CHAPTER ONE

INTRODUCTION

1.1 Overview

The firing system basically depend on three element are fuel, air and heat. The industrial firing system devices are called boilers including furnace or combustion chamber. The combustion process is to mixing fuel and air enough at burner, the ideal combustion process during which a fuel is burned completely is called stoichiometric combustion

In the power plant boilers are the devices that used to transfer the chemical power energy to thermal power energy. That means combustion inside the furnace and steam production through the feed water in boiler tubes.

For obtaining maximum fuel combustion efficiency it is required to proper and complete combustion of fuel inside the boiler furnace. For that, proper and sufficient supply of air and proper mixing of air with fuel are primary requirements. Adequate supply of fuel particles for proper burning of particles are also to be maintained.

In KNPS – PH 3 the combustion air is provided by force secondary air fans to give sufficient air for combustion.

The primary air fan takes air from the FD fan downstream through pipe duct with diameter 700mm distributed to the burners without warming the air in the air preheated; PA fans are controlled by power driver frequency convertor.

The Secondary air fans or force draught fans takes air from the atmosphere and, first warms the air in the air preheated for better economy. The preheated air (Secondary air) passes through rectangular duct 2000mmX1800mm and distributes to each burners via open / close damper with electrical actuator. FD fans are controlled by variable speed driver [2].

1.2 The problem statement

The boilers in the subject are Khartoum North Power Station KNPS – PH3 thermal power units. It constructs of two separated units, each one generates 100 Megawatt. The main problem is the bad firing due to the more air or more fuel flow inlet into the furnace and the flame shape is cause to the incompletion combustion [1].

The air flow increased basically during each burner start sequence due to fully open dampers. Increasing air supply causes mainly boiler's vibration, in addition to loss of flame and stop burners. It also leads to Increasing in exhaust gas temperature [1].

The air supply has economical effect hence it causes the increasing of fuel consumption.

1.3 The proposed solutions

Enhancing air supply in the plant that is the subject of study by

1. Adding new primary air system which enhances the shape of flame. The primary air supply source is 2x downstream main FD fans. On higher boiler load (>50% MCR) the primary fans are switched off and an open/close damper in parallel to the primary air fans is opened.

1. Adding the primary air control damper on primary air duct to control air pressure at burners by using PID in existing DCS control system.
2. To modifying control system to adapt new changes on system.
3. The secondary air damper of the burner should be opening during burner starting.
4. To add new configuration for primary air system on the existing DCS and also MMI Graphic modification on DCS.

1.4 Objectives

- To get economic effect of the air supply has cause the optimizing of fuel consumption.
- To add fuel flow measurement in each burner for observation.
- To add air pressure measurement in each burner for observation.
- To minimize the abnormal sound and vibration of the boiler.
- To Adjusting air/fuel ratio to guarantee proper combustion.
- To enhance of the flame shape.
- To decrease exhaust gases temperature.
- To Plenary combustion.

1.5 The project Scope

The main goal is to study and evaluate the new boiler air supply system and its efficiency in term of flame shape and exhaust gases temperature and decreasing vibration when the damper opening . Additionally, modifying control system to adapt new changes on system.

1.6 Methodology

The new PA fans added for balance the air supply at the middle of secondary burner gun

- In the boiler startup the primary Air fans [PA] fans are run automatically when the Forced Draught fans [FD] fan start in the sequence starting and it well stop when boiler load is more than 50% MCR and open the bypass damper of PA fan to supply the air to burners.
- The control damper adjusting primary air supply depending on the different pressure between the furnace and the primary air duct.
- The set point of control damper or frequency has two statuses

1. AUTO mode the damper position adjusted command and frequency convertor command are following the differential pressure between the duct and furnace.
2. MAN mode the damper position adjusted command and frequency convertor command be by Operator keypad

- Process logic configures in existing DCS to adapt air fuel ratio.
- New configuration for primary air system MMI Graphic modification on DCS.

1.7 Research Layout

- Chapter One: Introduced the general overview, the problem that solved by it and the objectives that will going to be achieved
- Chapter Two: Is about the boiler definition, types of the boiler, main cycles system of the boiler, boiler principle work and firing types, boiler instrumentation and control system, boiler safety issues , combustion air supply control and air to fuel ratio control
- Chapter three: Is about control and operation of the boiler demo of KNPS PH3 control system version GE OC4K6.3 with the virtual controller VDPU, primary air system configuration and mimic creation and modification.
- Chapter four: Is about the result and shows the comparison of firing before adding the primary air fans and after adding the primary fans
- Chapter Six: Conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Boilers are pressure vessels designed to heat water or produce steam, which can then be used to provide space heating and/or service water heating to a building. In most commercial building heating applications, the heating source in the boiler is a natural gas fired burner. Oil fired burners and electric resistance heaters can be used as well. Steam is preferred over hot water in some applications, including absorption cooling, kitchens, laundries, sterilizers, and steam driven equipment [5].

2.2 Boiler definition

Boiler is a device that used to transfer the chemical power energy to thermal power energy see following figure illustrating that.

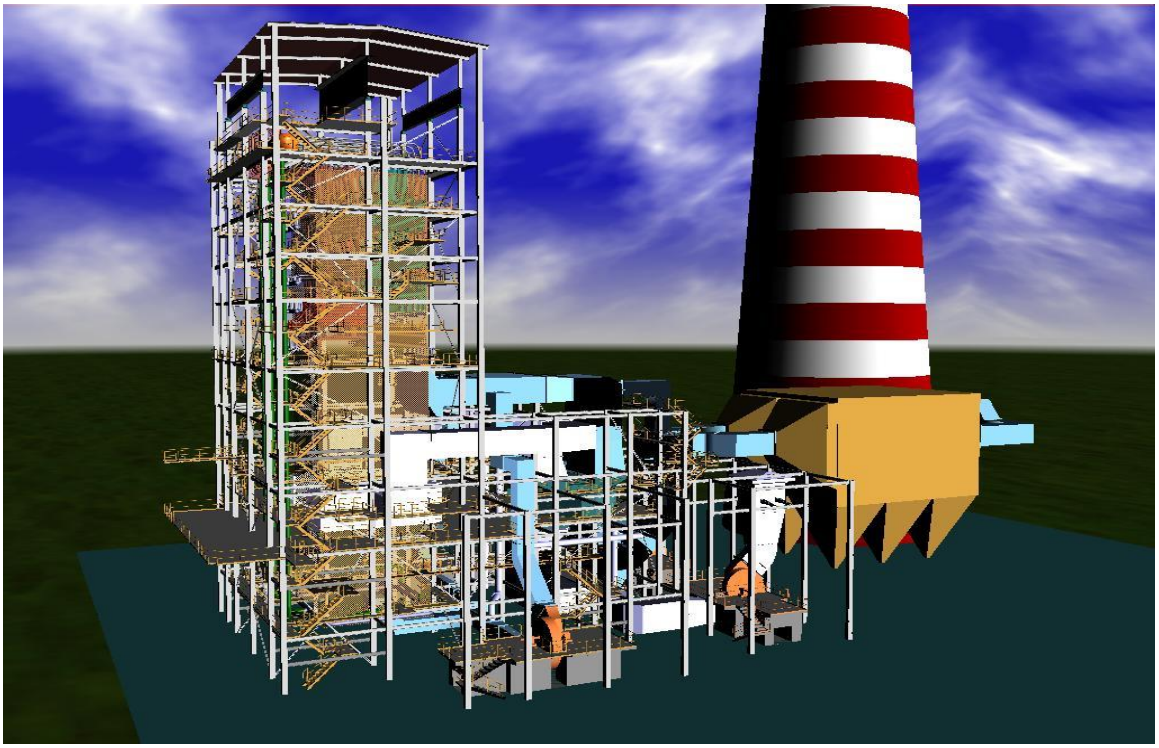

Figure (2-1) Power Plant Boiler

Another definition*:*

Boiler is pressure vessel designed to heat water or produce steam, which can then be used to provide space heating and/or service water heating to a building.

In the power plant boilers are the device that used to transfer the chemical power energy to thermal power energy. That means combustion inside the furnace and steam production through the feed water in boiler tubes [6].

2.3 Boiler types

There are many types of boilers manufacturing depend on the different function

2.3.1 Boilers According to Function

Boilers are designed for different applications in industrial and multi uses function. Boilers can be designed for two functions

- Hot water production
- Steam production.

Industrial boilers will always be used for steam production, which is a vital resource for different industrial applications such as turning turbines for power generation and heating kilns in cement plants.

2.3.2 Primary types of industrial boilers are:

In industrial field boilers classified into

- **Fire tube boiler**

In this type hot gases of combustion flow through a series of tubes surrounded by water see following figure (2-2) illustrating that.

- **Water tube boiler**

In this type water flows inside the tubes and then hot gases from combustion flow around the outside of the tubes see following figure (2-3) illustrating that.

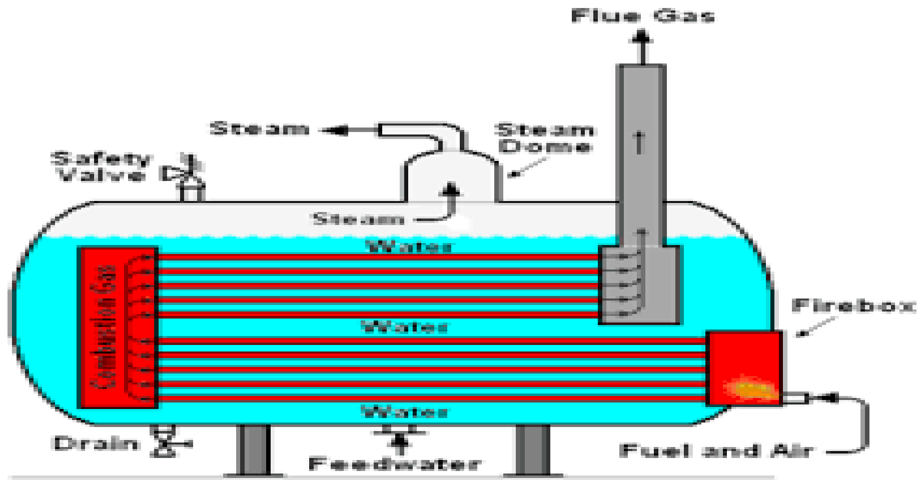

Figure (2-2) Fire tube Boiler

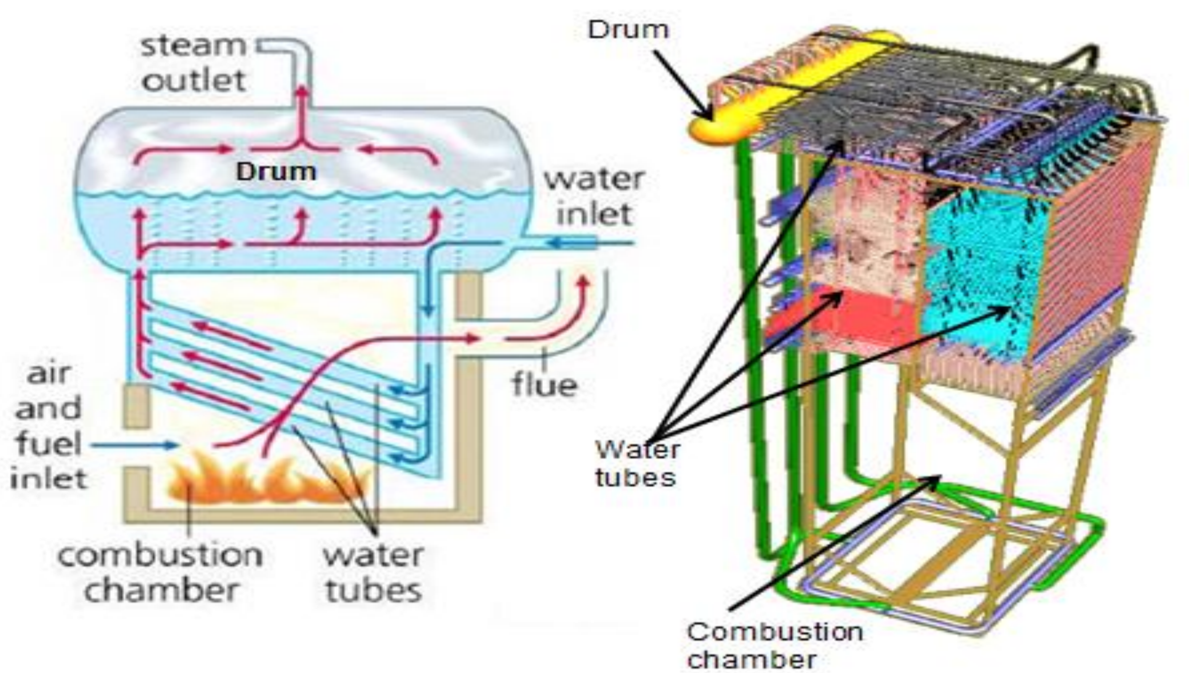

Figure (2-3) Water tube Boiler

2.3.3 Classified in to different types based on the work

Boilers also working in different base depend on the following item [7]:

- **Pressure and temperature**

Boilers are classified as either low pressure or high pressure for operating water temperatures and power generation.

- **Fuel type**

Some boilers are designed to burn more than one fuel, multi fuel boilers provide the operator with fuel redundancy in the event of a fuel supply interruption.

- **Draft method**

The pressure difference between the boiler combustion chamber and the flue produces a draft which carries the combustion products through the boiler and up the flue, where air is forced into the combustion chamber by a fan or blower to maintain a positive or negative pressure

- **Size and capacity**

There are small boilers in size and capacity variety of configurations to utilize limited space or to accommodate the equipment and large single boilers with large capacities

- **Condensing Method**

The traditional hot water boilers operate without condensing out water vapor from the flue gas. This is critical to prevent corrosion of the boiler components. Condensing boilers operate at a lower return water temperature than traditional boilers while condensing boilers generally operate in the range of 88% to 95% combustion efficiency

2.4 Boiler cycles

Mainly the entered fluids and outgoing fluids for boilers mentioned below

- Feed water cycle system, is the purification water feeding to boiler for steam product from the demineralization water through pumps.

- Supply air cycle system, is weather air that recant to the boiler through fans.
- Fuel oil cycle system, is the firing oil pumping from oil storage tanks according to the specific parameters
- Steam cycle system, is the product steam using for rolling the turbine and other application
- Flue gas cycle system is gases after firing and taken out with satisfaction of the environment through the chimney.
- Ignition system is a igniter for burner startup fire by using electrical spark and Liquefied Petroleum Gas.

2.5 Boiler firing element

The firing systems basically depend on three element fuel, air, and heat as show in the figure (2-4).

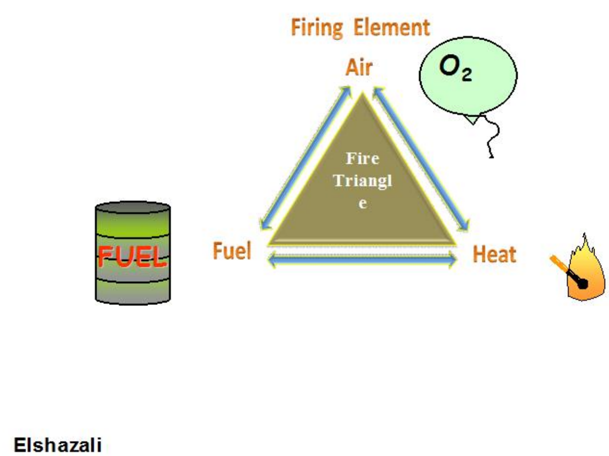

Figure (2 – 4) Fire element

2.5.1 Fuel

Many different solid, liquid, and gaseous fuels are fired in boilers. Sometimes, combinations of fuels are used to reduce emissions or improve boiler performance. Fuels commonly fired in boilers include fossil, and biomass as well as other types of fuels and fuel combinations

2.5.2 Air

The air is supplied from the atmosphere by fans and it is a main element for combustion; Combustion air is the air drawn through the firebox by the draughting system which allows combustion to take place. Only the oxygen content of the air (approx. 18%) is used in the combustion process, the remainder mostly nitrogen). Combustion air is divided into four types depending upon its role and the design of the particular burner.

2.5.3 Heat or Ignition

There are two type for an ignition system sequence direct spark ignition DSI and hot surface ignition HSI both of them are widely applied, DSI is generate a spark from high voltage charge occurs electrical arcs in an electrode to ignite a PLG gas-air mixture make ignition flame , but HSI it depend on heats or high temperature device.

2.6 Boilers principle of Work

Both gas and oil fired boilers use controlled combustion of the fuel to heat water. The key boiler components involved in this process are the burner, combustion chamber, heat exchanger, and controls.

The burner mixes the fuel and oxygen together and, with the assistance of an ignition device, provides a platform for combustion. This combustion takes place in the combustion chamber, and the heat that it generates is transferred to the water through the heat exchanger. Controls regulate the ignition, burner firing rate, fuel supply, air supply, exhaust draft, water temperature, steam pressure, and boiler pressure [8].

Hot water produced by a boiler is pumped through pipes and delivered to equipment throughout the building, which can include hot water coils in air handling units, service hot water heating equipment, and terminal units. Steam boilers produce steam that flows through pipes from areas of high pressure to areas of low pressure, unaided by an external energy source such as a pump. Steam utilized for heating can be directly utilized by steam using equipment or can provide heat through a heat exchanger that supplies hot water to the equipment.

2.7 Types fired furnaces

In modern power plants fired boilers have mainly furnaces with membrane walls and major heat transfer is due to radiation. The main criteria is location of burners on the boiler as follow:

- **Wall-fired furnaces**

With swirl burners, located at the front, back or side wall of the furnace

- **Corner-fired furnaces**

With jet-burners, located mostly at corners, sometimes at walls of the furnace

- **Roof-fired furnaces**

With jet-burners, located at the roof of the furnace

The following figure (2 - 5) show the corner burner and wall burner during fire

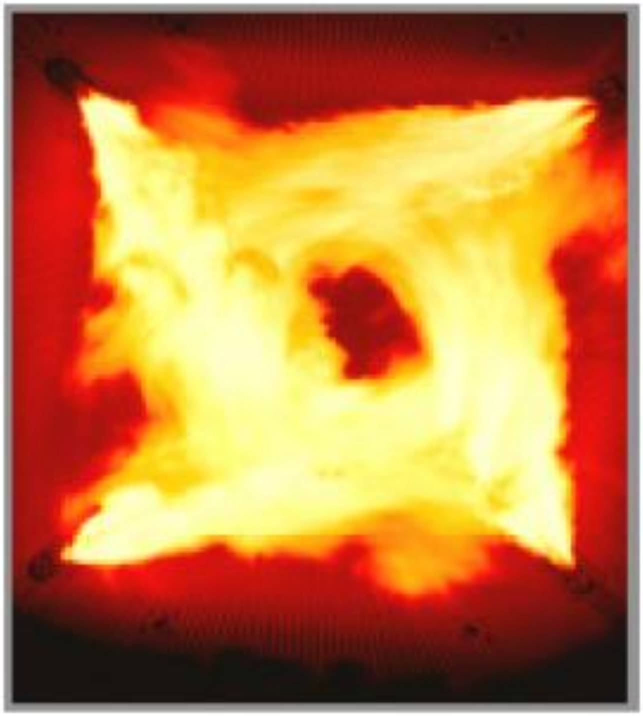

Figure (2 - 5 a) Corner burners

Figure (2 - 5 b))Wall burners

2.8 Boiler efficiency

Boiler efficiency is measure performance of the boilers depending on the effective of different element and their condition.

2.8.1 Combustion Efficiency

Combustion efficiency is an indication of the burner's ability to burn fuel. The amount of unburned fuel and excess air in the exhaust are used to assess a burner's combustion efficiency. Burners resulting in low levels of unburned fuel while operating at low excess air levels are considered efficient. Well-designed conventional burners firing gaseous and liquid fuels operate at excess air levels of 15% and result in negligible unburned fuel. Well-designed ultra-low emissions burners operate at a higher excess air level of 25% in order to reduce emissions to very low levels [9].

2.8.2 Thermal Efficiency

Thermal efficiency is a measure of the effectiveness of the heat exchanger of the boiler. It measures the ability of the exchanger to transfer heat from the combustion process to the water or steam in the boiler.

The term "boiler efficiency" is often substituted for thermal efficiency or fuel-to-steam efficiency. When the term "boiler efficiency" is used, it is important to know which type of efficiency is being represented, fuel to-steam efficiency, which does account for radiation and convection losses, is a true indication of overall boiler efficiency. The term "boiler efficiency" should be defined by the boiler manufacturer before it is used in any economic evaluation [9].

2.9 Boiler Instrumentation and Control

Mainly the instruments are used for measuring, control and protect any system, also for operation observation

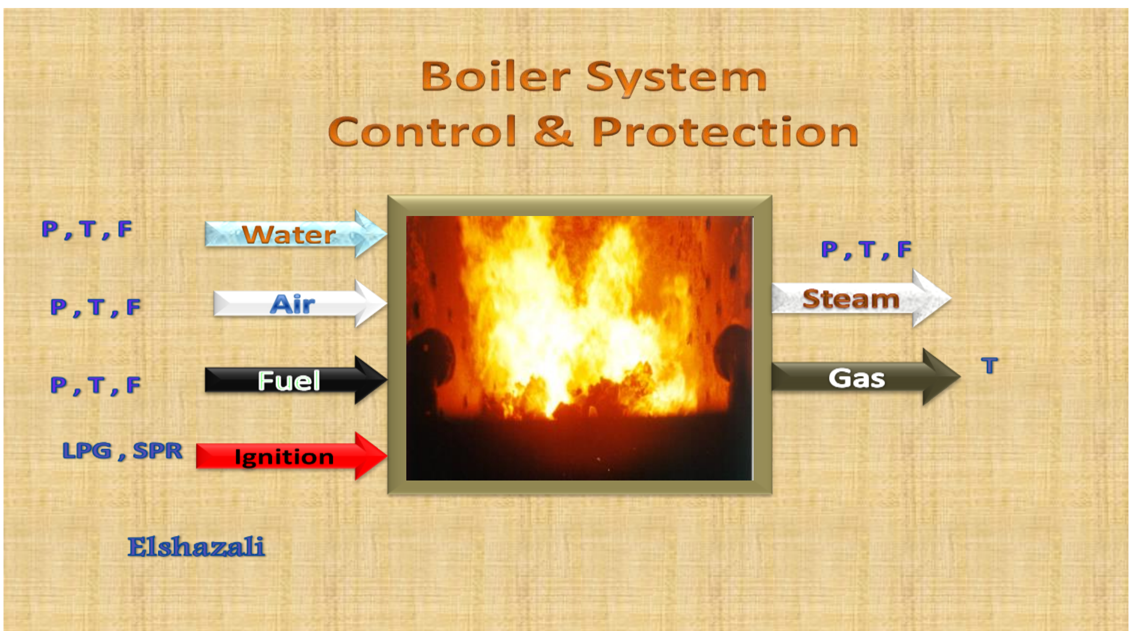

Figure (2- 6) boiler fluids cycles

Boiler fluids cycles to be under control and operation observation are flow:

a. Feed water cycle system
b. Supply air cycle system
c. Fuel oil cycle system
d. Steam cycle system
e. Flue gas cycle system
f. Ignition system

The operation people can observe pressures and temperatures of the boiler and also increase or decrease the demand of the fluids flow according to boiler situation.

