/2/3) put Day, Month, and Year. Then select Printer button to select printer, page setup. Then press Print button, it will print your report as per given shift, Day, Month & Year.

Graphic Reports



Graphic Reports:-

Master Control Mimic



Master Control Mimic:-

Appendex2

2.4.1 Boiler Control Loops in Assalaya Sugar Factory

In the past, boilers in an industrial complex were considered a necessary evil. However today's a business manager know this is no longer the case? Boilers are required to maintain maximum steam generation efficiency, maximum reliability, and comply with both stringent air emission and safety regulations. To achieve this goal you need modern control hardware and software. In today's competitive market minimization or reduction of operating costs is a valid method to increase profitability. Reducing fuel expenses associated with boilers can directly impact manufacturing costs. Boiler control is the most commonly implemented solution. Control systems for coal-oil-bagasse and mixed-fuel-fired boilers, were developed which allow the expertise gained from the implementation of many of the boiler control projects to be made available

2.4.2.1 Description

The Industrial Boiler Control solution implements the following major control loops.

- Combustion (Fuel Flow and Air Flow) Control
- Furnace Pressure Control.
- Feed water/Drum Level Control.
- Superheat Temperature Control.
- De aerator level control.
- De-aerator pressure control.

2.4.2.2 Combustion (Fuel Flow and Air Flow) Control

The main objective of automatic combustion control is to regulate automatically, the heat input to the boiler in terms of fuel and air supplied in relation to eat out put or steam demand. This should be implemented as efficiently as possible in terms of combustion quality and furnace stability .combustion air supplies are to be adjusted with change in boiler loads. Steam pressure is taken as the indication for boiler load as the steam pressure decreases in increasing load and vice versa. Hence variation in steam pressure is detected and the supply of fuel and air adjusted accordingly.

The successful operation of combustion control system depends upon the capability to vary the fuel supply to the furnace based on the signals from the control system. To achieve a system of baggasse storage and retrieval facility with about half an hour holding capacity should be provided before the baggasse system.

- Combustion (Fuel Flow and Air Flow) Control

The main objective of automatic combustion control is to regulate automatically, the heat input to the boiler in terms of fuel and air supplied in relation to eat out put or steam demand . This should be implemented as efficiently as possible in terms of combustion quality and furnace stability .combustion air supplies are to be adjusted with change in boiler loads. Steam pressure is taken as the indication for boiler load as the steam pressure decreases in increasing load and vice versa. Hence variation in steam pressure is detected and the supply of fuel and air adjusted accordingly.