2.9.1 Instrumentation of the Boiler

- ***Instrumentation*** is a branch of engineering which deals with measuring devices. The mechanical devices called local gauges and the electronic devices called sensors of the boiler, sensors are reflecting the situation in the boiler by converting the physical quantity to electrical signal and send it to the control system. Now a day there are smart and Intelligent, this type composes of sensor and programmable module [10].
- ***The measuring signals*** in boilers are
  a. Temperature measurement signals
  b. Pressure measurement signals
  c. Level measurement signals
  d. Flow measurement signals
  e. Oxygen analyzer signals

Figure (2-7) mechanical measuring devices on the boiler

Figure (2-8) sensors installing on the boiler

- ***Temperature measurement signals***

The wildly common used for temperature measuring are Resistive temperature detectors RTD and Thermocouples TC and there are analog or continuous signals.

a. Resistive temperature detector RTD

is capitalize on the fact that the electrical resistance of a material changes as its temperature changes, it will convert the resistance to mill amperes (R → mA) many type of RTD (Pt 100 two wire, three wire used in our objective) and it used to measure temperature of the sensitive equipment less than 400°C

b. Thermocouple TC

is two wire devices, the junction of two dissimilar metals which has a voltage output proportional to the difference in temperature between the hot junction and the lead wires, it will convert the voltage to mill amperes (V → mA cold junction Type K used in our objective) and it used to measure higher temperatures equipment more than 400 C°

c. The temperature switches

They are used as a digital or ON / OFF signal, it will act when temperature reaching to a set point.

a. Many unit used for measuring temperature as Kelvin, Fahrenheit and Celsius unit in our objective is Celsius unit (C°)

- **Pressure measurement signals**

a. Pressure

is the force applied perpendicular to the surface of an object per unit area over which that force is distributed, wildly common used for pressure measuring are diaphragms transmitters , it generate voltage between the diaphragm by changing the capacitance of plates and convert it to mill amperes ($V \rightarrow mA$) analog or continuous signals

b. Static pressure

Measurements are independent of direction in an immovable fluid and the dynamic pressure this directional component of pressure in a moving fluid.

c. Absolute pressure

Is zero - referenced against a perfect vacuum, using an absolute scale, so it is equal to gauge pressure plus atmospheric pressure.

d. Gauge pressure

Is zero - referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure negative signs are usually omitted.

e. The pressure switches

Are used as a digital or ON / OFF signal, it will act when pressure reaching to a set point.

f. The following devices used in our objective for measuring pressure in Bar and mbar.

- ✓ Pressure Gauges
- ✓ Draft Gauges
- ✓ Pressure Switches
- ✓ Pressure Transmitters
- ✓ Diaphragm seal transmitters
- ✓ Differential pressure instruments

❖ Level measurement signals

Level measurement devices can detect, indicate, and help for control the liquid or solid levels in vessels and it can be separated into two categories: direct, or mechanical, measurement and electronic measurement, level measurement devices can be used for continuous monitoring of fluid level. Most units using for level measurement is meter and millimeter. Types of level measuring devices

a) Reflex Flat Gauge Glass
b) Transparent Flat Gauge Glass
c) Magnetic Float
d) Float Switch
e) Torque Tube Displacer
f) Displacer Switch
g) Bubbler Tube
h) Hydrostatic Head Example / Differential Pressure
i) Ultrasonic

Figure (2-9) different level sensors for boiler

❖ **Flow measurement signals**

a. Flow measurement is the quantification of bulk fluid movement. Flow can be measured in a variety of ways. Positive-displacement flow meters accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow.

b. Many types of flow meters

- ✓ Mechanical flow meters (Piston meter)
- ✓ Pressure-based meters (Orifice plate)
- ✓ Optical flow meters
- ✓ Thermal mass flow meters
- ✓ Vortex flow meters
- ✓ Sonar Flow Measurement
- ✓ Electromagnetic , Ultrasonic and Coriolis flow meters

c. In our objective we used thermal mass flow for fuel measurement, thermal mass flow meters generally use combinations of heated elements and temperature sensors to measure the difference between static and flowing heat transfer to a fluid and infer its flow with a knowledge of the fluid's specific heat and density, for steam and air measuring we used Pressure-based meters Orifice plate , for water measurement electromagnetic and ultrasonic flow meter.

5. Oxygen analyzer signals

a. Is an electronic device that measures the proportion of oxygen (O2) content in the b oiler flue gas. In an oxidizing atmosphere more oxygen is available as necessary for complete combustion of all combustible components existing in the gas volume.

b. In our objective it used to measure the exhaust gas concentration of oxygen for boiler combustion and used also hypoxic air fire prevention systems to monitor continuously the oxygen concentration inside the protected volumes. Reducing atmosphere less oxygen is available as necessary to burn all combustibles [11].

Figure (2-10) Oxygen analyzer sensor and controller

2.9.2 Boiler Control system

Control system is branch of engineering which deals with directing or regulating of physical parameters (processes) of plant, monitor and control of the boiler system according to the signals measured by instrument from the boiler field.

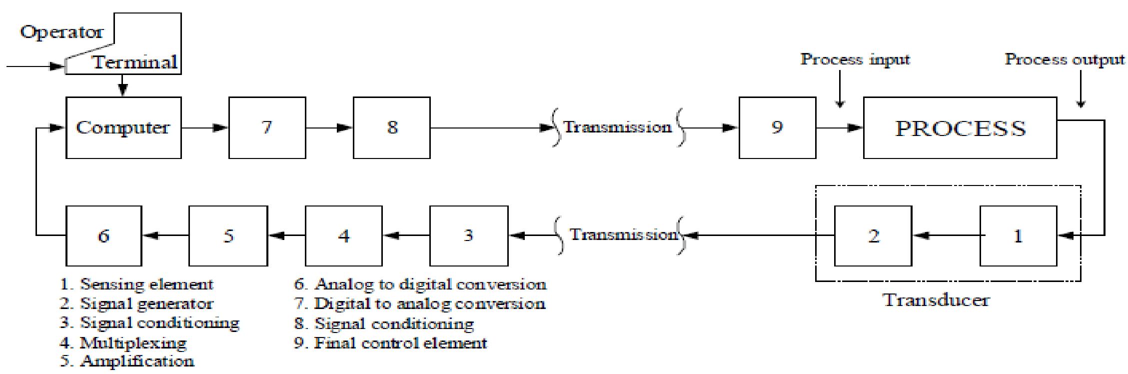

Figure (2-11) Control loop

The firing boilers used controlled combustion of the fuel to heat water. The key boiler components involved in this process are the burner, combustion chamber, heat exchanger, and controls

The burner mixes the fuel and air together and, with the assistance of an ignition device, provides a process of combustion. This combustion takes place in the combustion chamber, and the heat that it generates is transferred to the water through the heat exchanger. Controls regulate the ignition, burner firing rate, fuel supply, air supply, exhaust draft, water temperature, steam pressure, and boiler pressure.

The control system which is used in our objective is DCS system OC4K6.3 from GE Company

2.9.3 Distributed Control System DCS

Generally, the concept of automatic control includes accomplishing two major operations; the transmission of signals (information flow) back and forth and the calculation of control actions (decision making). Carrying out these operations in real plant requires a set of hardware and instrumentation that serve as the platform for these tasks. Distributed control system (DCS) is the most modern control platform see figure (2-12). It stands as the infrastructure not only for all advanced control strategies but also for the lowliest control system. The idea of control infrastructure is old. The next section discusses how the control platform progressed through time to follow the advancement in control algorithms and instrumentation technologies [3].

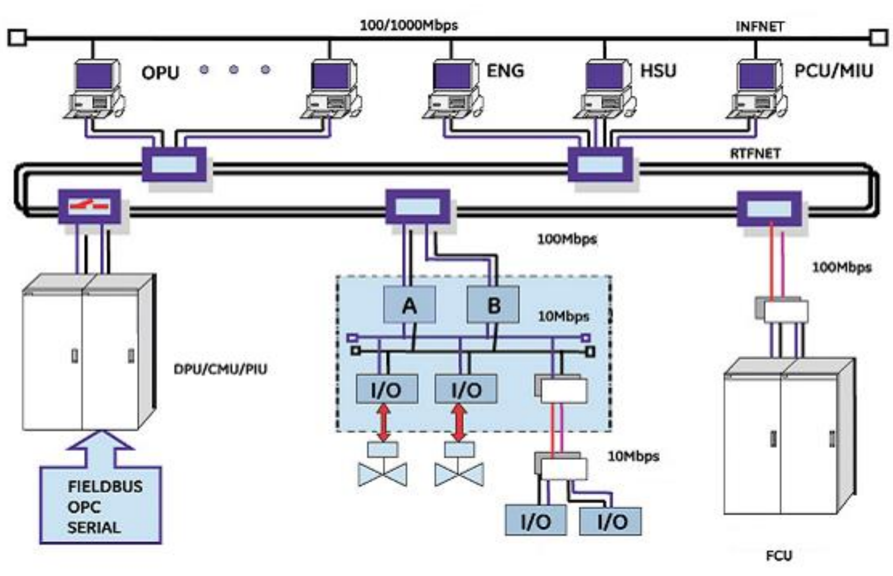

Figure (2 - 12) DCS architectural

❖ DCS Hardware components

The hardware component can separated in three main part

- **Process Control System PCS is part include**
  a) Distributed process unit DPUs , I/O station , BC net
  b) Field Control System FCS
  c) Communication interface to connect DCS with other system
  d) Power supply DC and AC
- **Network system (use Ethernet)**
  a) Real time network use to connect the operation management with process control system to operate the devices and processing
  b) Information network use just for monitoring the information not for operation
- **The operation management system: include**

  Computer work stations are divided in different user levels as follow
  a) Engineering work station
  b) Operator work station
  c) Historical data station
  d) Calculation unit
  e) Gate ways
- **Hardware Configuration**

  The configuration and interfacing will be via serial port as follow
  a) RS232/485 , through COM interface port in PC or Multi COM port Server, such as: NPort device
  b) Ethernet cable UTP version Cat 6 through RJ bulge

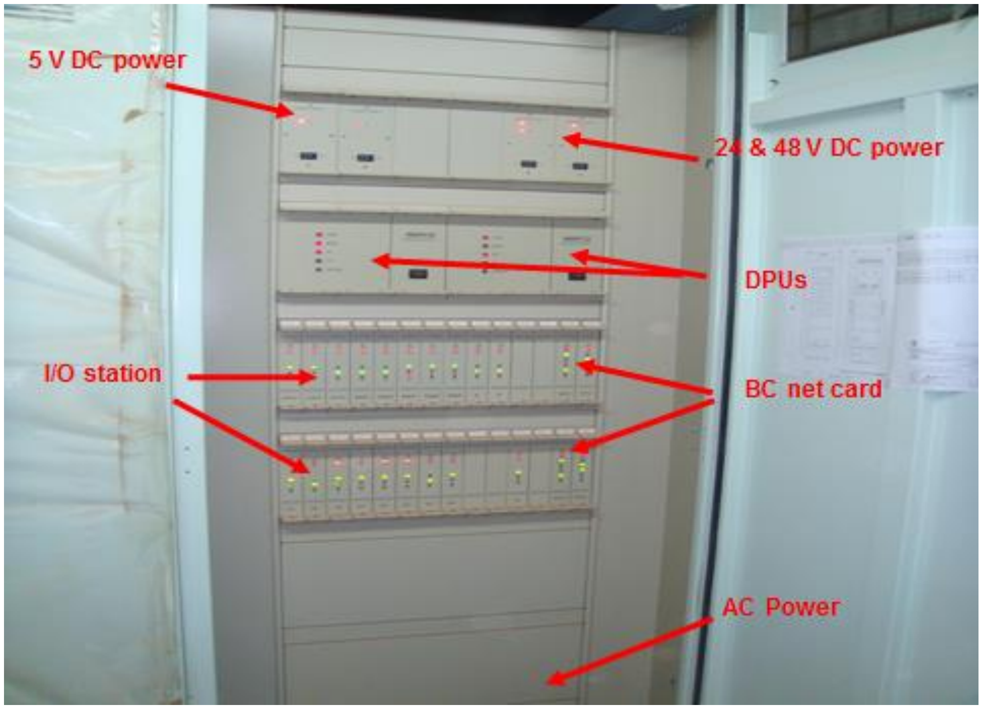

Figure (2 -13) Hardware DCS – control cabinet

- **DCS Software components**

MMI man machine interface from is part the operator can process and control the plant , interface software for connecting the DCS system and DCS with other system or DAS , PLC system in remote site, see figure (2-14)

- **Communication Protocol**

  In DCS the main communication protocol are used:

  a) MODBUS
  b) ETHERNET
  c) OPC,
  d) FIELDBUS, PROFIBUS
  e) VDPU, Virtual DPU technology to map local channel or local module of PLC, to that of XDPS in VDPU

- **DPU software** for configuration the logical programs and control with powerful Process Control and Process Capability as flow

a) Data Acquisition

b) Continuous Control

c) Logic Control

d) Sequence Control

e) Batch Process

f) Advanced Control Algorithm

g) User-Defined Block

- **Straight-Forward Control Configuration**

  a) What You See is What You Have

  b) Online Modification and Adjustment

  c) Design to meet IEC1131-3

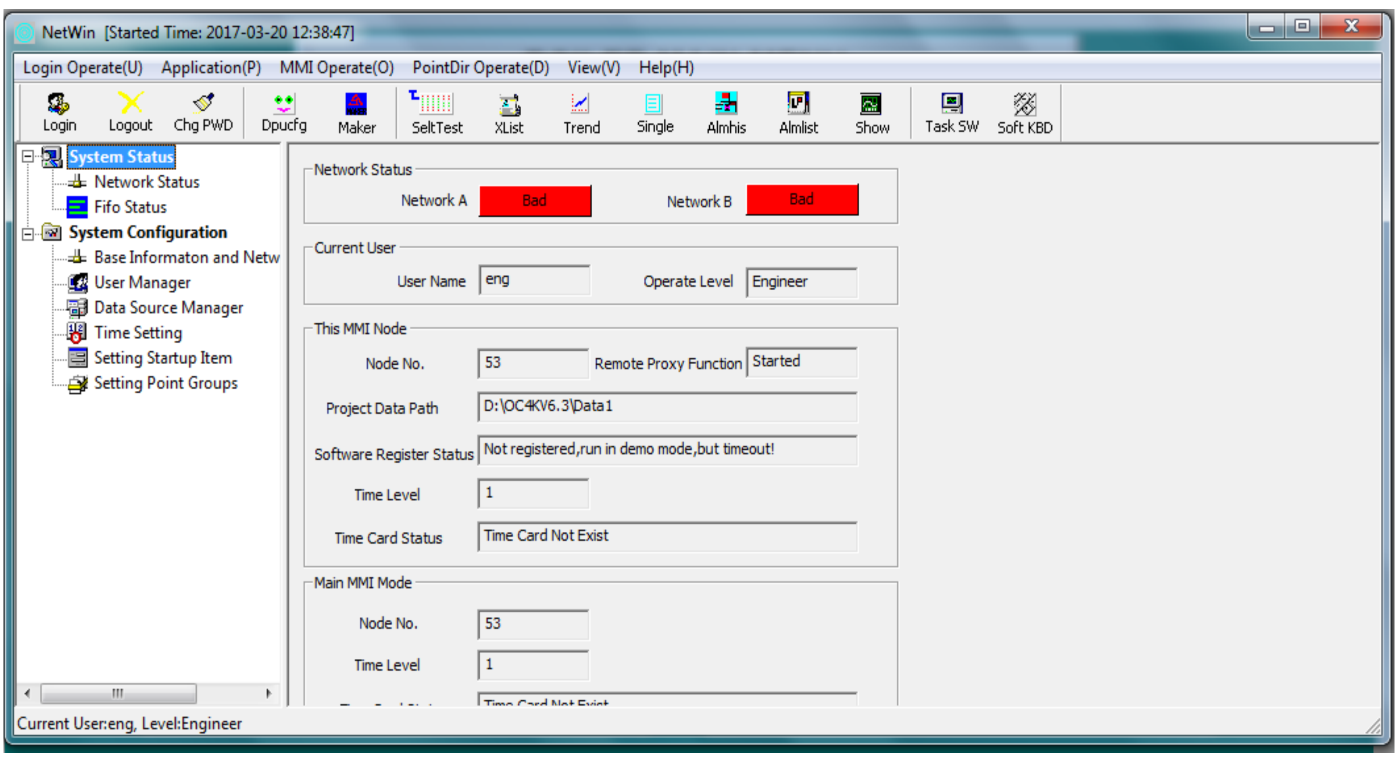

Figure (2-14) DCS software Net Win OC4KV6.3

The main DCS software tools bar include DPU configure, Maker, Trend, Alarm, Show , setting startup of the programs, setting point groups and time setting and also data and users management.

❖ Furnace Safeguard Supervisory System (FSSS)

The FSSS is also known as Boiler Management System BMS.

The figure No (2 - 15) show the FSSS Operating monitor FSSS a part of DCS designed to ensure the execution of a safe, orderly operating sequence in the startup and shutdown of boiler firing equipment and to prevent errors of omission and commission in following such a safe operating procedure.

The system provides protection, should there be a malfunction of fuel firing equipment and associated air systems. The safety features of the system are designed for protection in most common emergency situations. However the system cannot supplement the intelligence and the reasonable judgments of the operator in all the situations.

Fig (2-15) FSSS – man machine interface

In some phases of operation the Furnace Safeguard Supervisory System provides permissive interlock only to ensure safe start up sequence of equipment. Once the equipment is in service, the operator must use normally acceptable safe operating practices.

It is important that the operator is familiar with the overall operation of the unit and the operation of individual equipment as outlined in the various equipment sections of operating and instruction manual [2].

It is essential that all parts of the Furnace Safeguard Supervisory System are in service at all times, if the system is to provide protection for which it is designed. Proper maintenance and periodic inspection of the system and associated hardware is essential for continued reliable operations.

This instruction section of the system gives a complete description of the Furnace Safeguard Supervisory System furnished for this unit as it is related to the various operating phases and operation of the fuel firing equipment and associated air systems.

Basically the system is designed to perform the following functions [2]:

1. Prevent any fuel firing unless a satisfactory furnace purge sequence has first been completed.
2. Prevent start-up of individual fuel firing equipment unless certain permissive interlock has first been satisfied.
3. Monitor and control the proper sequence of operations during start-up and shutdown of fuel firing equipment.
4. Make continued operation of fuel firing equipment subject to certain safety interlock remaining satisfied.
5. Provide status feedback to the operator and in some cases, to the unit control system.
6. Provide flame supervision when fuel firing equipment is in service and affect a fuel trip upon certain adverse operating conditions.

7. Initiate a fuel trip when certain abnormal operating conditions

2.10 Boiler Safety Issues

1. All boiler combustion equipment must be operated properly to prevent dangerous conditions or disasters from occurring, damages in equipment and property loss. The basic cause of boiler explosions is ignition of a combustible fuels or gas that has accumulated within the boiler [7].
2. This situation could arise in a number of ways, for example fuel, air, or ignition is interrupted for some reason, the flame extinguishes, and combustible gas accumulates and is reignited.
3. Unsuccessful attempts at ignition occur without the appropriate purging of accumulated combustible fuels or gas.
4. Boilers must be inspected regularly based on manufacturer's recommendations [8].

2.10.1Boiler Protection Signals

When any one of the flowing signals occur during the boiler in service then boiler automatically trip or stop according to configuration and logic of signal[2]

1. All FD fans stopped
2. Drum level very high
3. Drum level very low
4. Pressure very high in furnace
5. Loss of all flames
6. Loss of all fuel
7. turbine tripped and Steam flow >30 t/h
8. Boiler air flow is low
9. Instrument cooling air Pressure is low
10. all rotary air heater motors stopped
11. Oil supply pressure is very low

12. Oil supply temperature is very low
13. Atomizing header pressure is very low
14. Air –Fuel ratio less than 9.5
15. Boiler Feed water Pump trip BFP
16. Reheat protection acted

2.11 Combustion air control

Combustion air is one the main element to come about firing and it must be maintaining in combustion chamber to give good fire commensurately with supply of fuel oil.

2.11.1 Combustion Control

The ideal combustion process during which a fuel is burned completely is called stoichiometric combustion .The efficiency of a boiler system is important in several ways. The constantly rising cost of fuel used means that by increasing the efficiency by several percent, substantial savings can be made on a yearly basis. By maximizing the amount of energy extracted from the fuel, not only does the fuel usage decrease and thereby reduce cost but it also has a significant effect on the emissions from the system [12]. Improving the efficiency of the combustion process can severely reduce the amount of harmful compounds; the following sub titles describe briefly about the combustion control ways.

See figure (2-16) illustrated what happen when air –fuel not rated according to the firing condition.

Figure (2- 16) boiler bad firing exhaust

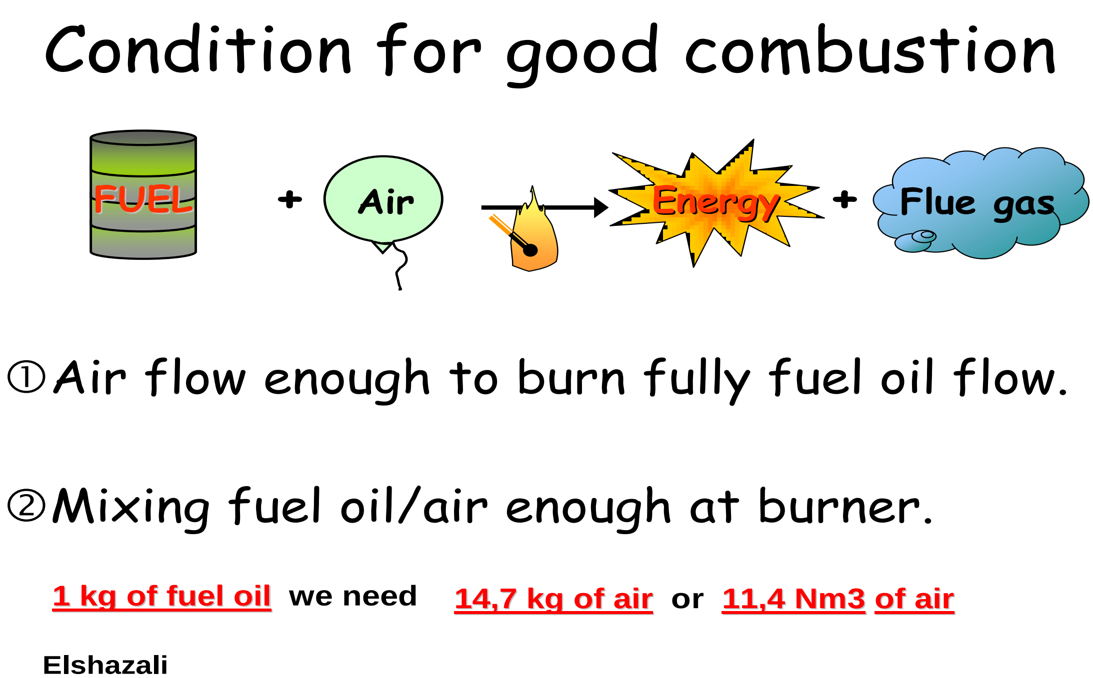

Figure (2 - 17) condition of combustion

❖ Control Schemes

A combustion control system for a boiler combines load control, air control and fuel control in order to ensure optimum and safe operation of the overall system**.** Parallel control systems provide separate controllers for fuel and air, and are therefore suitable for automated control (Controller Loops) [10].

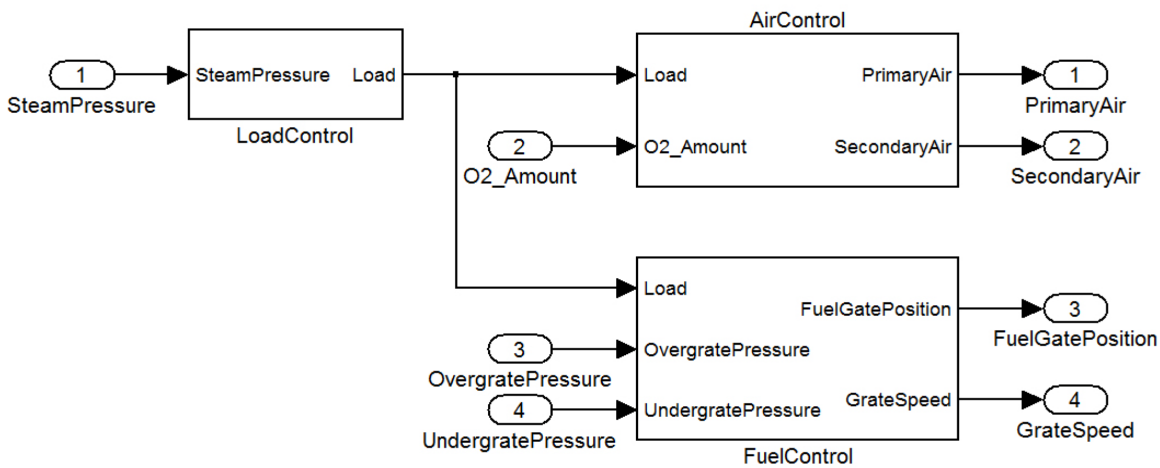

Figure (2 - 18) Block diagram of the overall control system

❖ Load Controller

The load controller calculates the set points for both the air and fuel controllers. The function of the load controller may differ somewhat depending on the size and setup of the boiler system [10].

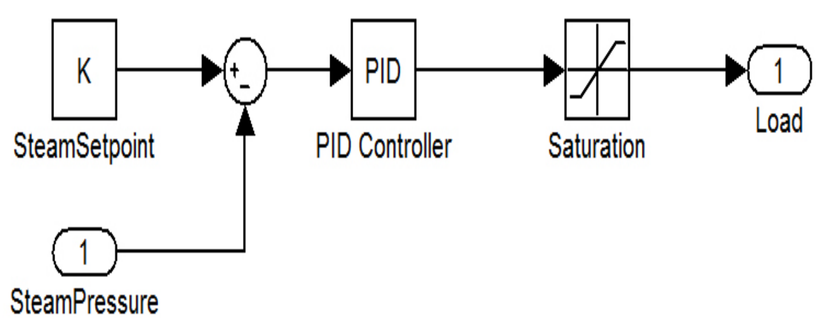

Figure (2 - 19) Block diagram of the load control system.

❖ Air Controller

The air technique is commonly used in the air flow is divided into primary air and over fire air. In practice it is impossible to maintain effective combustion using the exact stoichiometric amount of air [10].

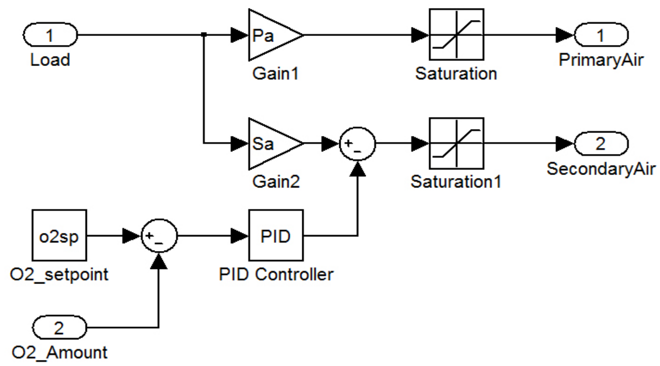

Figure (2 - 20) Block diagram of the air control system.

❖ Fuel Controller

Each fuel feed system needs specialized control signals to operate in such a way that optimum boiler performance is achieved. These controllers are usually rather simple in design, but vary slightly in complexity depending on the type of fuel [10]

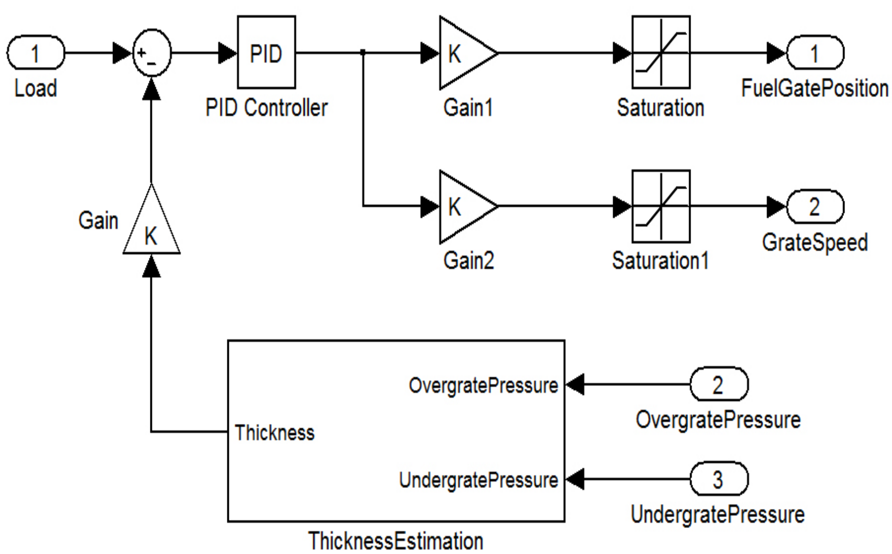

Figure (2 - 21) Block diagram of the fuel control system

- **Combustion control parameters**

From the description of the system several control parameters are evident. The air flow rate is controlled by varying the signal to the fans. The division of the air into zones could be automatically controlled, but in this case it is manually controlled. This is done because of the limited number of available outputs on the controller. Other control parameters also in include fuel parameters, The Oxygen O2 content in the flue is measured and steam parameters

Table (2-1) Air Control parameter

Signal	I/O	Type
Primary air flow rate command	Output	Analog
Secondary air flow rate command	Output	Analog
Primary air flow	Input	Analog
Secondary air flow	Input	Analog
Primary air fan speed	Input	Analog
Secondary air fan speed	Input	Analog
Inlet air temperature	Input	Analog
Guide Vane moving command	Output	Analog
Guide Vent moving position	Input	Analog
Oxygen O2 content	Input	Analog
Control damper command	Output	Analog
Control damper position	Input	Analog
Outlet flue gas temperature	Input	Analog

2.11.2 Combustion Air supply

Each boiler in the unit is provided with fan sets of single-suction centrifugal fans. Fans absorb air from entrance duct, and air is delivered to boiler furnace by overcoming resistance in the whole duct after it is boosted through the fan so as to provide air amount required by combustion. The diagram below shows connection mode of the fan in flue gas and air system. Air enters into the fans through muffler and dustproof filter screen. The outlets of the two fans connect to one header. The inlets and outlets of the fans are equipped with dampers, and the outlets are also equipped with steam air heaters in order to increase air temperature. The main function of inlet regulation damper of the fans is to cause airflow spin when power consumption of the fans. The air fans described in this manual is kind of single-absorption centrifugal air fans.

The fan comprises casing, impeller, main shaft, air inlet box, air intake and inlet adjustment valve etc. Casing encloses the shaft-mounted impeller which imparts energy to the gas and provides connections to the outlet ducts. The air inlet box is attached to the casing. The inlet adjustment valve is connected with the inlet of air inlet box. The inlet pipe is connected with the inlet adjustment valve. The air enters into the impeller via adjustment valve, air inlet box and air intake. The inlet adjustment valve adjusts the demanded air flow. The inlet adjustment valve is driven by the electric actuator via interlock rod

- **Primary air**

Primary air (PA) is supplied by one 100 % capacity centrifugal fan. Primary air fans fed the air to a burner to be mixed with oil or gas in the fuel stream or area ahead of the combustion zone in a burner. Primary air provides a percentage of the combustion air, but more importantly, controls the amount of fuel that can be burned. Primary air releases heat from the fuel. The primary airflow is controlled by primary air fan inlet vane. Primary air is one of the boiler interlocking quantities. MINIMUM _____ Nm3/s of primary air required by boiler interlocking must be supplied under the furnace grid, regardless of the control mode, to maintain stable combustion [4].

➢ Secondary air

Is air supplied to the combustion process to ensure each fuel molecule is completely surrounded by sufficient combustion air; the term excess air refers to the amount of air in the combustion process that exceeds the theoretical or stoichiometric amount. In practice it is impossible to maintain effective combustion using the exact stoichiometric amount of air. This is due to several reasons, for example the fact that burners are unable to mix air and fuel completely. Each type or design of burner and furnace has a specific optimum level of excess air which often is highly dependent on the type of fuel used. Controlling the amount of excess air is one of the most effective methods for improving boiler efficiency. If the amount of excess air is not correctly controlled however, the result can be severely reduced energy efficiency [6].

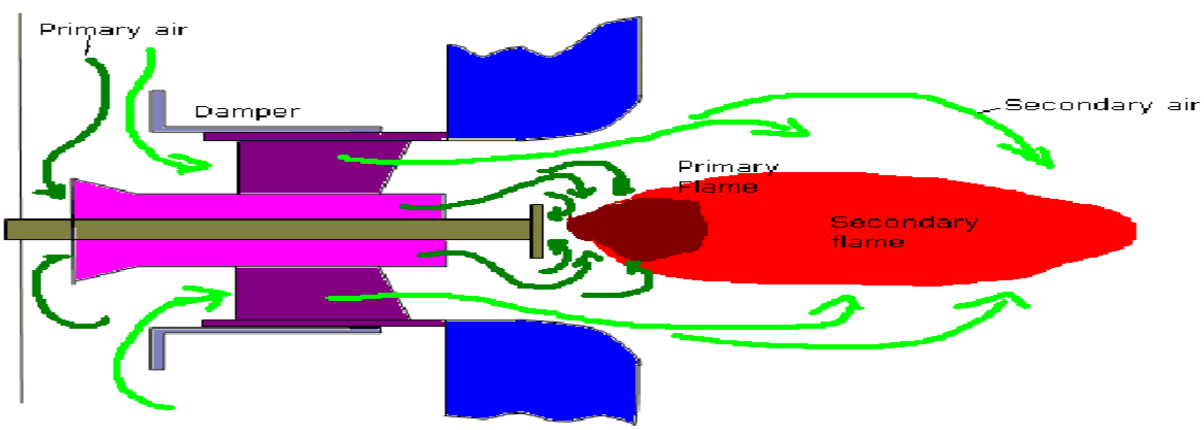

Figure (2-22)Combustion air at the burner

➢ Excess air

In a real process this ideal oxygen volume is not sufficient for complete burning because of insufficient mixing of fuel and oxygen. The combustion process, therefore, must be supplied with more than the stoichiometric volume of oxygen. This additional amount of combustion air is called excess air and the ratio of the total air volume to the stoichiometric air volume is the excess air value ex.air; another expression for that is _ (lambda) see figure (*2-23*). Consequently the highest combustion efficiency is achieved with a (limited) excess volume of oxygen, i.e. ex.air >1 (oxidizing atmosphere). The excess air value is of great importance for an optimum combustion process and economic plant operation [12].

Unnecessary high excess air volumes reduce combustion temperatures and increases the loss of energy released unused into the atmosphere via the hot flue gas stream.

• With too little excess air some combustible components of the fuel remain unburned. This means reduced combustion efficiency and increased air pollution by emitting the unburned components to the atmosphere

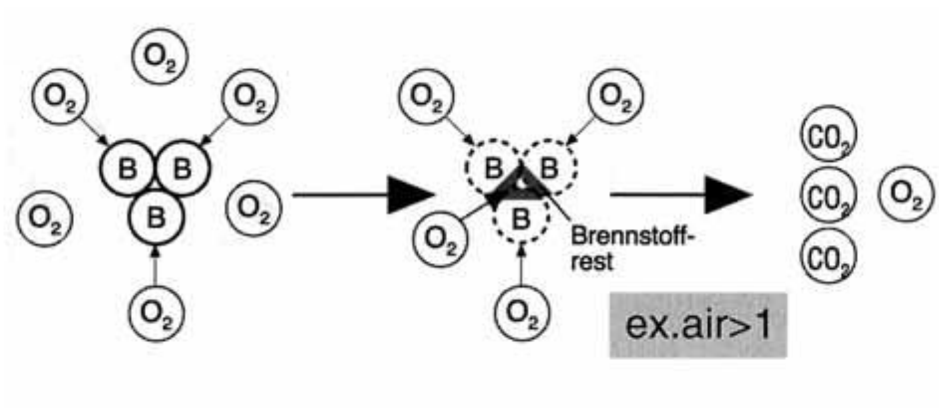

Figure (2 -23) Excess air combustion model

For calculation of the excess air value from the measured values of CO2 or O2 the following two formulas may be used:

$$\lambda = \frac{CO_{2\,max}}{CO_2}$$ ---------------------------- Equ (2 - 1)

$$\lambda = 1 + \frac{O_2}{21 - O_2}$$ ---------------------------- Equ (2 - 2)

- **Cooling and Sealing air**

Air improves combustion efficiency by promoting the fuel to burn completely. Power burners generally do not require secondary air. However, air leaking in through access/clean out doors, burner mounting flanges, boiler sections, etc., dilutes the flame and flue gas temperatures, reducing operating efficiencies as well as our ability to accurately monitor combustion conditions.

- **Dilution air**

Is that air mixing with flue gases in a draft hood or regulator, does not participate directly in the combustion process and is primarily required to attempt to control stack draft and reduce the likelihood that moisture in the flue gases will condense in the vent system --- which directly influences combustion air intake, safety and efficiency

- **Air flow**

The total airflow includes combustion air, infiltration air, and dilution air; there are three important factors to airflow equalization among the burners

1. The primary air has to be kept at the minimum required level with designed excess air level
2. The secondary and tertiary air combined together enter the individual burner, and this needs to be equal between all burners

3. The proportioning of secondary and tertiary air is done within the burner and also needs to be equal in all burners but the setting can change slightly depending upon the variation in burners due to manufacturing tolerances.

Air flow and air pressure are assist to carried fuel into the furnace, so when the air flow suddenly increases, which is driven by fuel demand, it takes extra amount into the furnace before the required extra the result is air – fuel ratio value effect , boiler sound high and vibration increasing [5] .

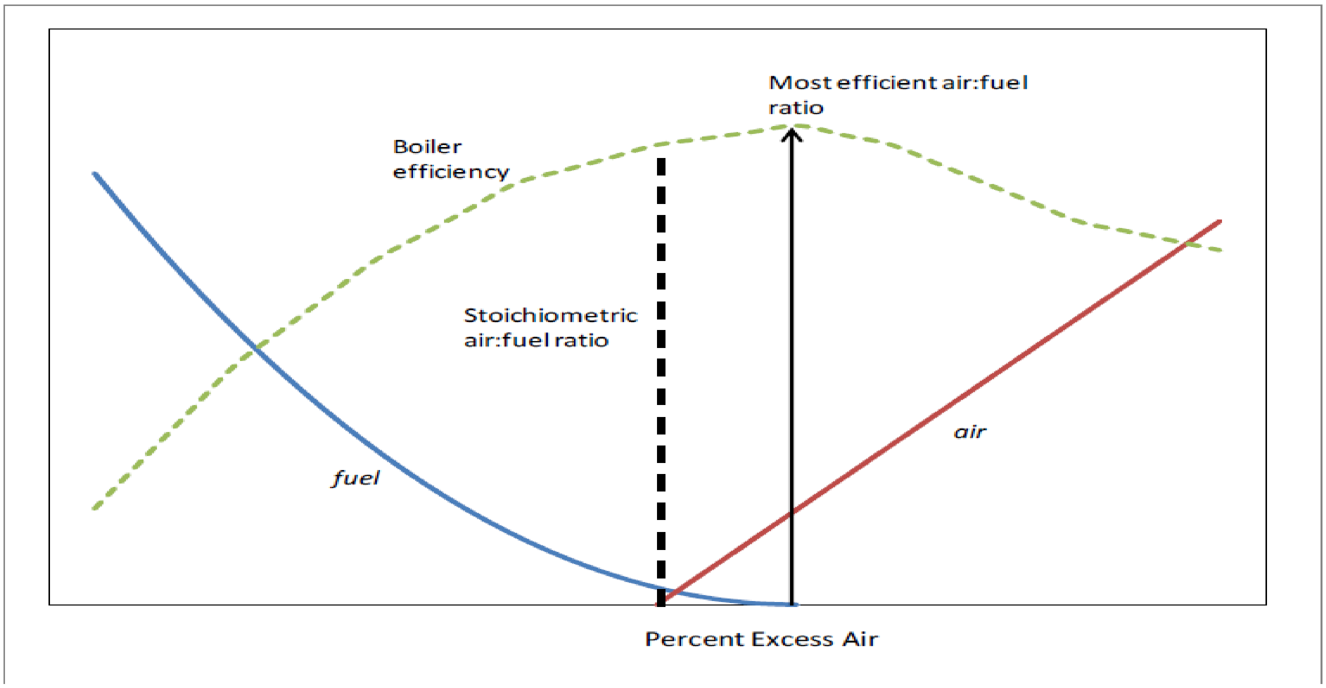

Figure (2-24) excess air and fuel curves

CHAPTER THREE

AIR SYSTEM MODIFICATION

3.1 Introduction

While selecting the various elements for the instrumentation care should be taken to select the correct range. A well-engineered system / configuration play a major role in the availability of the instruments. Staffing of the sugar plant maintenance crew with trained and qualified instrument mechanics is essential for calibration and maintenance of the equipment.

On the air system of the boiler unit #5 in KNPS we do some modification by adding new primary air system which enhances the shape of flame. The primary air system include a new primary air duct 65.3m , two fans, one ON/OFF damper and one control damper all off them controlling from DCS. Supply source of PA fan is 2x downstream main FD fans. The following figure shown boiler side burners

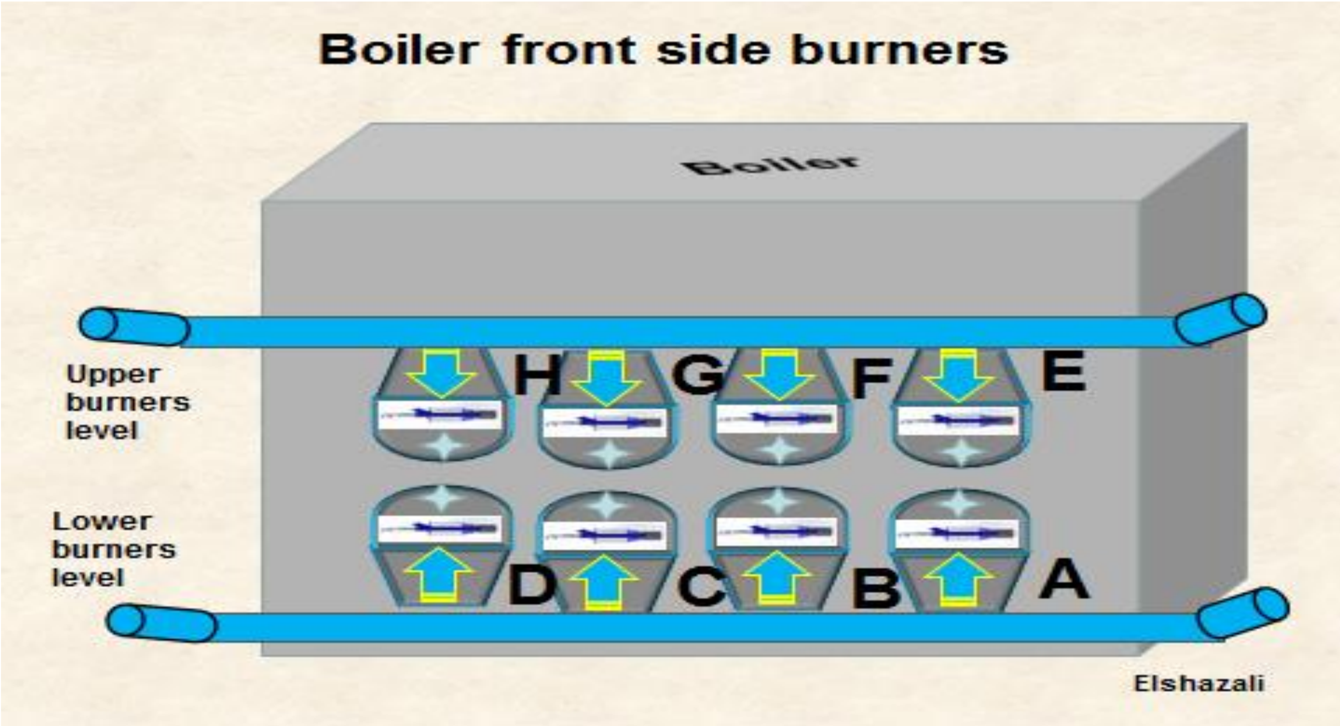

Figure (3 – 1a) Wall-fired burners – front side Sketch

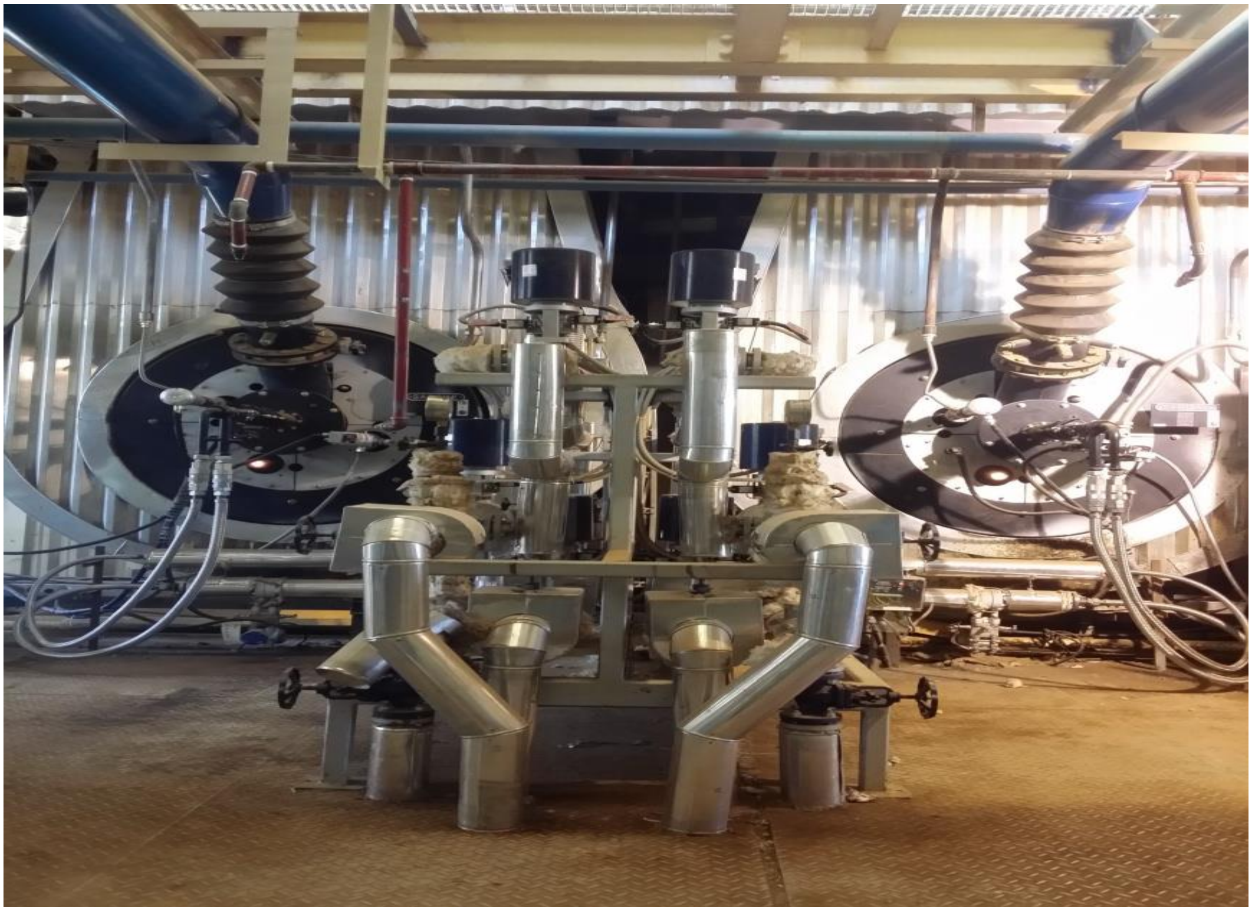

Figure (3 – 1b) Wall-fired burners – front side

Primary air system specification in the flowing table

Table (3 -1) Primary air system speciation

Technical Data_Primary air supply		
1	Number of FD fans	2
2	Installation	outdoor
3	Primary combustion air temperature:	20…40 °C
4	Primary air flow max	28.000 Nm³/h
5	Primary air flow max (at 35°C)	32.000 m³/h
6	Stat. pressure increase	20 mbar
7	Motor	30 kW, IP54, ISO F

3.2 Mechanical erection

The mechanical erection is fixing the duct and fans in the planed space with supporting beams.