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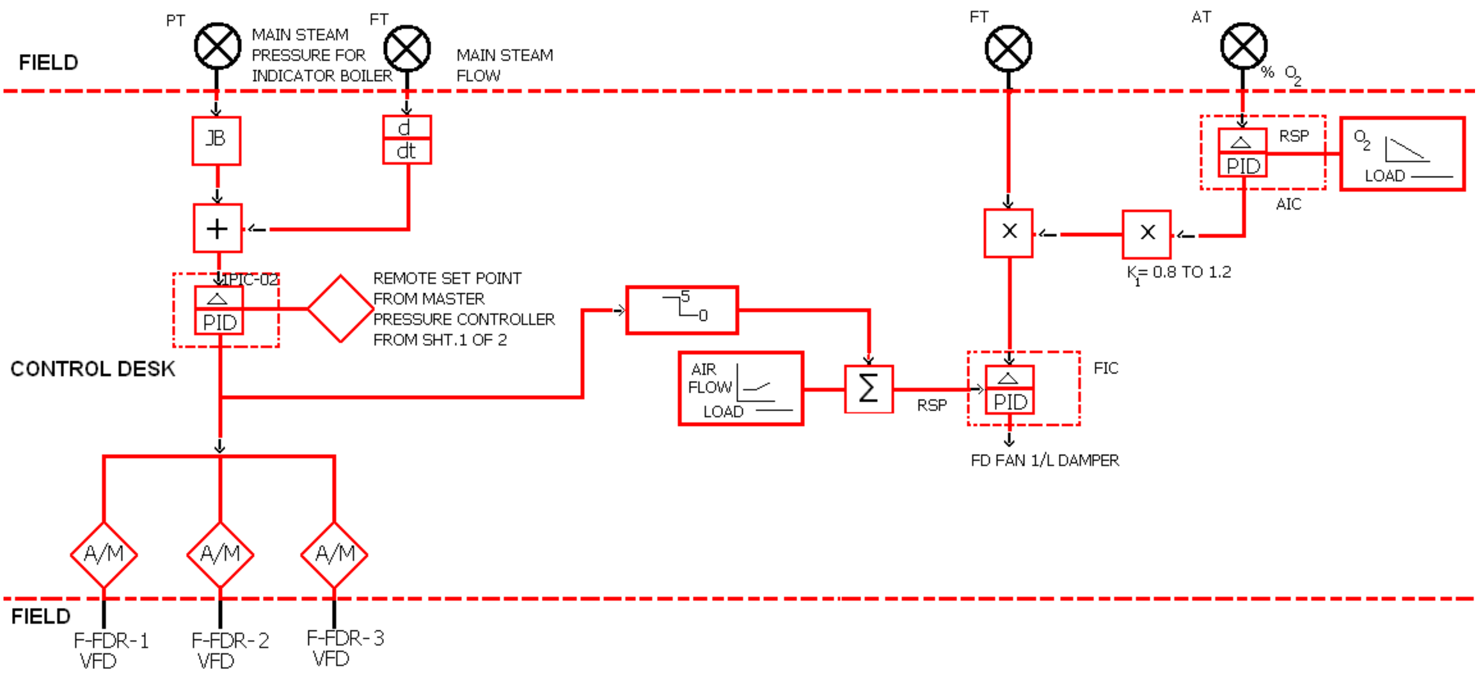
COMBUSTION CONTROL