3.2.1 Duct installation:

Duct installed with length 65.8 meters in different stages figures (3 - 2) shown the layout of the primary air duct

1. Duct transition from rectangular duct 1008mm X 608mm to the pipe with diameter 813 mm , this transition used in FD fan downstream duct connection
2. Pipe duct with diameter 813mm passing through fans , bypass damper up to the control damper
3. Duct transition from pipe 813mm DN to rectangular 1210mmX610mm for distributing in sub ducts to the burners
4. Rectangular duct 1210mmX610mm within sub transition via pipe 273mm DN to burners D & H
5. Rectangular duct 910mmX610mm within sub transition via pipe 273mm DN to burners C & G
6. At the end of rectangular duct 610mmX610mm within sub transitions via pipe 273mm DN to burners A, B, E and F

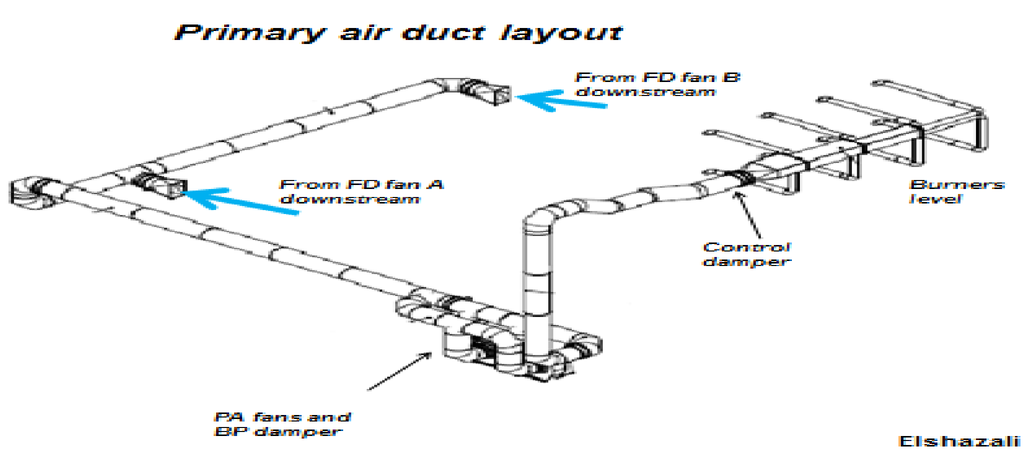

Figure (3 -2a) layout of the primary air duct

Figure (3 -2b) PA duct start from DF Fan downstream

Figure (3 -2c) PA duct to PA fans as build

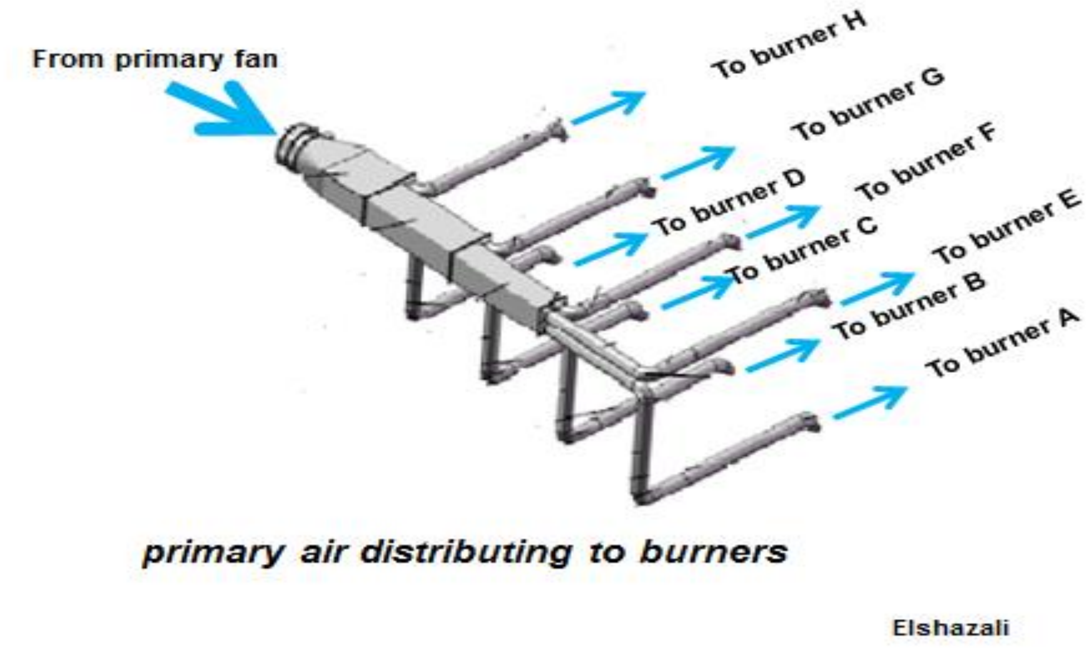

Figure (3 – 2d) duct distributing to burners drawing

Figure (3 – 2e) duct distributing to burners as build

3.2.2 Fans Installation

Fans are installed in middle of the duct far about 34.5 m from the connection of primary duct with FD fan downstream in figure (3-3)

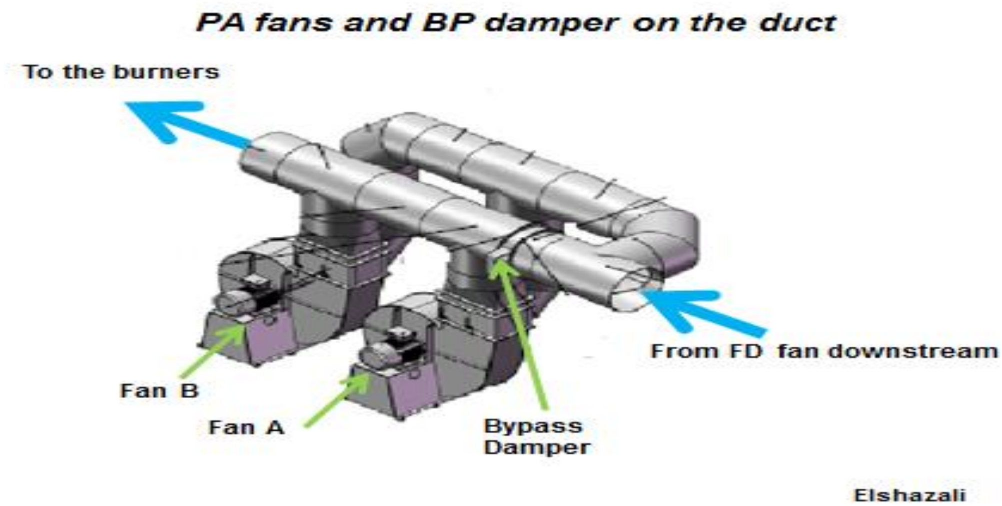

Figure (3-3a) PA fans and Bypass damper drawing

Figure (3-3b) PA fans and Bypass damper as build

3.2.3 Bypass Damper Installation*:*

bypass damper is installed in parallel position with fans

Figure (3-3c) PA Bypass damper

3.2.4 Control Damper Installation*:*

Control damper is installed between pipe duct and distributing rectangular duct near the burner in figure (3-4)

Figure (3-4) P A control damper

3.2.5 Burner Modification*:* burner modified by adding primary air pipe 273mm and pressure transmitter for ensuring about air pressure in burner chamber and also flow meter on fuel oil line to insure the performance of burners. You observe than in figures (3 -5).

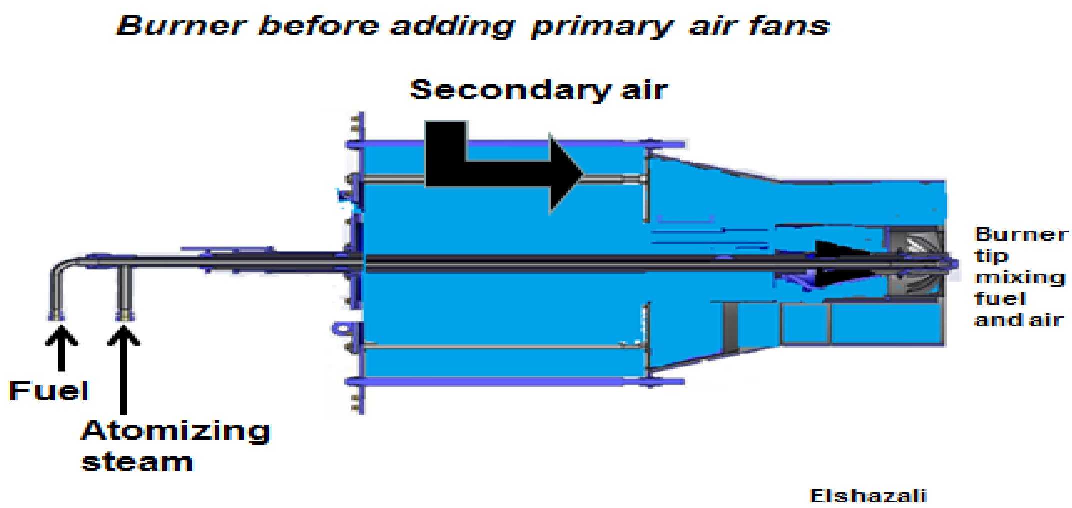

Figure (3 – 5a) burner before modification

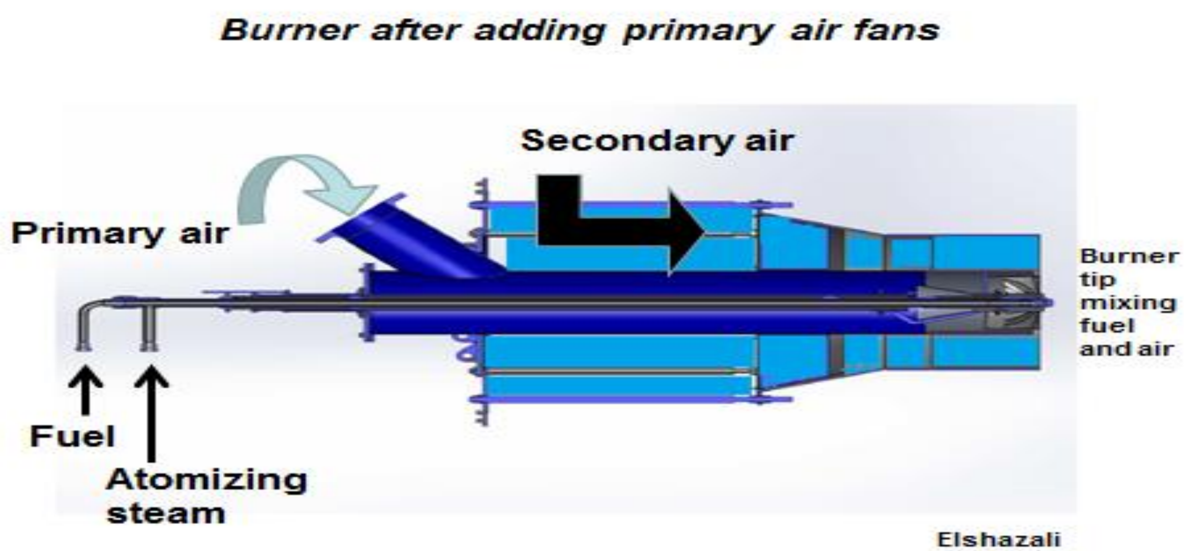

Figure (3 – 5b) burner after modification

3.3 Electrical Working

All power and signal cables are laid and terminated in the specified panel, power cables 415 VAC on strip for external items equipment 380 for fans and their convertors, 220 VAC on distribution terminal strip 230VAC also strip for control damper and bypass damper external items equipment VAC/VDC, Control signals cables wired and terminal strip for output commands relays 48 VDC and for indication equipment lamp test 24VDC and other instruments.

Connection of communication cable LAN port with RG-45 cat 5, cross-over STP connector cable and linked it in D-Link switch LAN (B) 222.222.222 (hardware connection)

The following Figure (3- 6) is electrical control panel which include power supply contactors, fuses, controller, I/O card and wiring termination

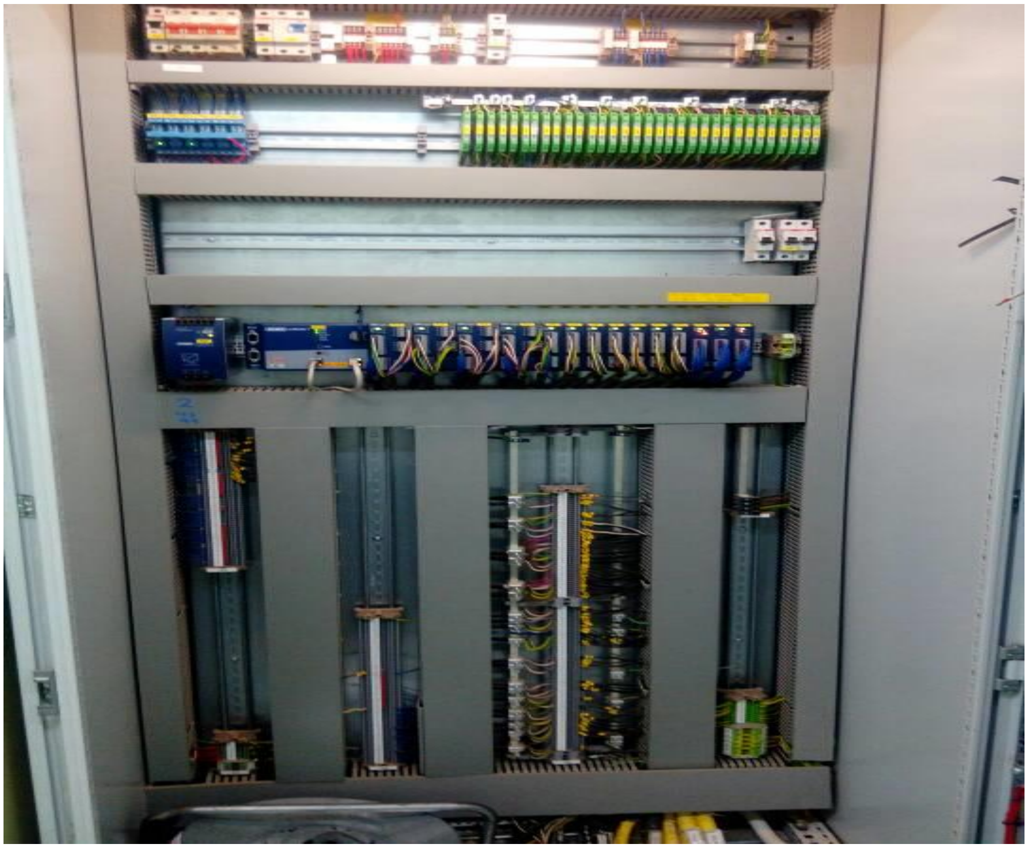

Figure (3- 6) Electrical control Panel

3.4 Software Configuration

The DCS software using is KNPS PH3 control system version GE OC4K6.3 with the virtual controller VDPU.

To create the mimic and logic protection of primary air system on boiler operation panel.

3.4.1 Man Machine Interface Configuration

The graphic making software (Maker) is an executable program on MS Windows, which can be used to make system flow charts and operation status figures. Maker is a powerful, convenient and flexible graphic making tool. For instance, the user can edit several graphic files at a time and can copy and paste different graphic files using clipboard or other drag-and-drop tools in Windows. And Maker uses the object-oriented method to realize real-time animation, which provides the users with powerful tools to make and process objects [3].

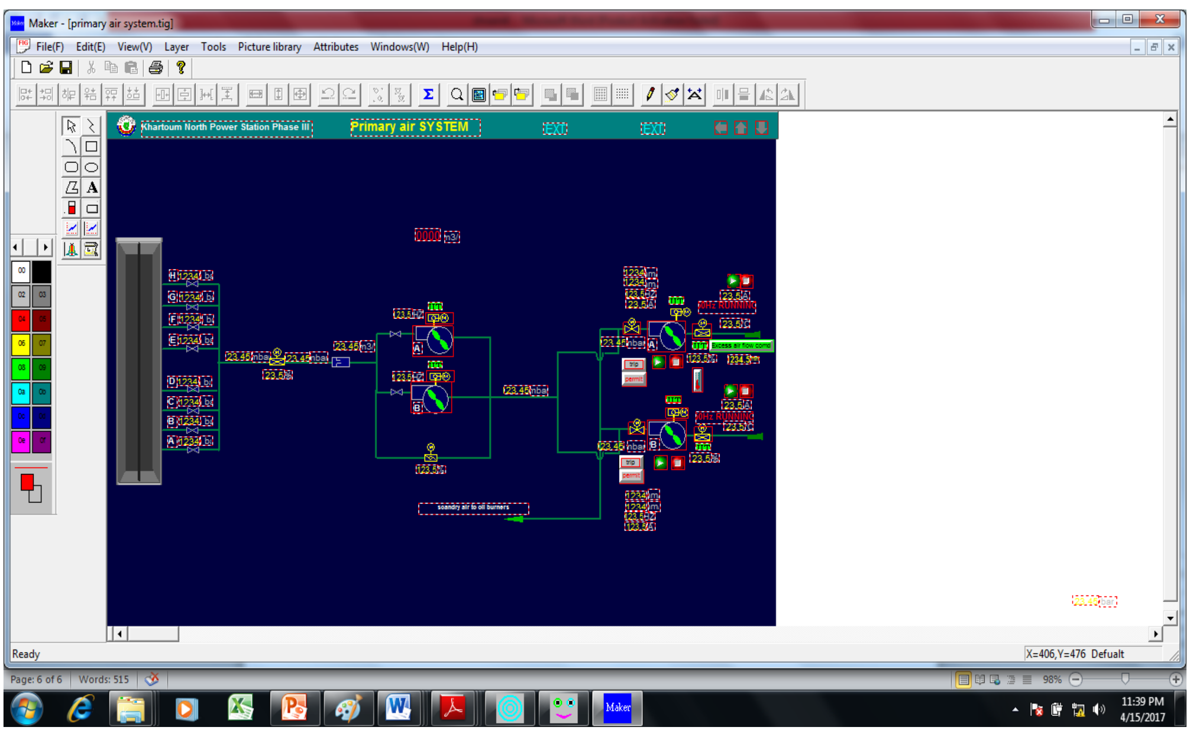

Figure (3- 7) man machine interface configuration (Maker)

Maker provides all kinds of analog basic objects, as well as special objects as the trend figure, X-Y curve, alarming and the dynamic bitmap, and it can dynamically connect the objects in the graph with real-time data and alarming record. Maker also provides such methods as editing, copying and modifying for the object or all kinds of dynamic link so that the users can efficiently make colorful figures connected with real-time database [3].

1. Graphic Modification (SCADA) done for the fuel oil system by adding the oil flow measuring reading and display for each burner (figure 3-8)
2. Boiler main menu Modification by adding Push button to show primary air fans mimic POP UP screen (figure 3-10)
3. Boiler Alarm Modification by adding the trip alarm indication for each primary air fan in boiler alarm panel 1 (figure 3-9)
4. New Graphic (SCADA) by creation a new HMI for Primary air fans (figure 3-11) included

a. Exiting FD Fans (A & B)
b. Primary air fans (A & B) status and frequency feedback
c. Bypass damper status and situation feedback
d. Control damper status and position feedback
e. Wind box air pressure measuring display for each burner
f. Diff pressure measuring for primary air Pre line display
g. Diff pressure measuring for control primary air supply display
h. Diff pressure measuring for control primary air burner display
i. Primary air flow measuring display.

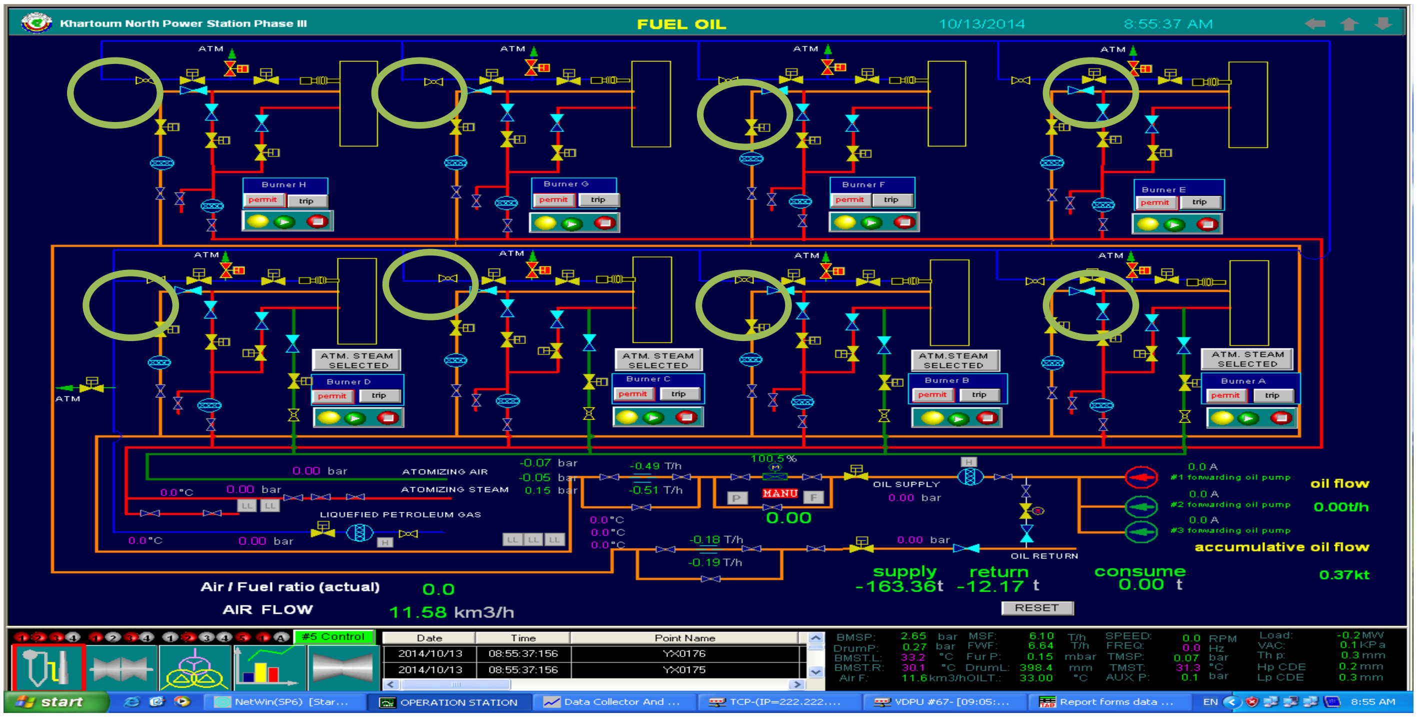

Figure (3-8a) mmi fuel oil system before modification

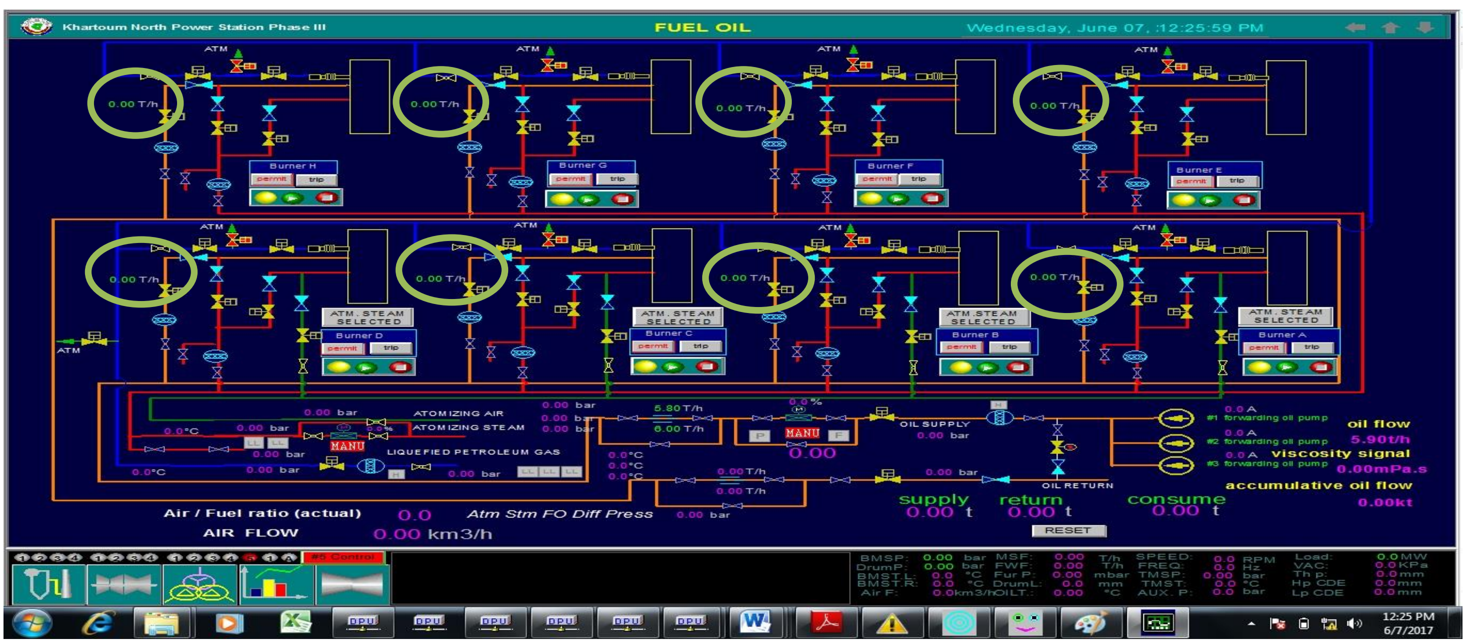

Figure (3-8b) mmi fuel oil system after modification

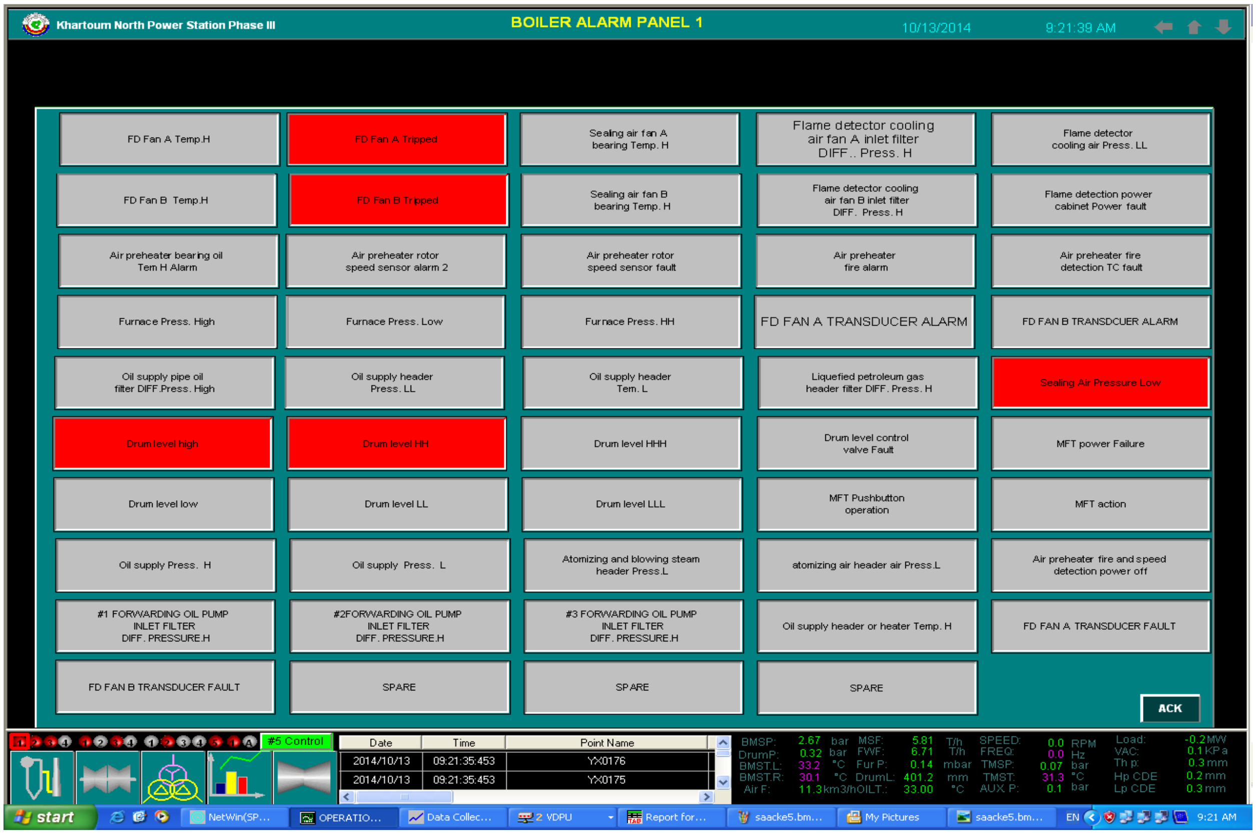

Figure (3-9a) boiler alarm system before modification

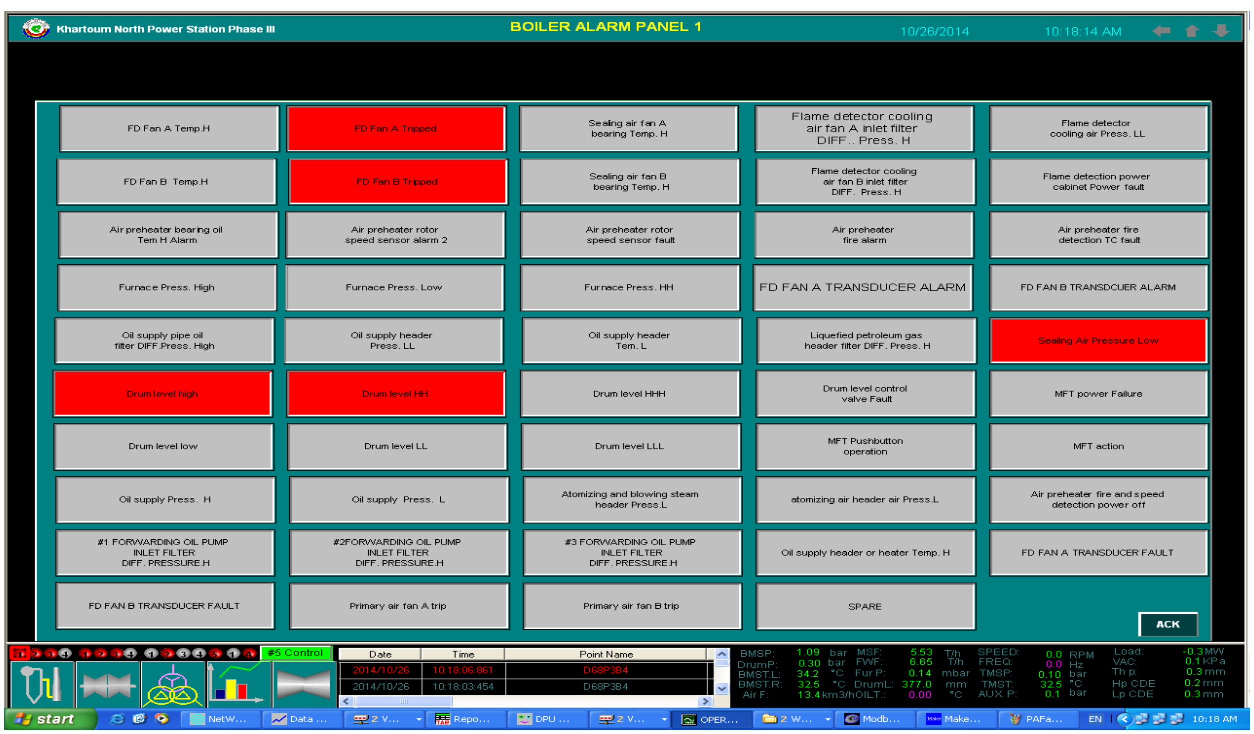

Figure (3-9b) boiler alarm system after modification

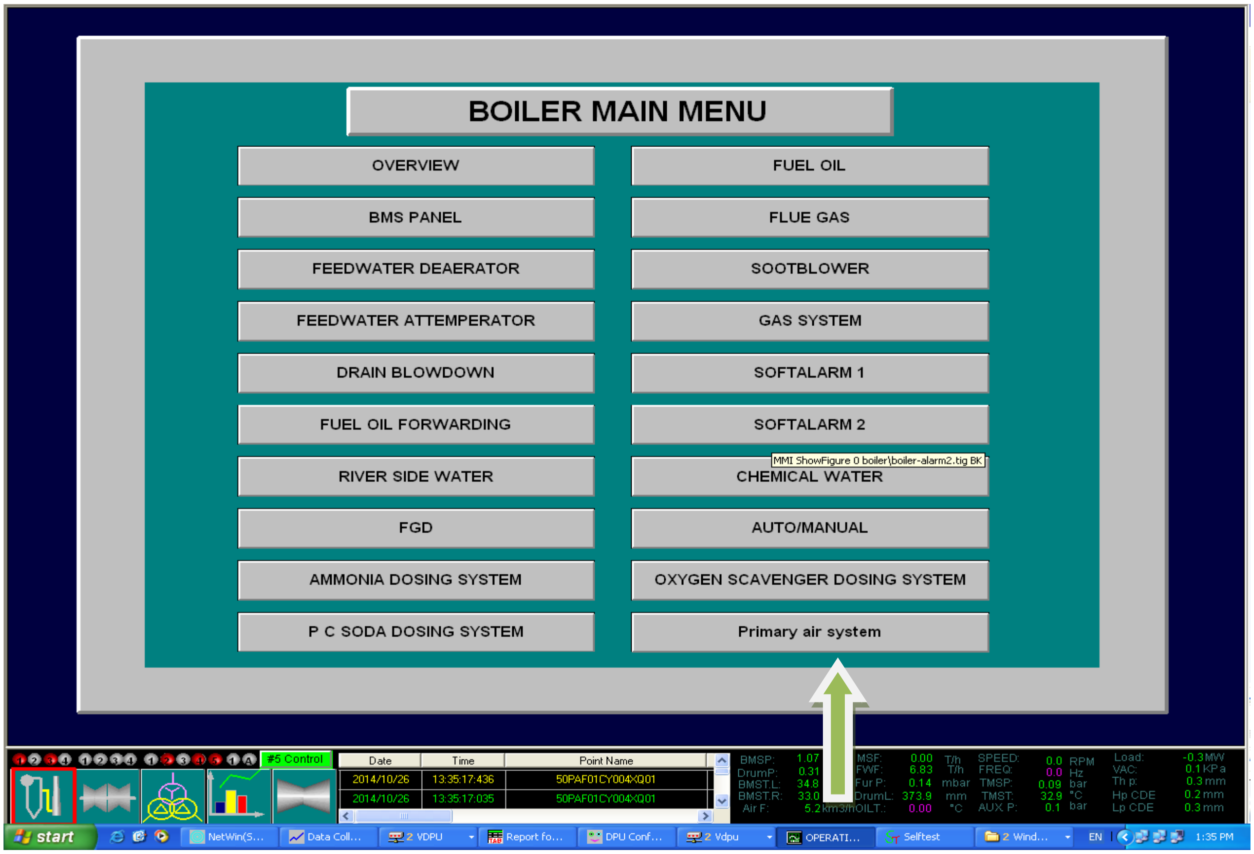

Figure (3-10) New PA push button on boiler main panel

Primary air push button added on FSSS MMI page

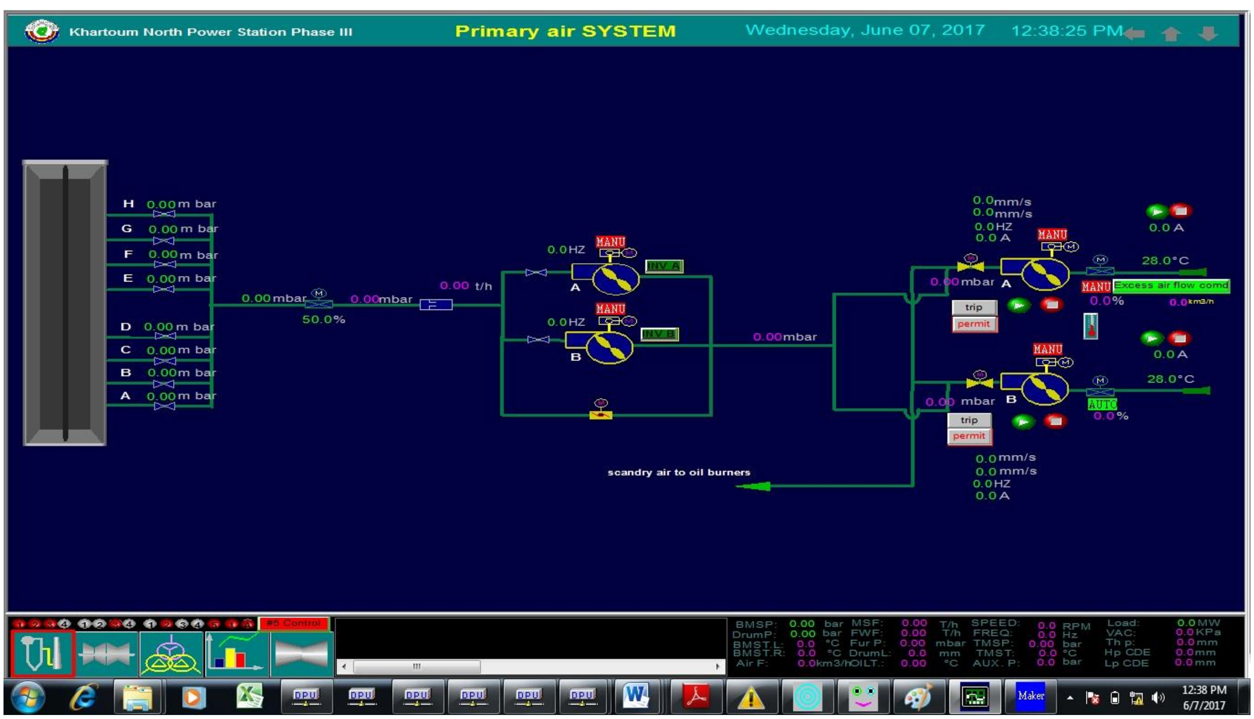

Figure (3-11) New PA HMI system

3.4.2 DPU logic configuration

As a key component of OC 4000 software, DPU configuration software （DPUCFG.EXE） In ENG station, users can run this software only after login in NetWin Dpucfg provides two configuration modes: offline and online. Each process control station corresponds to a DPU configuration file; this DPU file is stored in ENG station in ".txt" format. User can create a new configuration file in Dpucfg, or upload files in DPU to modify offline [3].

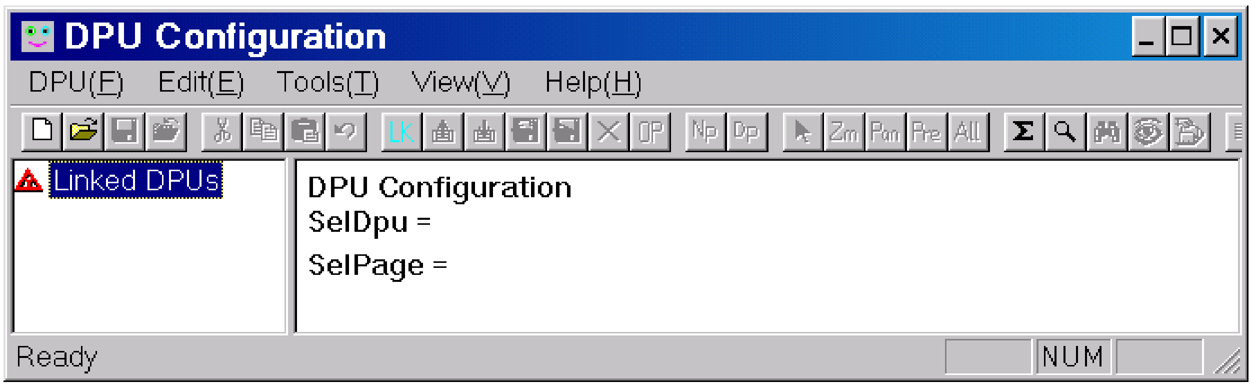

Figure (3 - 12) DPU logic software configuration program

The main functions of DPU are:

1. DPU Off-line Configuration

DPU can be configured off line and saved on ENG disk. The configuration interface meets the IEC-1131-3 standard concerning graphic configuration function blocks.

2. DPU or VDPU, Online Configuration

DPU or VDPU configuration download, online configuration and debugging the configuration files on ENG hard disk can be downloaded into DPU. And the user also can directly modify, operate, debug the DPU as well as observe the trend curve on graphic configuration interface [3].

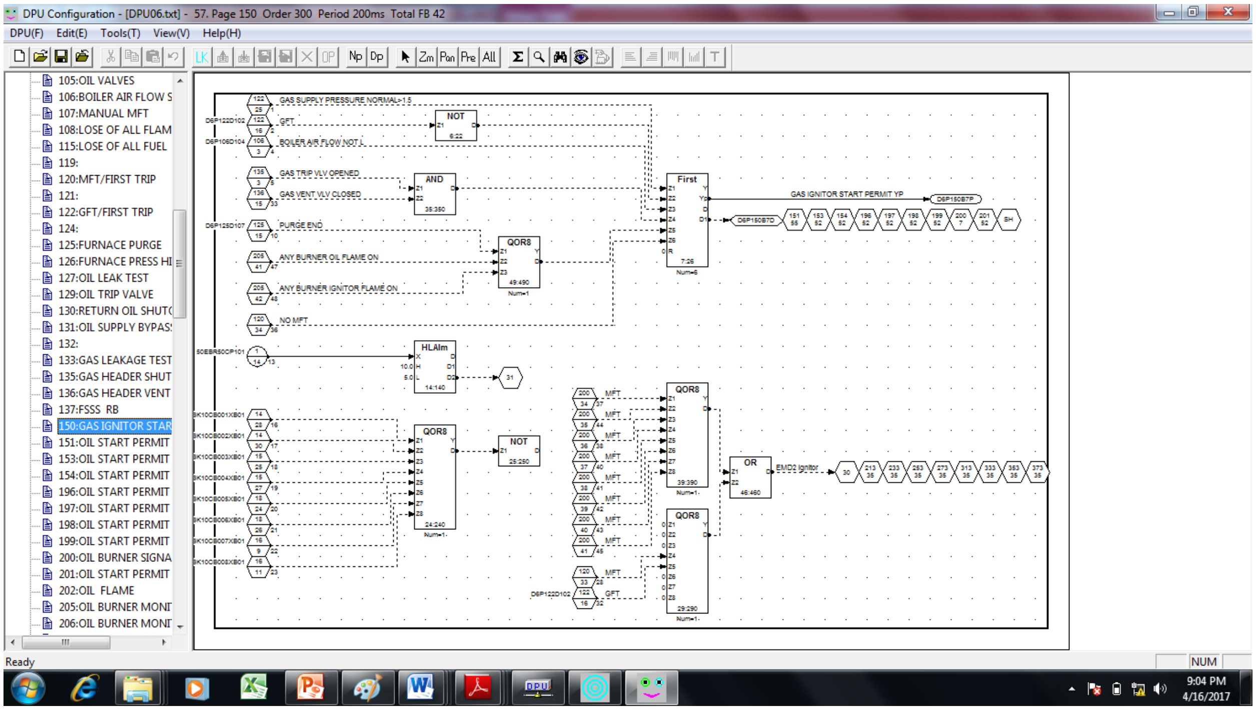

Fig (3- 13) DPU offline configuration

Off line configuration show the blocks in non-green color and not connect

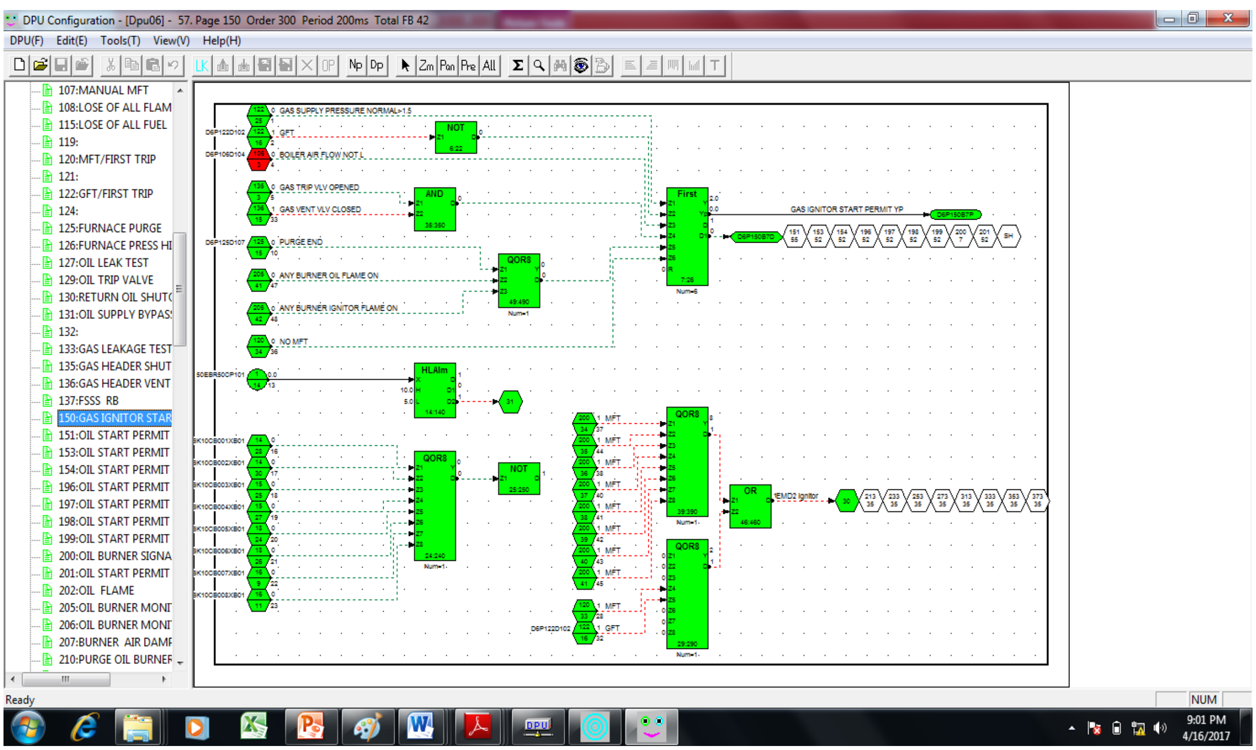

Figure (3- 14) DPU online configuration

On line configuration show the blocks in green color and connect

3. DPU Configuration files saving

Configuration in DPU can be uploaded into ENG and saved to ENG disk. DPU configuration must be done on the basis of existing point directory. Because the point directory defines the set of all real-time points on DPU while DPU configuration software is only used to define I/O and algorithm, namely control strategy of a certain DPU. When the relation between one DPU and other DPUs is defined, the point directory must be used to uniquely identify all real-time points on network. And therefore before DPU configuration, the global point directory must be created. Read "Section 4 Global Point Directory Configuration" for more specific information [3].

The point directory can be created by text edit tool or generated through configuration software. And any global point referenced during configuration must exist in the point directory. This configuration software does not include the functions of global point directory configuration and modification.

4. Page or Control Page

The control Page is a basic object in DPU configuration software. Function blocks must exist in page and page instance includes properties such as: page number, execution number, page status, page size, execution period, page description, I/O driving number and address form etc. Function block instances are also included in page instance [3].