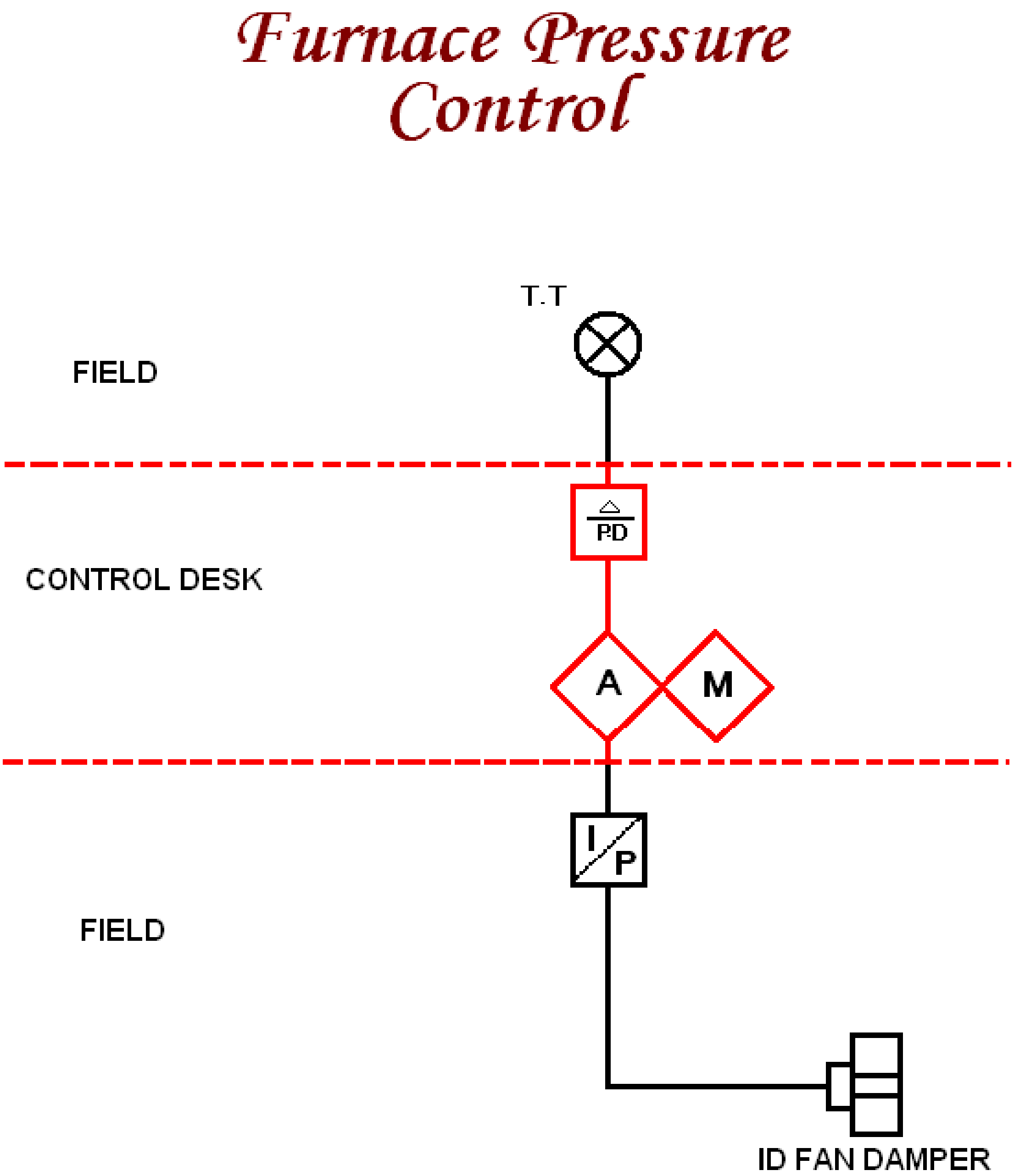


Control Loop:-

Combustion control achieved on the basis of steam demand of master pressure controller. If it is high, in comparison to the header pressure the steam generation shall be increased by increasing combustion air and fuel flow. The measured value of individual boiler pressure is compared with remote set point from master pressure controller and the steam pressure controller will generate the demand signal for fuel and air. This signal shall control fuel feeder speed through VFD giving the fuel demand for boiler. Air flow controller will get remote set point from load v/s airflow characteristic curve added with a signal from fuel demand controller through a HI-LO limiter. Airflow signal from flow transmitter is going to the airflow controller. Oxygen trimming controller is also giving the output to the airflow controller and oxygen controller is getting remote set point from load v/s oxygen characteristics curve through HI-LOW limiter. Final output from air flow controller shall regulate the control damper of the FD fan.