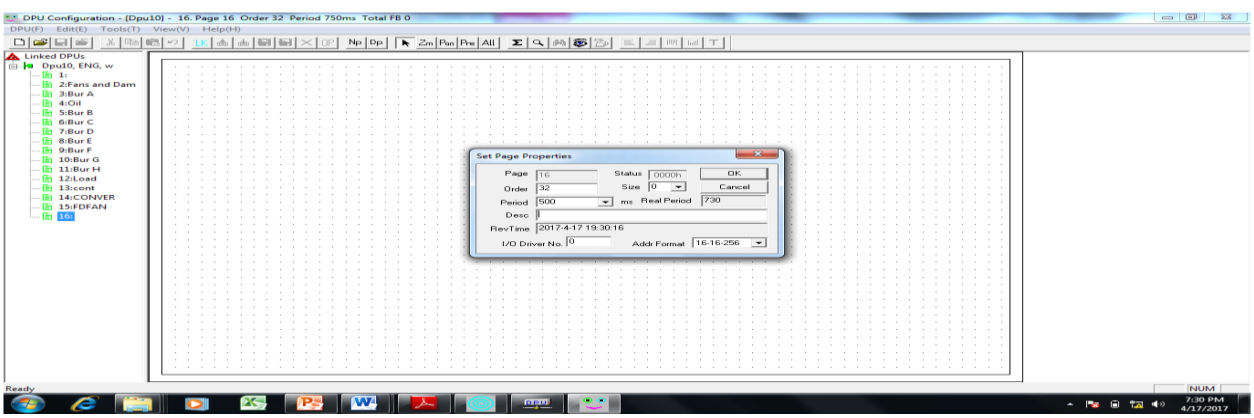

Figure (3-15) DPU configure Page

5. Function Blocks

Function block is a basic element of DPU configuration. OC 4000 system pre-defines function blocks with many kinds of types and functions, for user's convenience. Function blocks are a group of sub-programs, which comply with IEC61131-3 standard. When a function block is called, the system will run this sub program, and send operation result to the corresponding storage unit of the output that the connected block could reach [3].

a. I/O Function Blocks

Generally an I/O block has only one input or output There are three kinds of I/O blocks: hardware I/O blocks, network I/O blocks and page I/O blocks. See figures (3-12)

Hardware I/O block defines a corresponding relationship between a variable inside DPU and hardware channel. I/O channel number and conversion type are indicated below the symbol.

As hardware I/O block can broadcast in network, which can be acquired through other DPUs and MMI stations, point names connecting to network are shown in symbols [3].

b. Analog Function Blocks

This function blocks for Adder, Multiplication, Divider, sector Function Transform, Thermal Parameter Calculation, and Water Level Compensation Calculation of two float variables, and outputs one float variable [3].

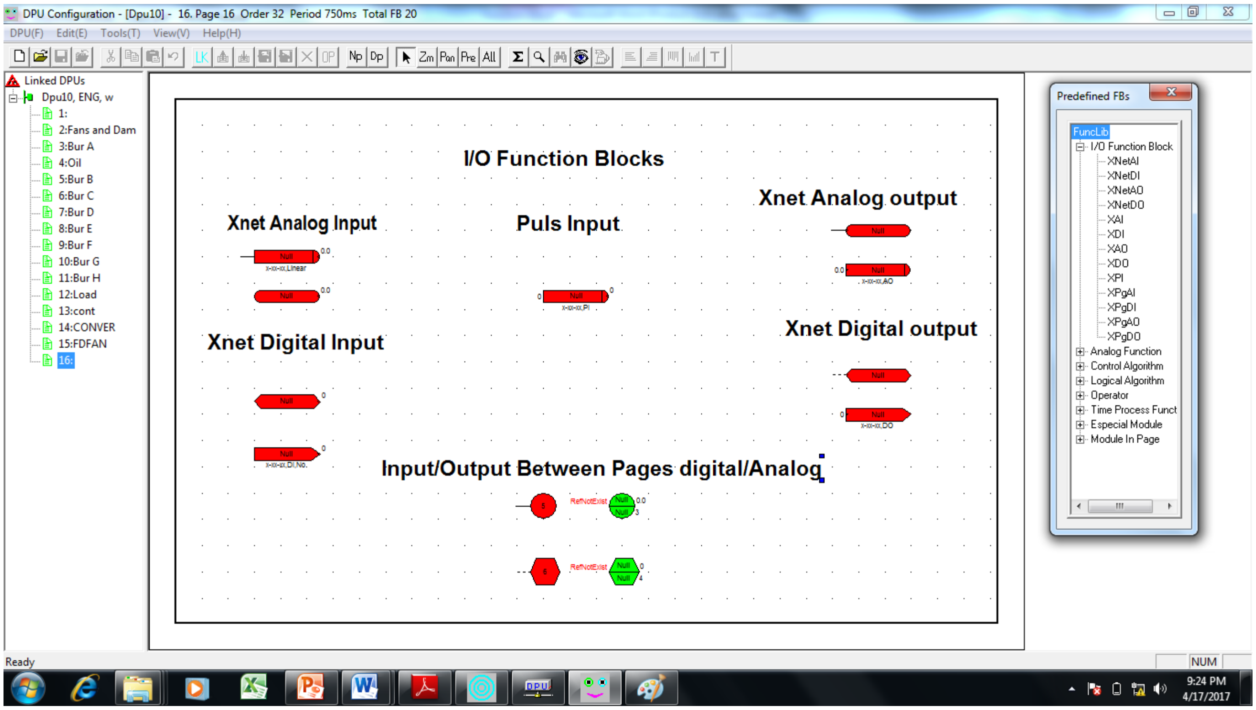

Figure (3-16a) I/O blocks on DPU configure Page

Different types of function block used for input and output as require

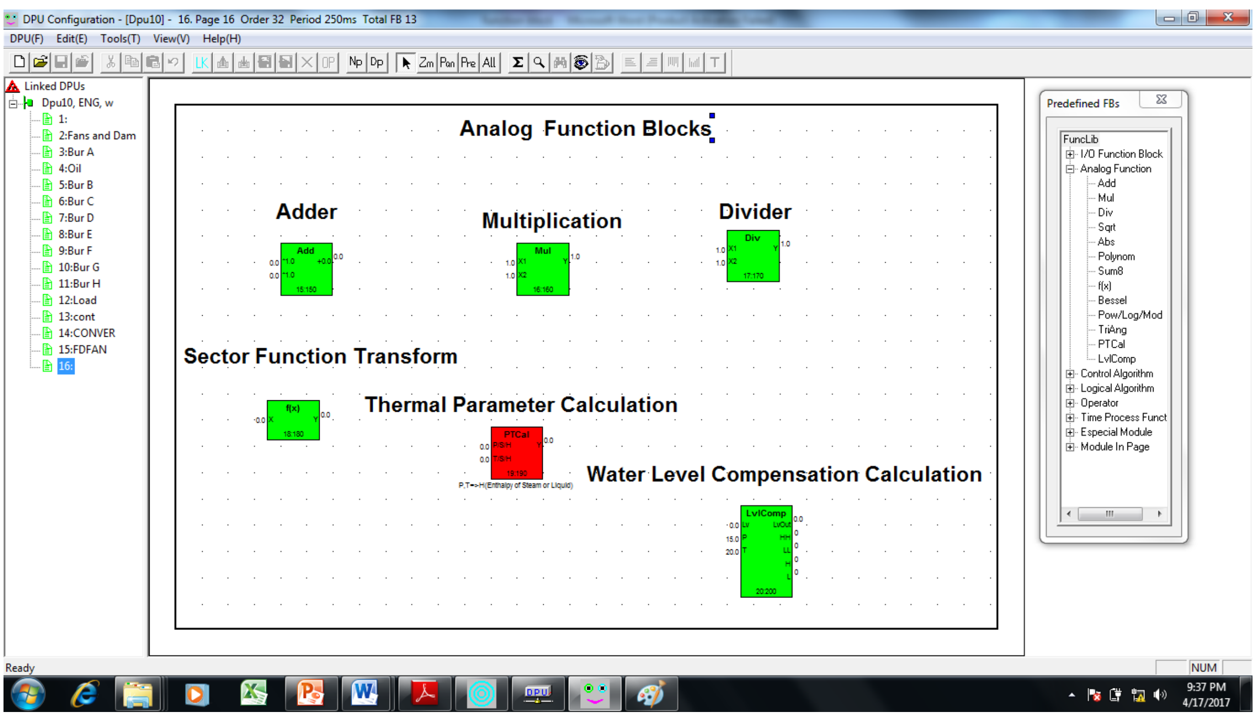

Figure (3-16b) analog blocks on DPU configure Page

Analog function blocks used for continuous generating signal

c. Time Process Function Blocks

This function blocks Lead and Lag Block, Delay Block, Time Field Statistic Block and Digital Filter, for conducts pure lag calculation on input, Laplace transfer function, calculation period and the final stead value and controls timer start and end with Set signal [3].

d. Control Algorithm Function Blocks

One out of Three Selector block for three input signals. Depend on selection Mode, High-low Range Limiter block for limits range of inputs, and output is limited between High and Low, Deviation Computing block for is a control block with non-linear magnification coefficient, PID Calculation block for PID regulator and has anti integral saturation, Table Lookup Fuzzy Controller block for fuzzy logic control is rule of fuzzy relationship between controller input and output , It output fuzzy variable according to inputted fuzzy variable Fuzzy control table can be created through fuzzy statistics according to control rule of fuzzy control, SFT block this is a non-disturbance shift function block. When shift signal Z changes, output of function block can shift between X1 and X2 signal [3].

e. Logic Algorithm Function Blocks

This function blocks for digital signals which are ONE or ZERO.

AND block , OR block, NOT (Reverser) block , Timer block work according to parameter Mode(on delay , off delay ,pulse) , Counter block is to count and accumulate digital signals , Step Controller block for The step logic algorithm and the device control algorithm provide the standard implementation methods of the group and the sub-group sequence control. It can accept the upper sequence-control logic or the operator’s starting command, and set the corresponding device running in the sequence-control mode [3].

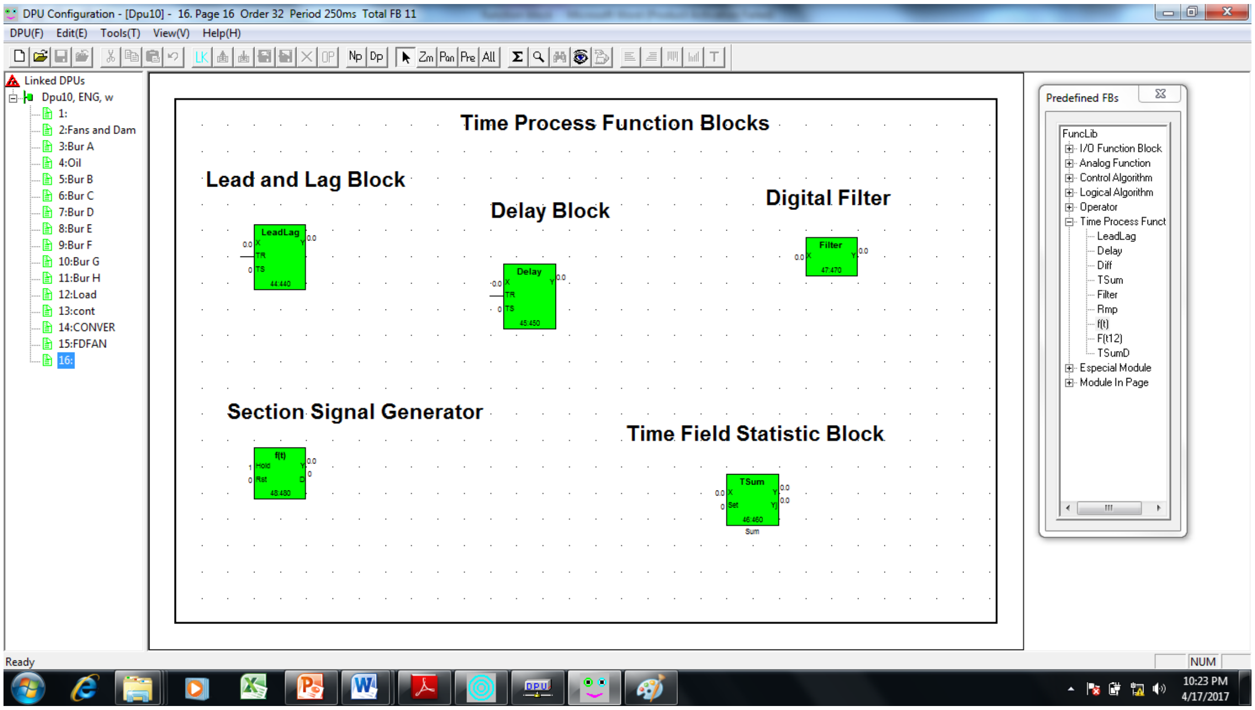

Figure (3-16c) time process blocks on DPU configure Page

It special blocks for time processing as delay on delay off

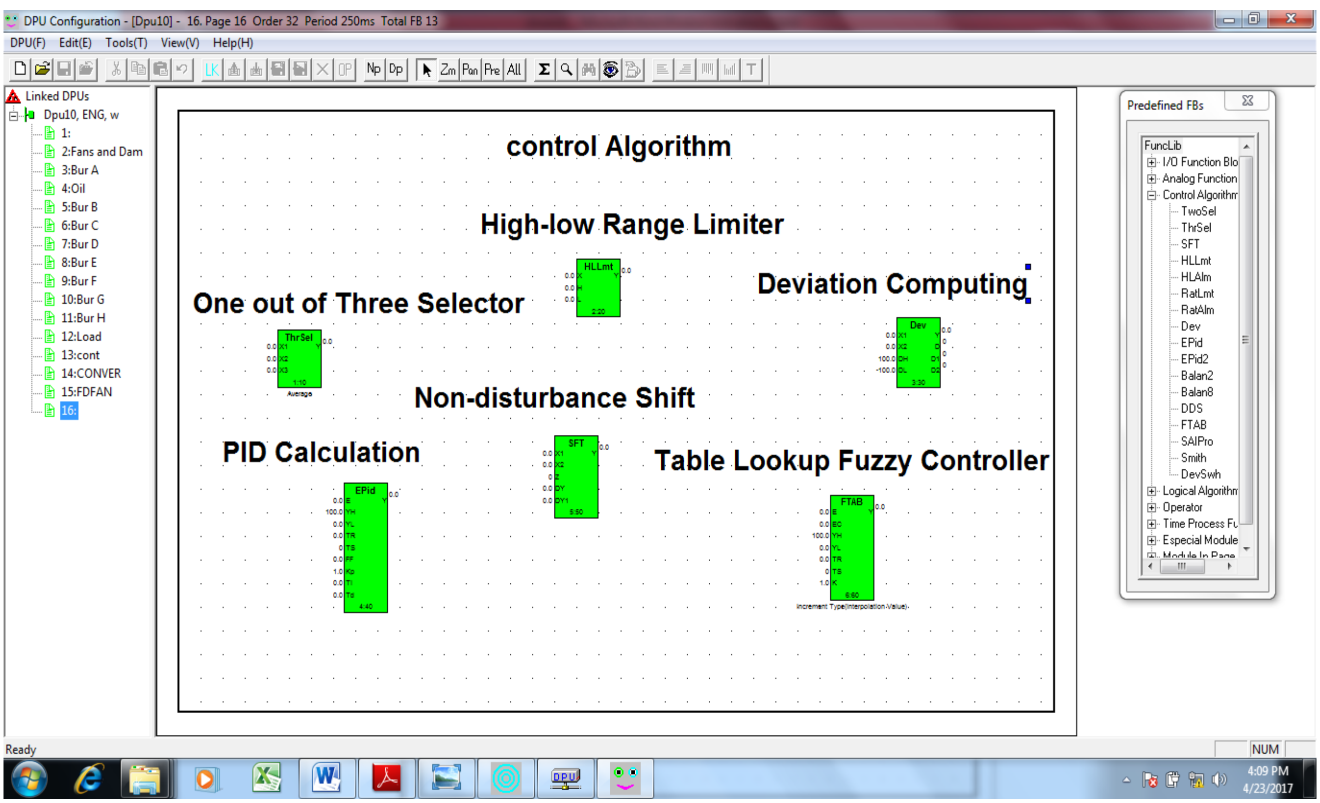

Figure (3-16d) Control blocks on DPU configure Page

Control algorithm is block built to calculate specific signals and function

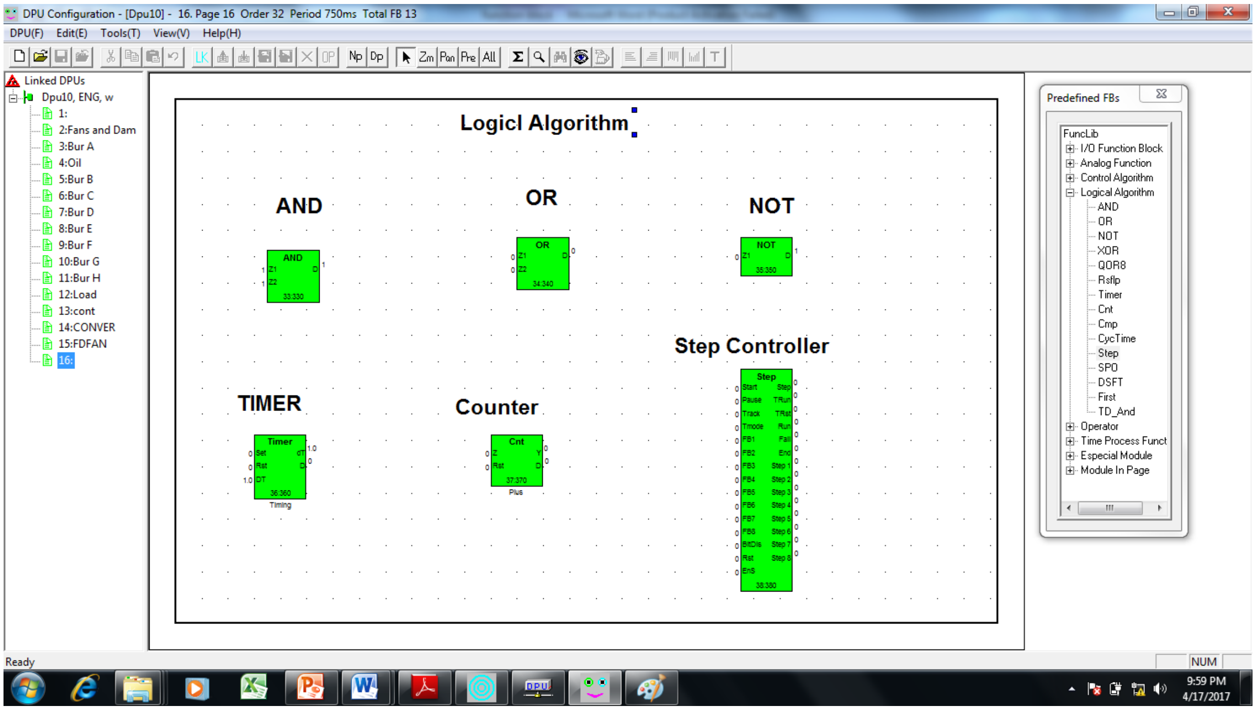

Figure (3-16e) Logic blocks on DPU configure Page

Logical algorithm used for discrete generating signal

f. Operator Function Blocks

All operators have four parameters: LID, SH, NAA and T. Each operator is identical to be attached with an X Net AO block, so each operator can define a real-time point, which is called virtual point (VC point). VC point is unique identifier to an operator. Any operative command can be sent to VC point, and it is not necessary for operative command to search by algorithm address P.B. VC point can be referred to between pages. VC point is defined as analog point, means packing digital point, VC point record occupied 6 bytes, first 2 bytes is real time status, last 4 bytes are packing value Enhanced Type Analog Soft Manual Operator ES/MA block is a percentage realize soft operator for loops, and receive operation command operation, Keyboard Analog Increase/Decrease KBML for outputs one operable float variable, receives increase/decrease and set value command, DEVICE for Digital Operator affords the basic control and inter-locking protective logic of single device. It can be controlled and operated by the upper sequence-control command, Simple Digital Manual Operator D/MA for outputs one Boolean number that can be operated and accepts the command, such as Pulse, Set, Reset, and Topple, Remote Controller block YKQ for mainly operates on remote control signal [3].

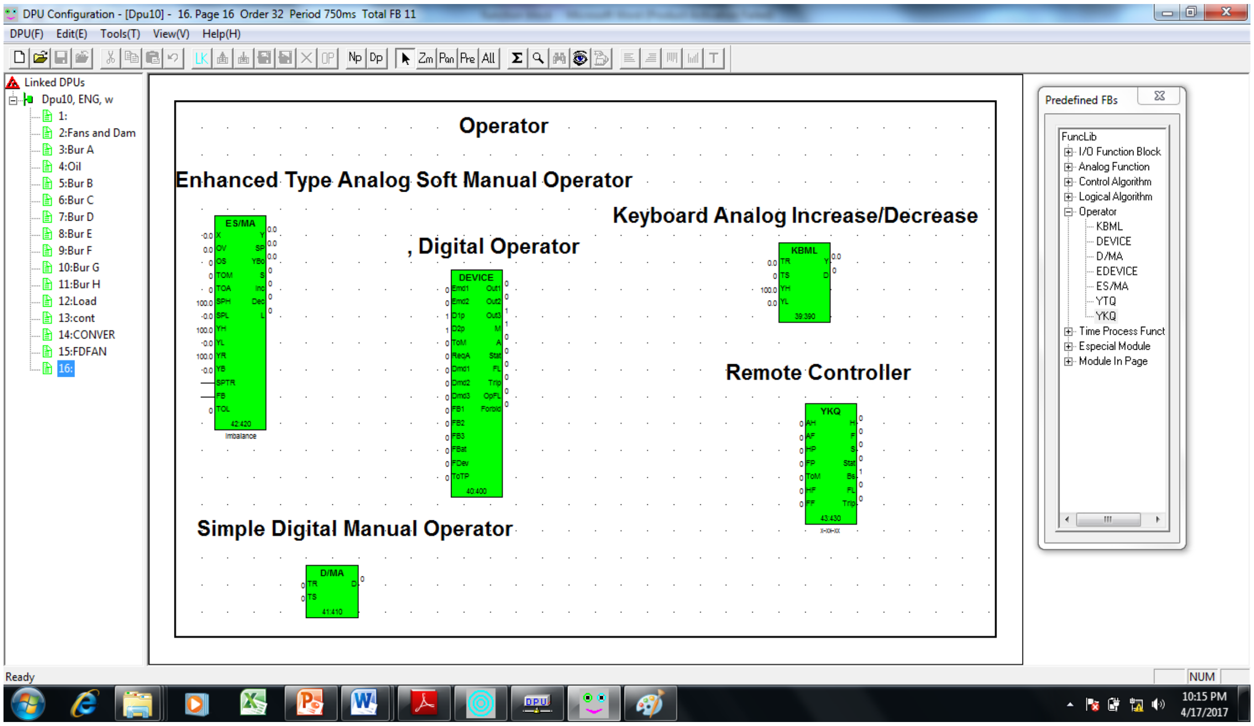

Figure (3-16f) Operator blocks on DPU configure Page

Operator is the block function send the order to the actuator in the filed

g. Special Function Blocks

Quality (state) Test Block for acquires the states of the block that includes the input variable, and changes them to the bool output, DPU (state) Test Block for gets the state of the appointed DPU and TDPU gets the state of the appointed DPU. to, Time Transfer Block TtoS or StoT transforms the internal time to normal expressing method of 7 analog points. Time Record Block TREC If the input value of Tday1 or Tms1 is an empty or illegal pointer, the function block will record the current time of DPU into output T [3].

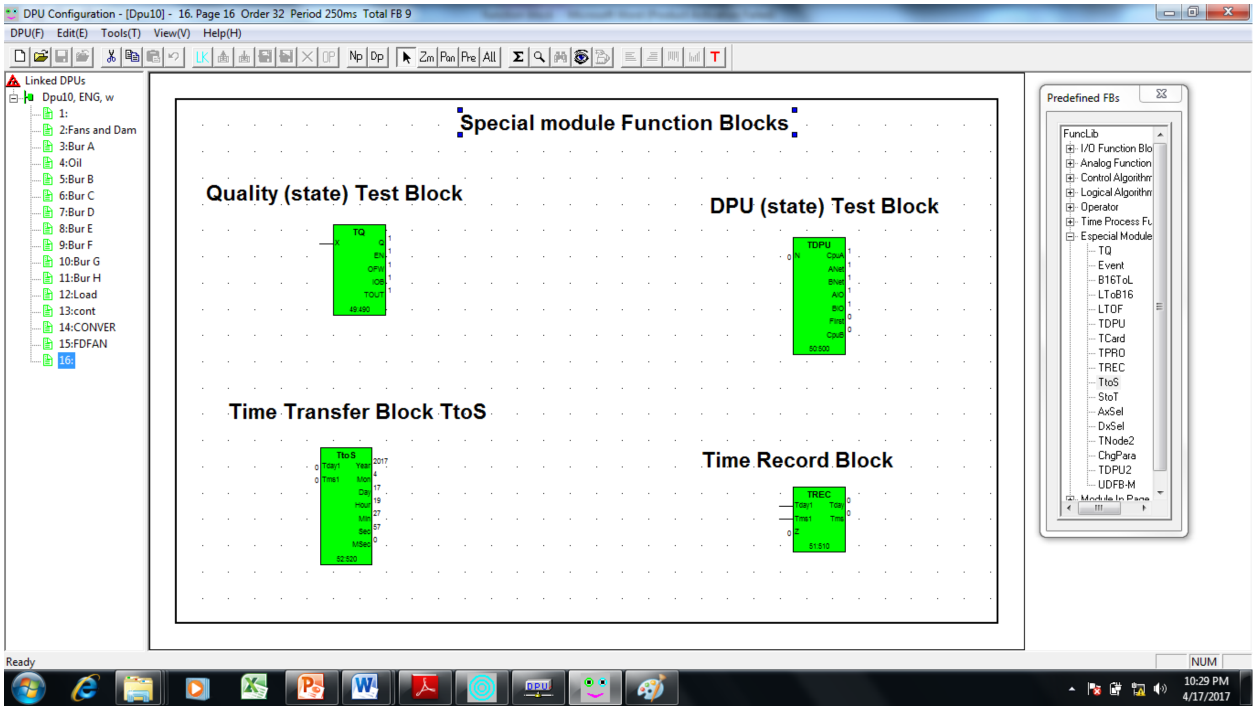

Figure (3-16g) Special blocks on DPU configure Page

Some special modules used for canalizing and diagnosing

3.4.3 Primary Air Supply Control Philosophy

Primary air supply differential pressure control. It will be active during boiler start under low load with primary air fan in operation and bypass damper Closed. The change over between primary fans is passable during the operation and only one fan must be in operation. For the fans 30 KW we used frequency converter 30KW to control the speed.

The analog input signal 4 to 20 mA it the measured actual value of differential pressure between the common primary air duct and furnace pressure, the analog output signal 4 to 20 mA is a command signal to frequency convertor control to ensure the constant differential pressure between the common primary air duct and furnace pressure. Control damper with electrical actuator and Bypass damper with electrical actuator (de-energized open) situation [4]

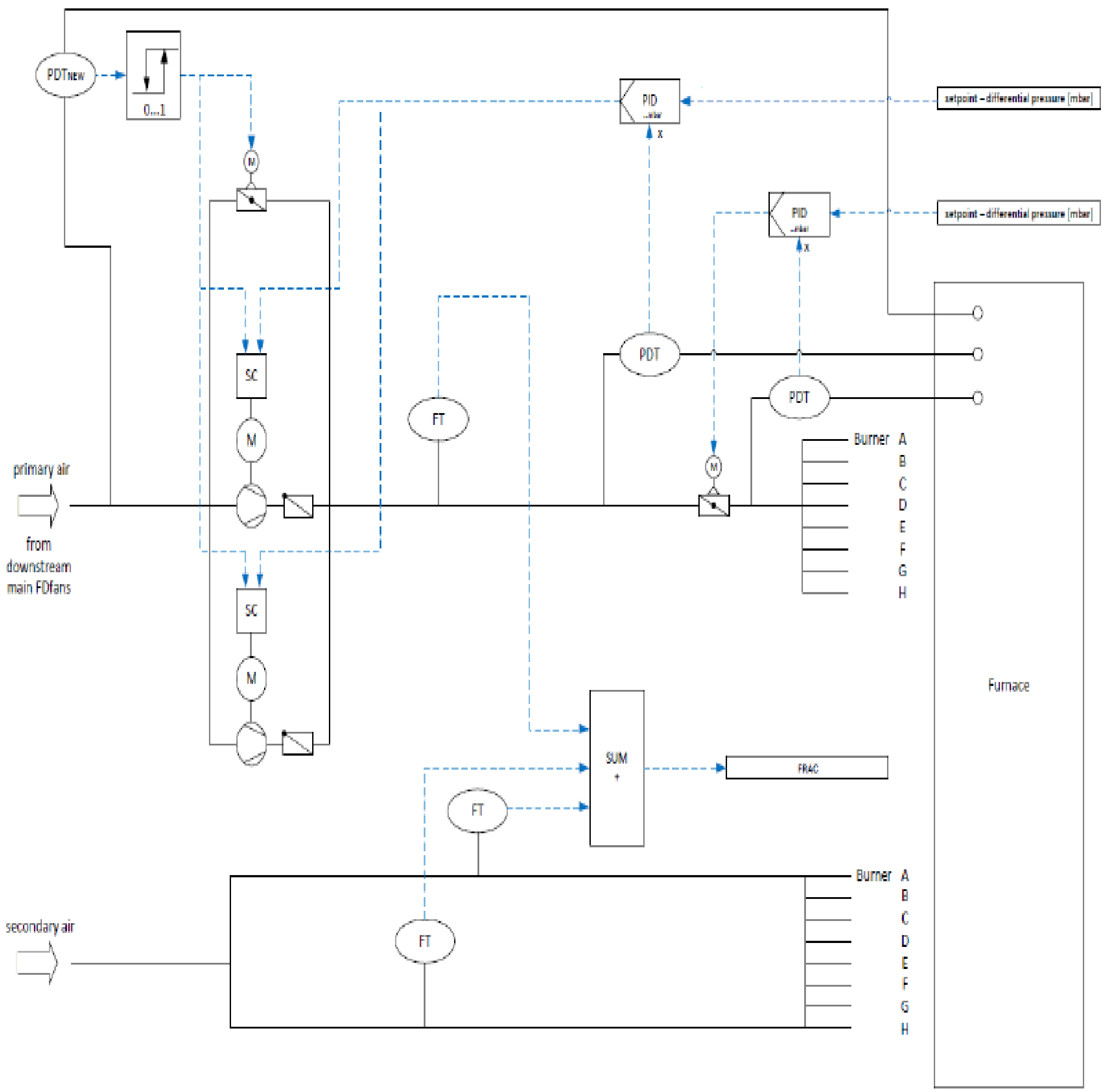

Figure (3-17) Sketch diagram of PA system

This sketch diagram is primary system P&ID piping and instrumentation drawing with existing secondary air at the burners

Table (3 - 2) Primary air I/O signal function

No.	I/O	Quantity	Signal type	functions
1	AI	22	4 to 20 mA	• Actual value of differential pressure in three points on primary air • Supply pressure in common PA duct to the furnace pressure • Control damper position • Fans speed feedback • PA flow measurement • Oil flow in each burner • Combustion camper pressure in each burner
2	AO	3	4 to 20 mA	• Command signal to frequency converters • Control of frequency converter to ensure constant differential pressure • Primary air pressure control damper
3	DI	6	24 VDC	• Stop /trip frequency converter • Fan in operation status • Bypass damper status
4	DO	6	48 VDC	• Start /Stop command to frequency converter • OPEN/CLOSE command to Bypass damper”

3.4.4 Configuration of PA system

Under the enhancement of the boiler firing and oil burner's modification to improve the performance of the firing adding the new primary fan system configuration control system by extension the existing DCS modification, We created a new VDPU with node number 75 and we name it Primary Air by file version 2.0.3.1 standard of OC4000 system and linked with LAN through D-Link switch. VDPU75 logic configuration included

a. Analog input / output signals , see figures (3-19)
b. Digital input / output signals , see figures (3-20)
c. Primary air fans A & B , see figures (3-21)
d. Primary air Bypass damper , see figure (3-22)
e. Primary air Control damper , see figure (3-23)
f. Primary air flow calculation to add it to secondary to get total air flow of the boiler, see figure (3-20).

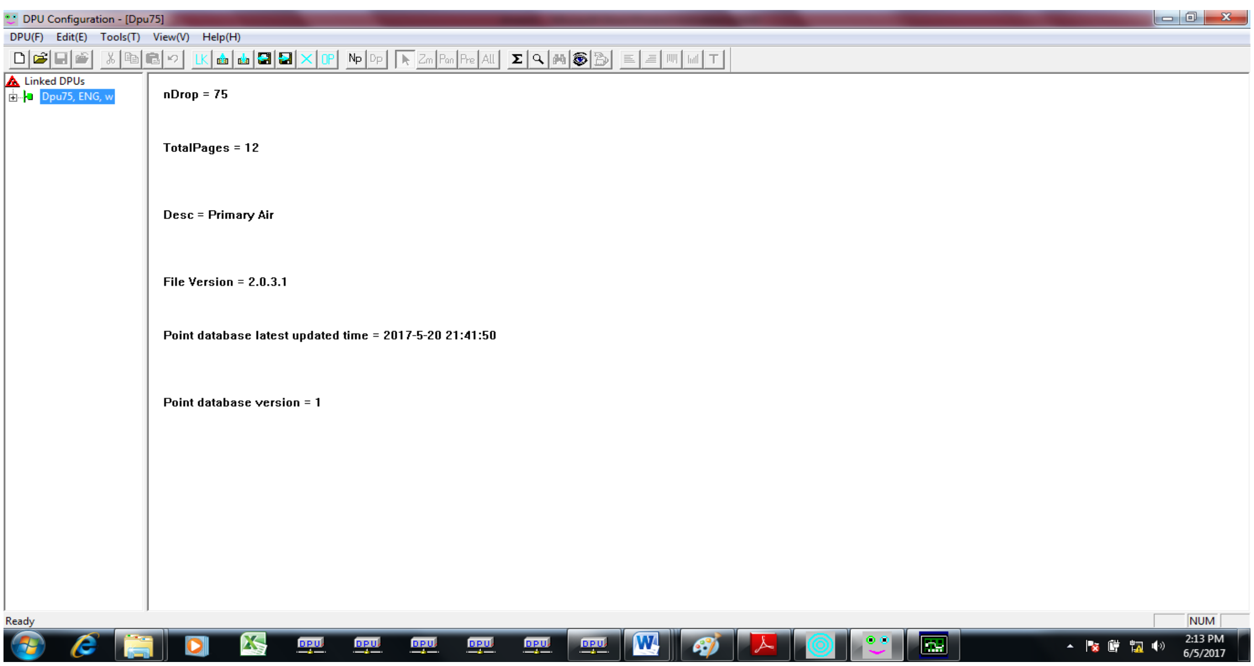

Figure (3-18) VDPU node 75creation

Victual DPU created file version2.0.3.1 for database of PA system

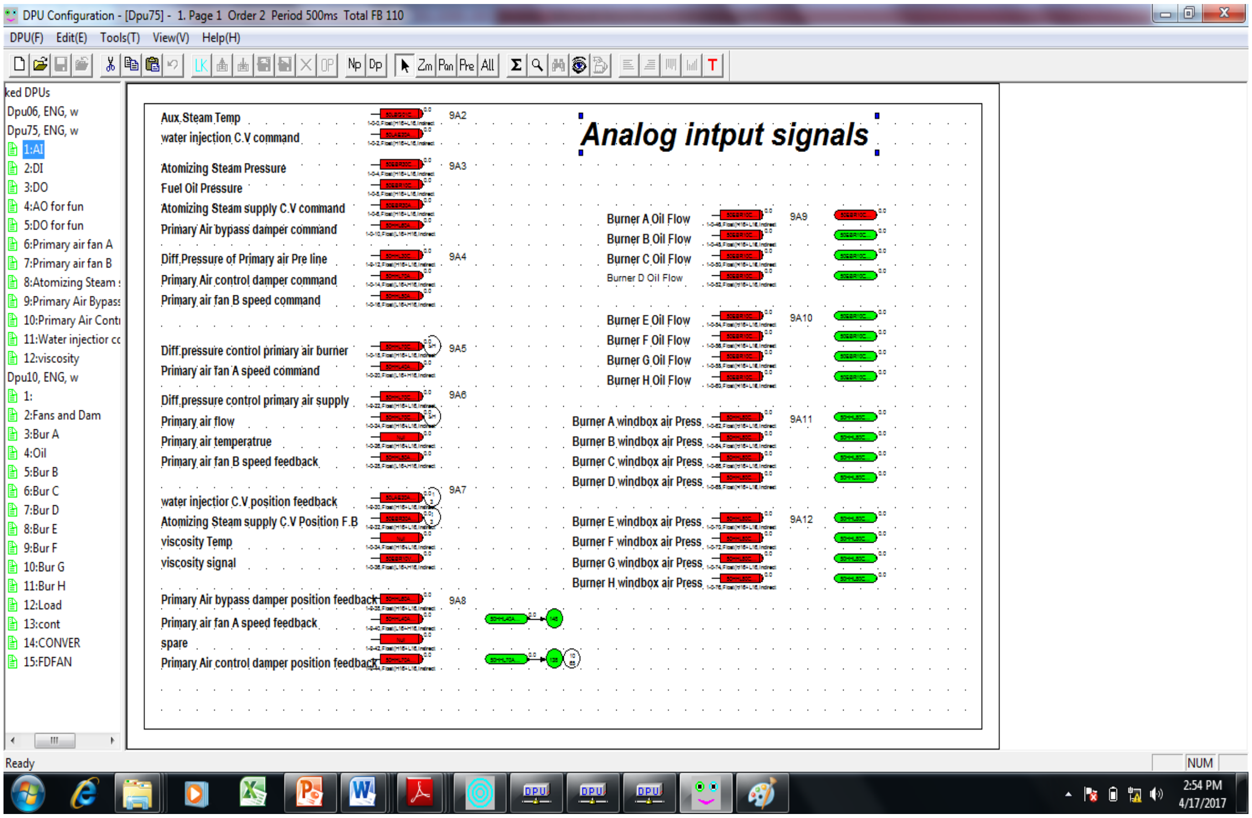

Figure (3-19a) PA system AI signal

Analog input signals on this page include burner oil flow, burner combustion air pressure, air flow, fan speed, convertor frequency and dampers position,

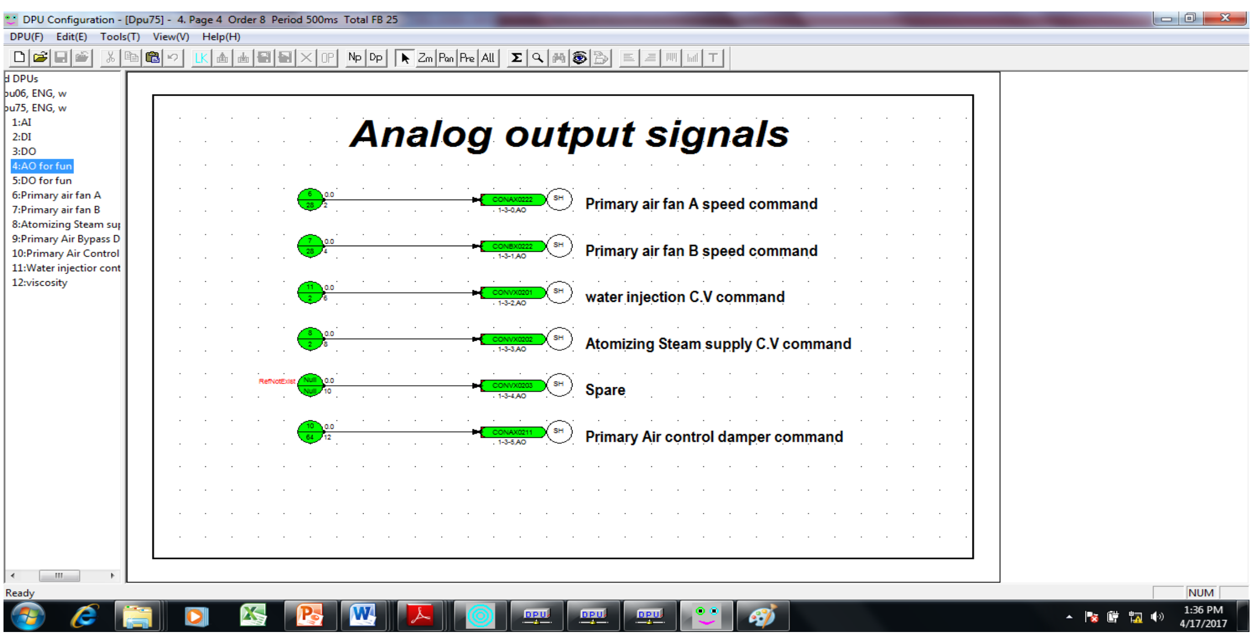

Figure (3-19b) PA system AO signal

Analog output signals on this page include fans speed and dampers commands

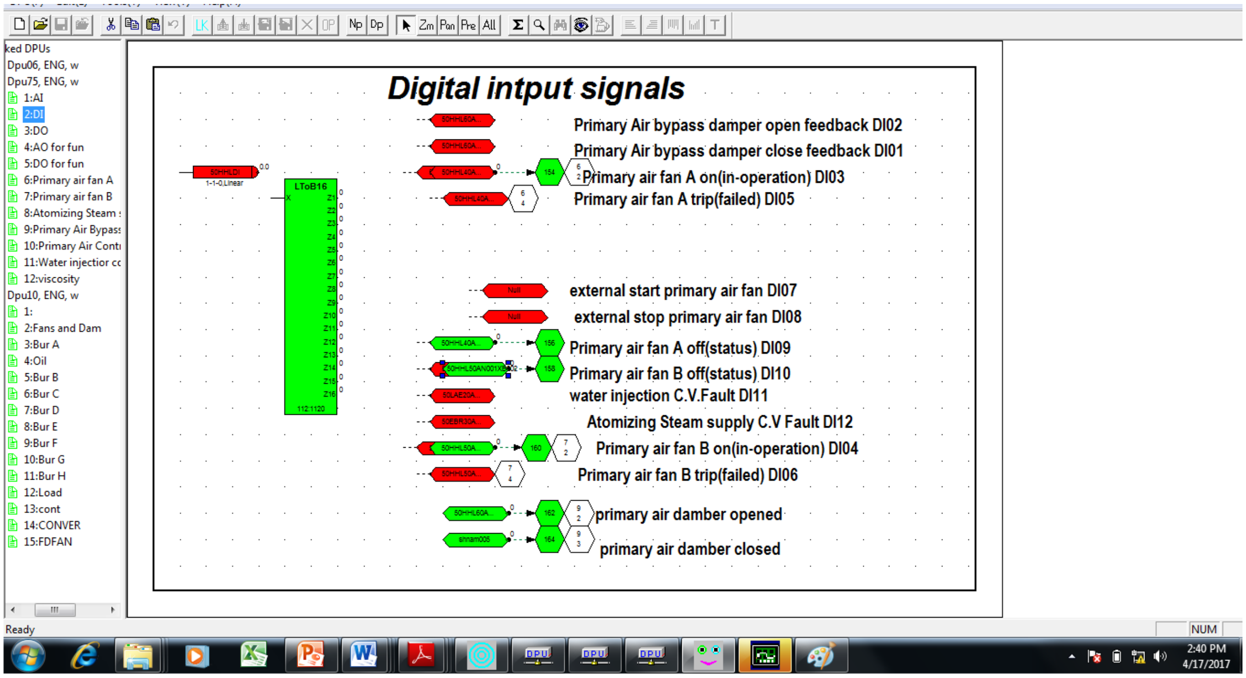

Figure (3-20a) PA system DI signal

Digital input signals on this page include fans and damper feedback status

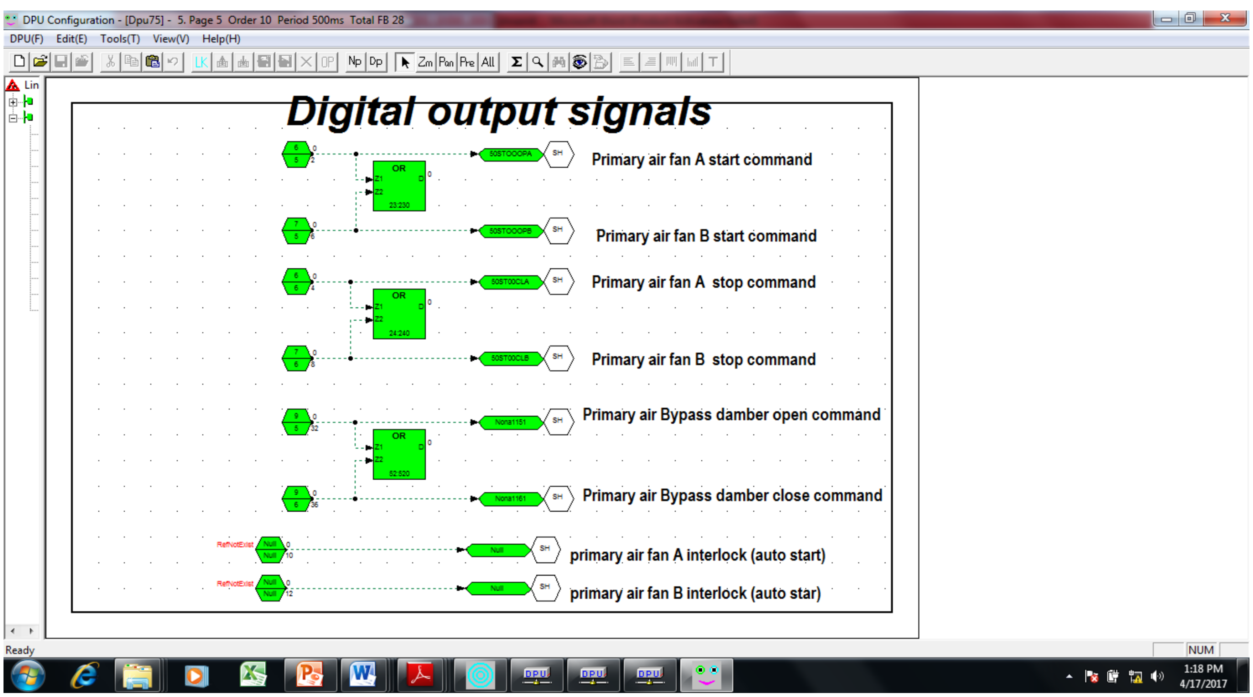

Figure (3-20b) PA system DO signal

Digital output signals on this page include fans start / stop and dampers open / close commands and fans interlock