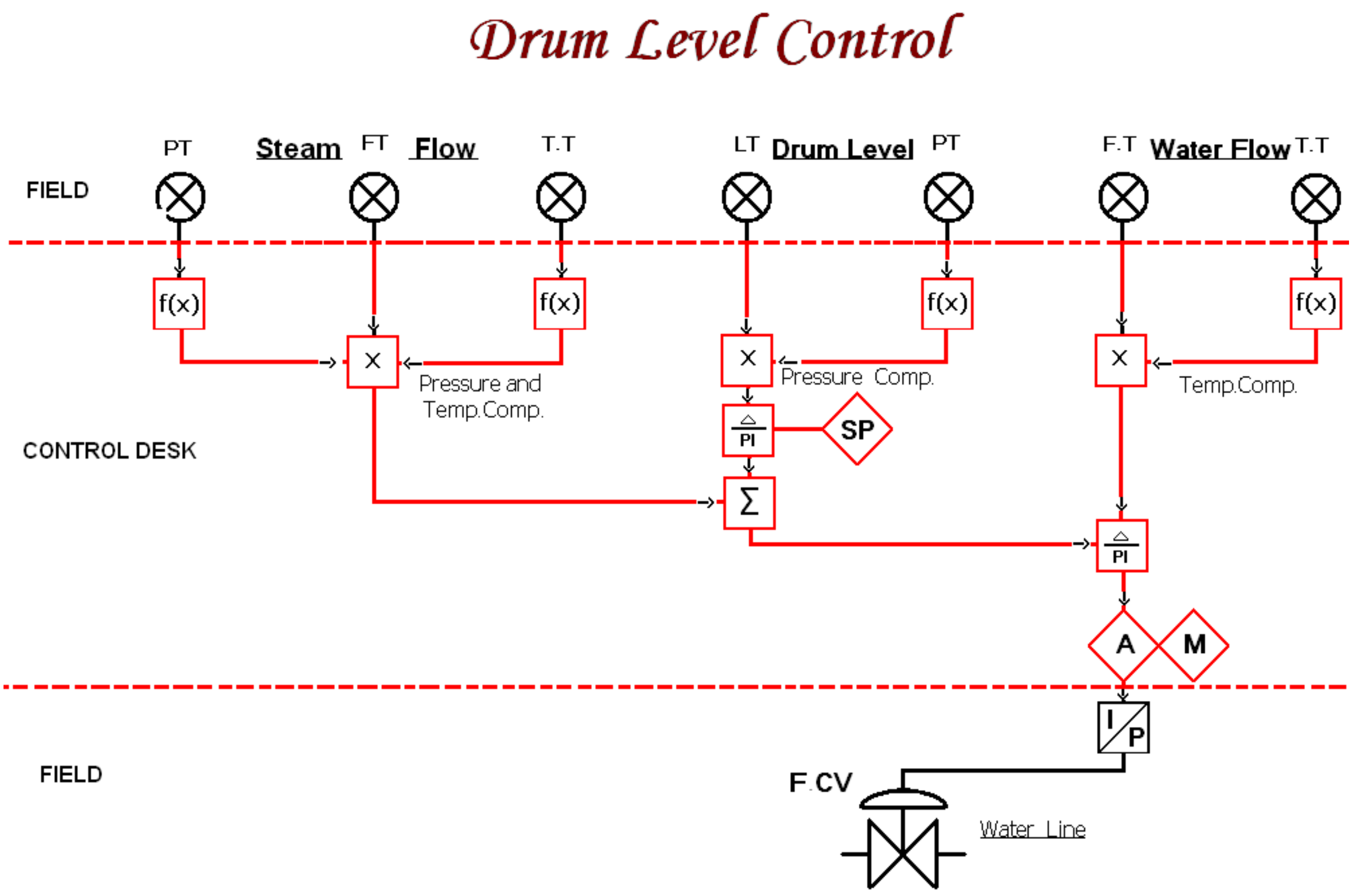
- Furnace Pressure Control

In all the combustion control systems, irrespective of the type, an independent control loop is provided to maintain a small constant negative draft inside the combustion chamber. Any variation from the set value is detected by the controller, and the resultant output signal directly goes to regulate the position the position of ID damper.



- Feed water/Drum Level Control:

Maintaining drum level at the normal recommended operating level very important. Too low a water can cause starvation in boiler tubes and lead to failures. Too high a level will lead to carry over of boiler water and reduce the steam purity.



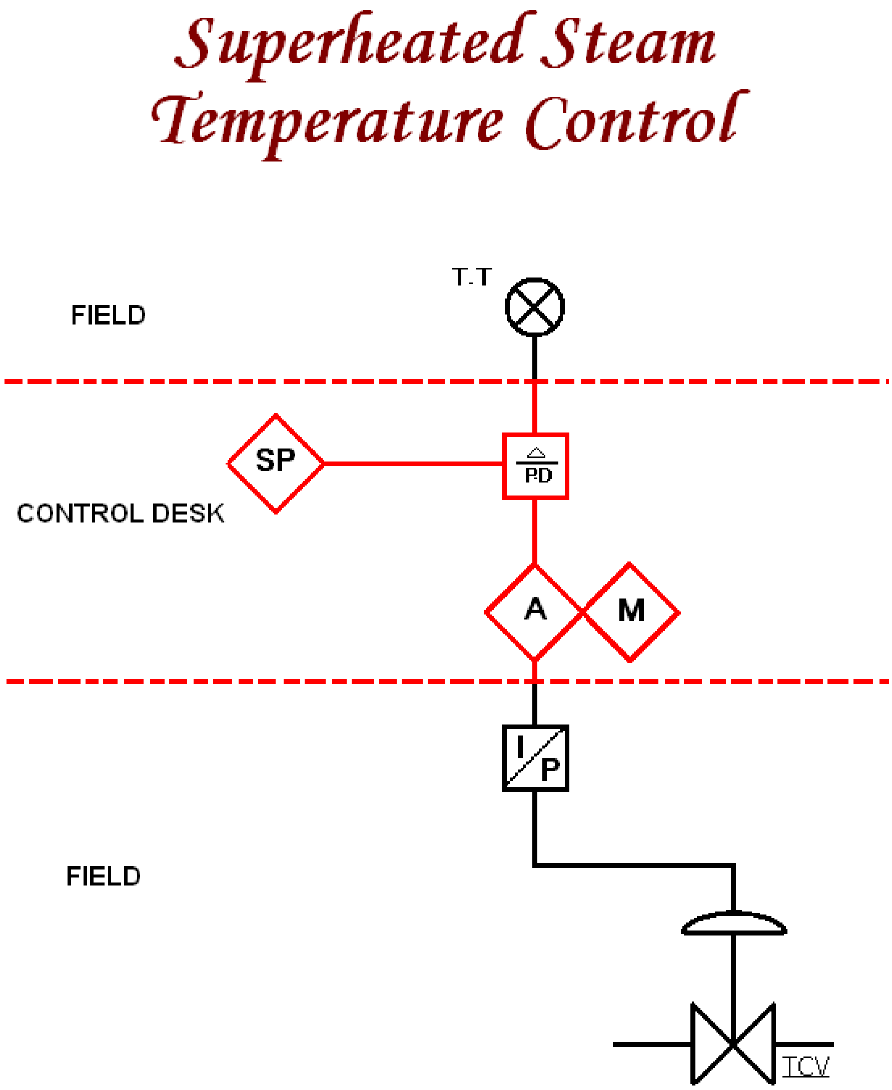
Feed water/Drum Level Control

Feed water to the drum should be continuous , failure of flow even for a brief period of time can cause serious and hazardous effect on the plant and operating personnel. Most of the modern boilers today operate at temperatures near the maximum permissible metal temperatures and temperature fluctuation as a result of poor feed water control can cause damage to boiler tubes. The three elements employed are drum level, steam flow and feed flow, the basic control is from the relation of steam flow to feed water flow. At normal conditions with drum level at correct value this ratio should be 1:1. any change must result in a control signal being applied to the feed water control valve

Control loop

Compensated drum level signal compared set point of primary level controller and out put is compared with the compensated steam flow signal the computed out put becomes set point to secondary feed control system then the out put is send to regulate the control valve through I/P converter at correct drum level value and steady conditions, steam flow to feed flow RATIO is 1:1. At any change control signal is fed to control valve. water level signal affects adjustment of feed valve, to trim the level back to its set value. Water flow signal enters the control system to position the control valve for water input equals steam output. Variations in feed water pressure causes change in water flow detected by flow meter and control valve will react.

- Superheat Temperature Control.



With the sprary attemperation or de superheater method ,fine jets of water on steam condensate is sprayed nozzles into the steam in its steam in steam in its passage between the first and second stage of superheaters . In order to achieve this, the temperature of a team is meatured and any variation from a desired value is detected by a cotroller. The latter then sends out a signal to the regulating value in the injection line. The system is suitable for sugar plant boilers where the mass super of superheater and hence, thermal inertia time is small. This greatly minimises the time lag in the heat transfer.

Appendex3

2.4.2BOILER CONTROL SYSTEM SYZING

The Input Sensors

Parameter	Tensor	Transmitter	Type	Location
A – super heated steam temperature control loop				
Temperature	T\C	T.T	analog	S.H.zone
B – furnace pressure control loop:				
Pressure	P.T.	P.T	analog	furnace area
C – drum level control loop:				
Pressure	P.T	P.T	analog	steam line
Flow	D.P.T.	D.P.T.	analog	steam line
Temperature	T\C	T.T	analog	steam line
Level	D. P.T	D.P,T	analog	steam drum
Level 2	D.P.T	D.P.T	analog	steam drum
Level 3	D.P.T	DPT	analog	steam drum
Pressure	P.T.	P.T	analog	feed water line
Flow	D.P.T	D.P.T	analog	feed water line
D – combustion control loop:				
Pressure	P.T	P.T	analog	steam line
Flow	D.P.T	D.P.T.	analog	steam line
Flow	D.P.T	D.P.T	analog	combustion air line
Oxygen%	O2	analyzer	analog	flue gases line
E – De aerator control loops:				
Level	D.P.T	D.P.T	analog	De aerator
Pressure	P.T	P.T	analog	De aerator
F – indicating and protection measurements:				

Temperature	PT100	T.T	analog	steam drum
Temperature	PT10	T.T	analog	after super heater elements
Temperature	PT100	T.T	analog	at furnace exit
Temperature	PT100	T.T	analog	before air heater
Temperature	PT100	T.T	analog	after air heater
Temperature	PT100	T.T	analog	before economizer
Temperature	PT100	T.T	analog	after economizer
Temperature	PT100	T.T	analog	De aerator
Temperature	PT100	T.T	analog	
Temperature	PT100	T.T	analog	
Temperature	PT100	T.T	analog	
Temperature	PT100	T.T	analog	
Temperature	PT100	T.T	analog	
Temperature	PT100	T.T	analog	
Pressure	P.T	P.T	analog	feed water to de aerator
Pressure	P.T	P.T	analog	steam drum
Pressure	P.T	P.T	analog	FD line near furnace entrance
Pressure	P.T	P.T	analog	id line
Pressure	P.T	P.T	analog	secondary air line
Pressure	P.T	P.T	analog	
Pressure	P.T	P.T	analog	
Pressure	P.T	P.T	analog	
Pressure	P.T	P.T	analog	
Pressure	P.T	P.T	analog	
Pressure	P.T	P.T	analog	

Pressure	P.T	P.T	analog	
Current	C.T	C.T	analog	De aerator pump1 motor
Current	C.T	C.T	analog	De aerator pump2 motor
Current	C.T	C.T	analog	feed water pump1 motor
Current	C.T	C.T	analog	feed water pump2 motor
Current	C.T	C.T	analog	forced air fan motor
Current	C.T	C.T	analog	induced air fan motor
Current	C.T	C.T	analog	feeder1 motor bagasses
Current	C.T	C.T	analog	feeder2 motor bagasses
Current	C.T	C.T	analog	secondary air fan motor
Current	C.T	C.T	analog	feeder3 motor bagasses
Current	C.T	C.T	analog	stoker drive motor
Current	C.T	C.T	analog	
Current	C.T	C.T	analog	
Current	C.T	C.T	analog	
Voltage	V.T.	V.T.	analog	id motor operating voltage
Voltage	V.T.	V.T.	analog	FD motor operating voltage
Voltage	V.T.	V.T.	analog	SA motor operating

				voltage
Voltage	V.T.	V.T.	analog	fuel feeders operating voltage
Voltage	V.T.	V.T.	analog	f w p motor operating voltage
Voltage	V.T.	V.T.	analog	d. p. motor operating voltage
Voltage	V.T.	V.T.	analog	
Voltage	V.T.	V.T.	analog	
Voltage	V.T.	V.T.	analog	