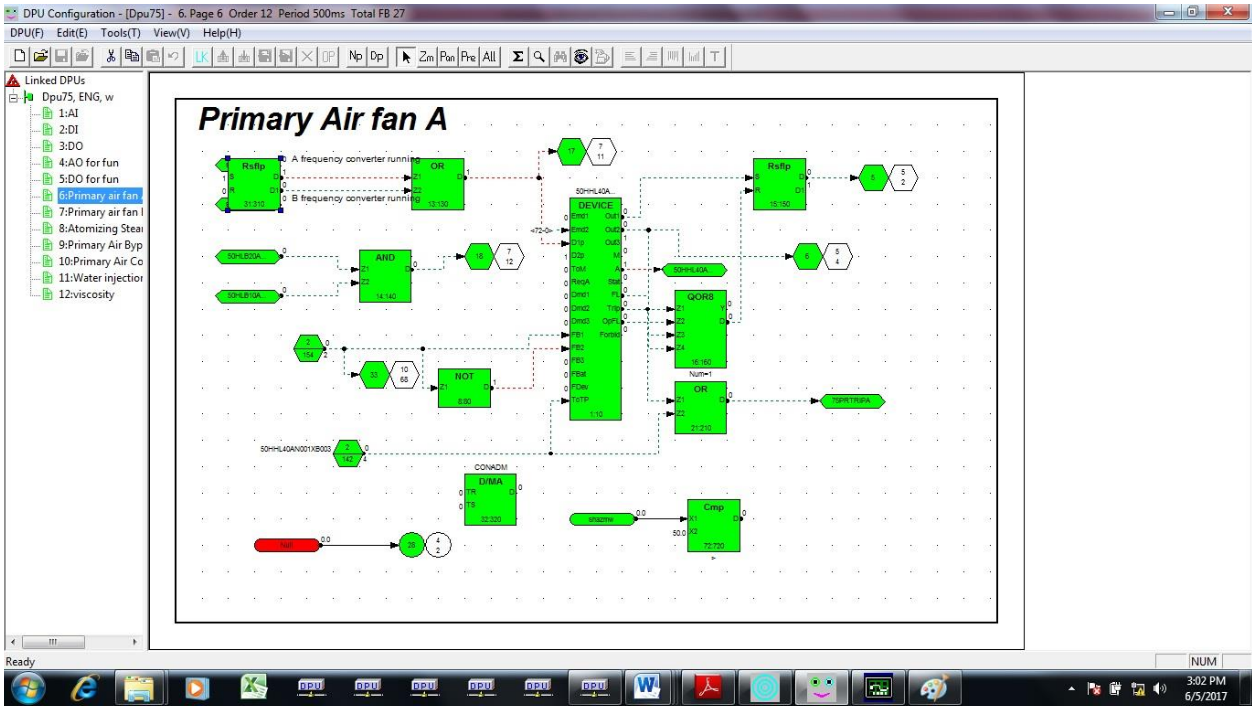

Figure (3-21a) PA fan A configuration

Operator DEVICE is function block configured as PA fan A with logic

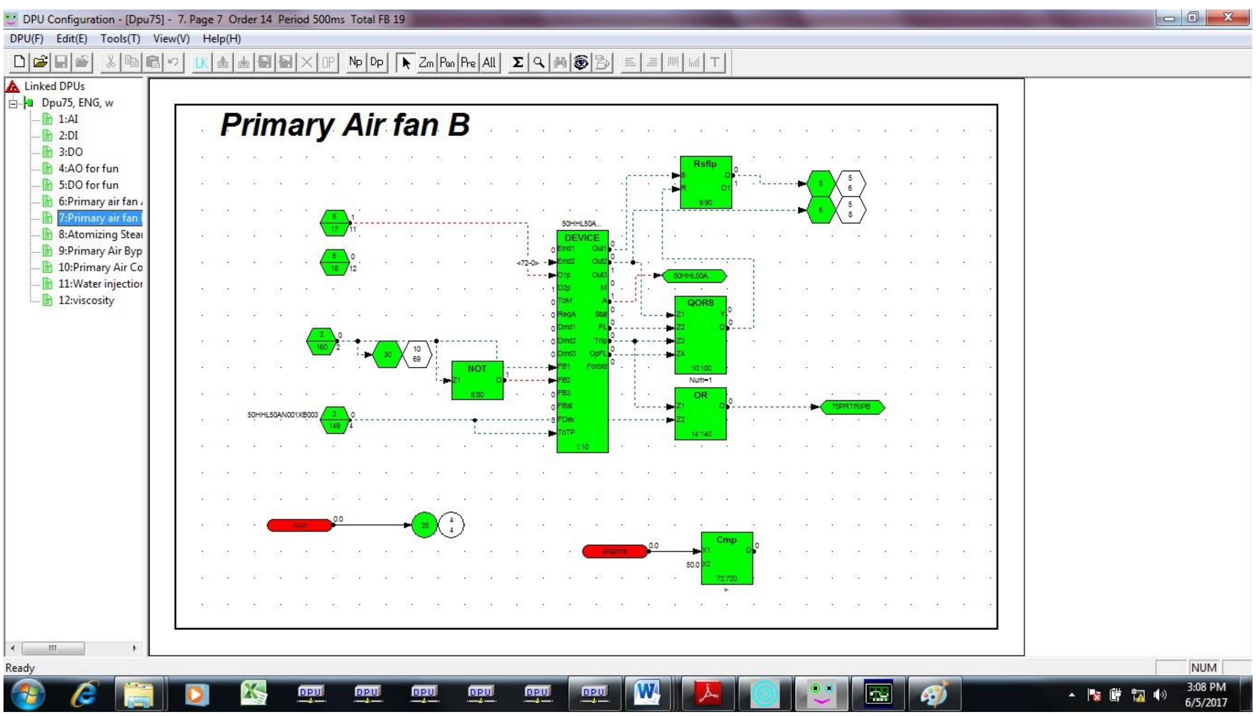

Figure (3-17b) PA fan B configuration

Operator DEVICE is function block configured as PA fan B with logic

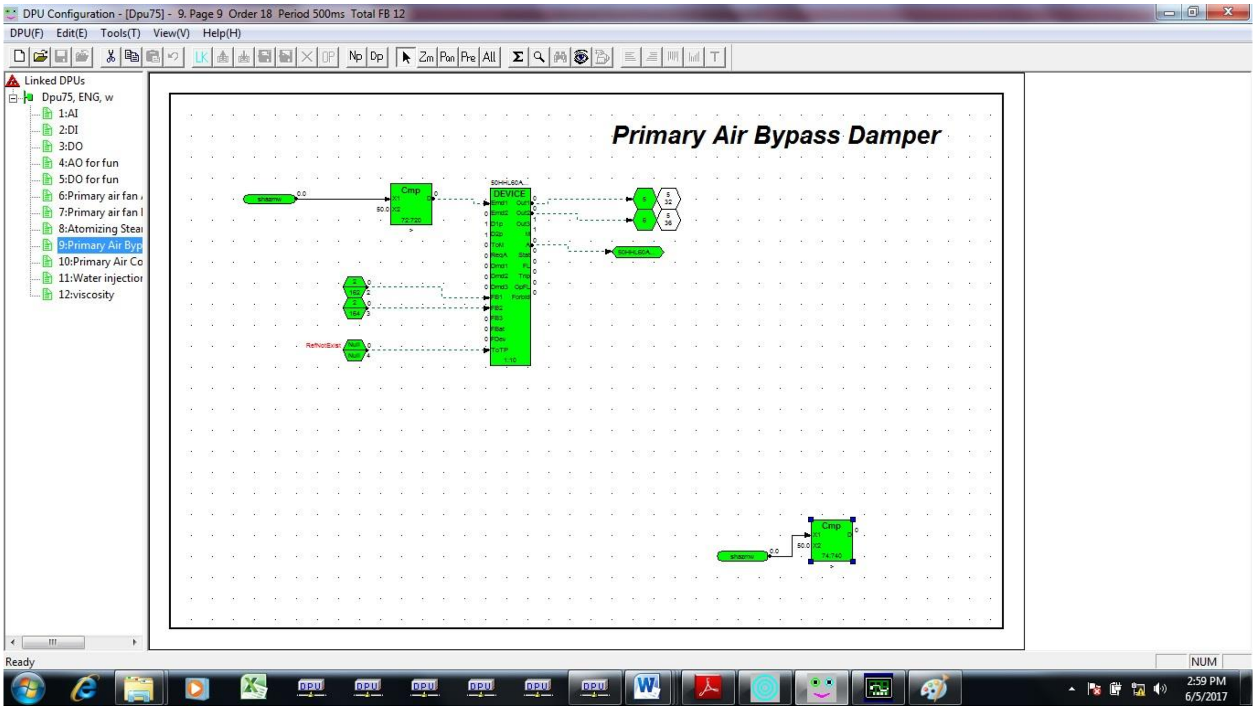

Figure (3-22) PA Bypass damper configuration

Operator DEVICE is function block configured as Bypass damper with logic

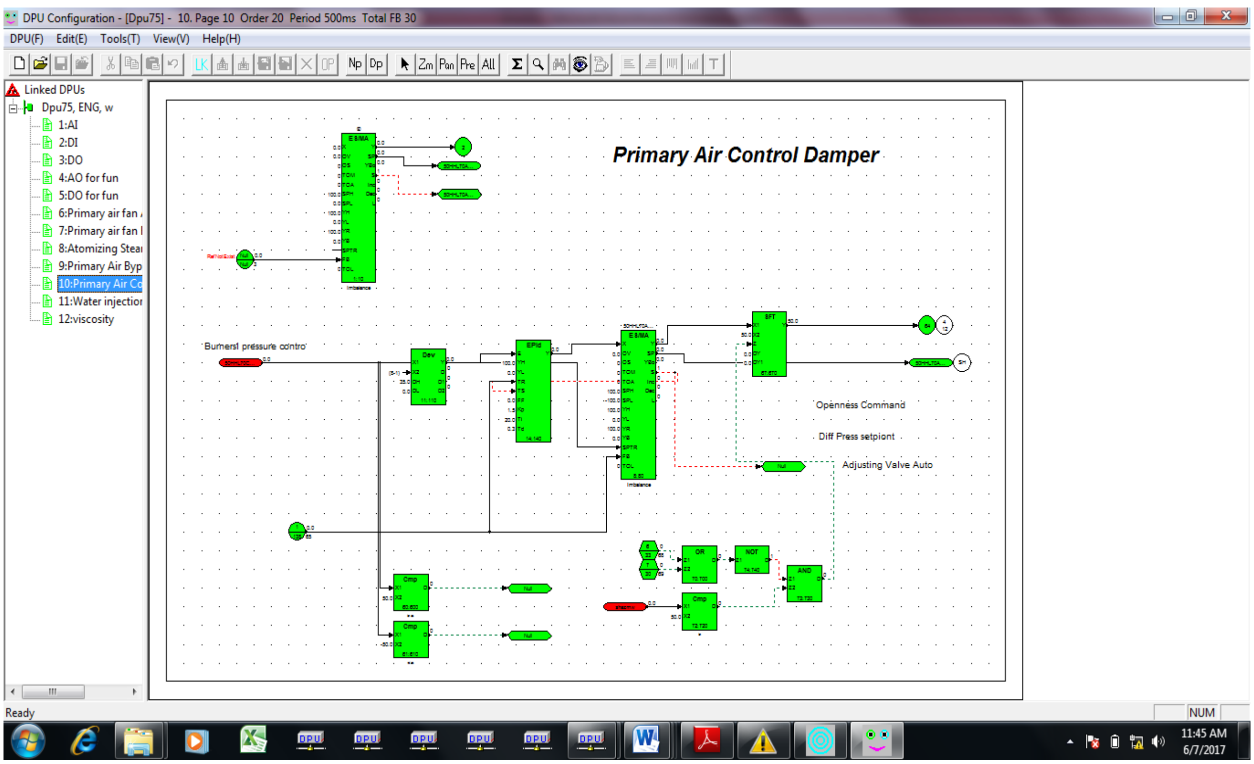

Figure (3-23) PA Control damper configuration

Operator ES/MA is function block configured as Control damper with logic

Air flow is measured by PTF flow sensor which installed in primary air fan downstream, Based on the generation of the deferential pressure by retardation of line within fluid stream.

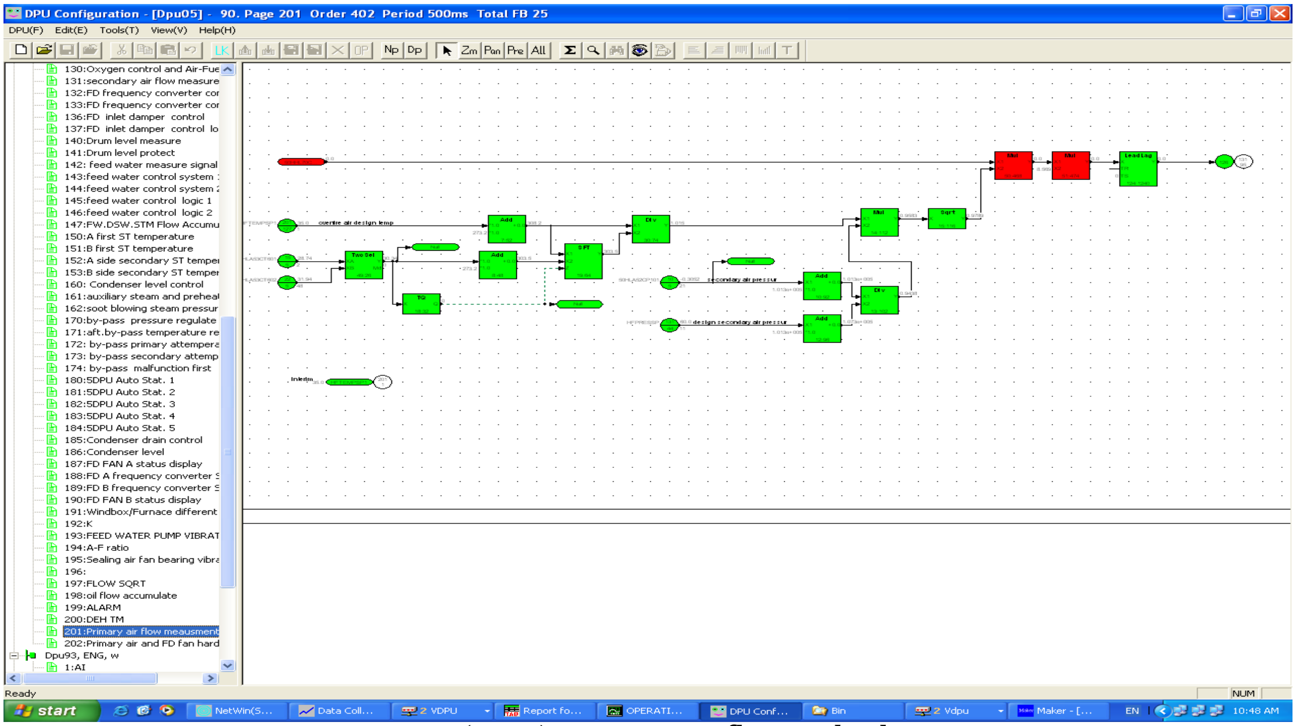

Figure (3-24) PA system flow calculation

Flow calculation with temperature and pressure compensation

3.4.5 Fuel Air Ratio Control (FARC) adaptation

Air to fuel ratio calculation is depend on the total air flow is all three combustion air flows to all burners (two side of secondary hot air and the NEW primary air) Calculation for boiler divided on the total fuel consumption in the firing combustion.

$$Ratio = \frac{\text{Total air flow}}{\text{Total fuel consumption}}$$

Adapt the existing lambda control / alarm / trip with implemented NEW primary air flow Lambda calculation with total combustion air flow.

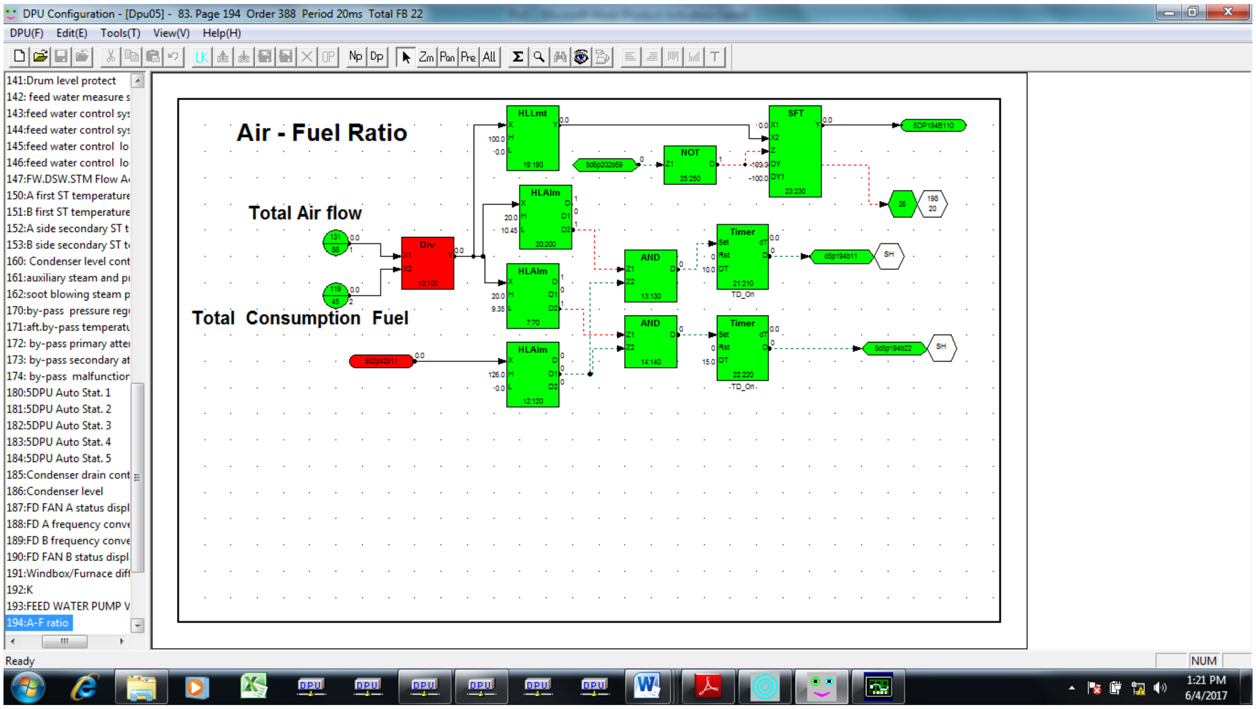

Figure (3-25) Air – fuel ratio calculation

The air - fuel ratio calculated on is page by given the total air flow which is a summation primary air flow and secondary air flow divide on total consumption fuel oil, then take limitation range for boiler protection

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Result and Discussion

The combustion stoichiometric air flow for objective boiler as the designed is 307.732 ton per hour and the total air must be calculated according to the lambda factor for the boiler and our lambda is 1.15 (lambda must be more than one) by using this equation $\lambda = \frac{Maximum\ Air}{\text{stoichiometric air}}$ to find total air flow (under normal conditions) is 353.892, then the excess air percentage is 15 %. For the primary total of it must be less than 8% from the total air combustion is about 28.311 (under normal conditions).

The following table (4-1) is a summary detail of the total combustion air flow under normal operation and normal condition Total stoichiometric air flow and total air flow at 100% maximum continuous rate MCR calculation from boiler manufacture and for the new primary system is not more than 8% taken for calculation primary air flow

4.2 Total combustion air

The total flow of combustion air is summation of the three measured values primary air flow, right side hot secondary air flow and left side hot secondary air flow calculated in DCS; the coming table (4 - 4) shown measuring values when the unit in maximum continuous rate eight burner in service .

Table (4-1) combustion air calculation summarize

Summary of combustion Air in KNPS unit 5		
Total stoichiometric air flow	307732	Nm3/h
Total air flow(under norm conditions)	353892	Nm3/h
Excess air	15	%
Lambda factor	1.15	%
Total primary air ratio	8	%
Total secondary air ratio	92	%

Table (4 -2) combustion air under normal condition

Description	Primary Air	Secondary Air
Ratio from the total air (%)	8	92
Primary air temperature (◦C)	35	235
Total air flow (under norm conditions) (Nm^3/h)	28311	325581
Total air flow (at operating conditions) (Nm^3/h)	31941	605842
Burner air flow (at operating conditions) when seven burner in service (Nm^3/h)	4563	86549
Burner air flow (at operating conditions) all eight burner in service (Nm^3/h)	3993	75730
Total air flow (at operating conditions) when seven burner in service	28311	612842

4.3 Primary air parameters

The flowing table is measuring values demonstrate parameters for the new system added. Primary air data recorded during the trial run commissioning period, readings were taken every five minutes for two hours when the unit in full loads (100 MW). Supply pressure in common ducts to the furnace pressure, pressure in common ducts after control damper for burner’s pressure control and Pre line pressure is DP between common ducts before fans and Furnace, Primary air system parameters measuring value shown on table (4 -3)

4.4 Secondary hot air parameters

The secondary air is heated by air preheater exchange with outlet of the flue gases before distribution on burners. Secondary hot air data recorded during the trial run commissioning period of the new primary air system, readings were taken every five minutes for two hours when the unit in full loads (100 MW), Secondary hot air parameter measuring values shown on table (4 -4)

Table (4 -3) Primary air system parameters measuring value

Primary Air system parameters							
No.	**Time**	**Load (MW)**	**flow (T/h)**	**Temp (C◦)**	**Pre Line (mbar)**	**Supply Pressure (mbar)**	**Control pressure (mbar)**
1	13:05	101.018	16.599	37.981	9.058	42.08	24.349
2	13:10	101.018	16.605	37.449	9.058	42.08	24.349
3	13:15	101.064	16.579	36.969	9.043	42.08	24.349
4	13:20	101.064	16.599	36.878	9.043	42.08	24.349
5	13:25	101.064	16.599	35.971	9.043	42.08	24.349
6	13:30	101.064	16.569	34.804	9.043	42.08	24.349
7	13:35	100.958	16.702	34.04	9.043	42.08	24.349
8	13:40	100.958	16.726	34.182	9.043	42.08	24.349
9	13:45	100.958	16.696	34.61	9.043	42.08	24.349
10	13:50	100.958	16.935	35.763	9.043	42.08	24.349
11	13:55	101.018	16.905	37.462	9.043	42.08	24.349
12	14:00	101.231	16.798	39.006	9.461	42.08	24.168
13	14:05	101.338	16.896	39.928	9.404	42.08	24.232
14	14:10	101.475	16.778	40.799	10.447	42.08	23.826
15	14:15	101.094	16.687	42.814	11.071	42.08	23.314
16	14:20	101.064	16.737	43.412	9.04	42.08	24.229
17	14:25	101.155	16.737	44.31	8.996	42.08	24.158
18	14:30	101.246	16.615	42.905	8.996	42.08	24.158
19	14:35	101.246	16.613	42.45	8.996	42.08	24.158
20	14:40	101.140	16.763	42.268	8.996	42.08	24.158
21	14:45	101.140	16.792	41.917	8.996	42.08	24.158
22	14:50	101.246	16.635	41.527	8.996	42.08	24.158
23	14:55	101.186	16.617	41.371	10.069	42.08	24.244
24	15:00	100.958	16.598	38.955	9.043	42.08	24.349

Table (4 -4) Secondary hot air parameter measuring values

Secondary hot air system parameters								
No.	**Time**	**Load (MW)**	**Right side wind-box**			**Left side wind-box**		
			flow (T/h)	Temp (C◦)	Pressure (mbar)	flow (T/h)	Temp (C◦)	Pressure (mbar)
1	13:05	101.018	153.757	235.243	36.512	153.727	213.149	35.131
2	13:10	101.018	153.757	235.317	36.512	153.727	213.223	35.131
3	13:15	101.064	153.833	235.317	36.512	153.727	213.223	35.131
4	13:20	101.064	153.833	235.317	36.512	153.727	213.223	35.131
5	13:25	101.064	153.833	235.317	36.512	153.727	213.223	35.131
6	13:30	101.064	153.833	235.317	36.512	153.727	213.223	35.131
7	13:35	100.958	153.833	235.25	36.665	153.727	213.118	35.169
8	13:40	100.958	153.833	235.241	36.665	153.727	213.11	35.169
9	13:45	100.958	153.833	235.241	36.665	153.727	213.11	35.169
10	13:50	100.958	153.97	235.246	36.634	153.355	213.152	35.108
11	13:55	101.018	153.97	235.212	36.634	153.355	213.194	35.108
12	14:00	101.231	154.308	235.179	37.031	154.718	213.161	35.467
13	14:05	101.338	153.066	235.222	36.817	153.417	213.166	35.505
14	14:10	101.475	154.599	235.188	36.482	154.022	213.169	35.406
15	14:15	101.094	152.913	235.281	36.634	154.089	213.225	35.055
16	14:20	101.064	153.806	235.201	36.565	153.992	213.221	35.192
17	14:25	101.155	153.806	235.201	36.565	153.992	213.221	35.192
18	14:30	101.246	152.993	235.177	36.863	153.049	213.234	35.406
19	14:35	101.246	152.993	235.177	36.863	153.049	213.234	35.406
20	14:40	101.140	154.213	235.239	36.726	153.872	213.221	35.177
21	14:45	101.140	154.213	235.239	36.726	153.872	213.221	35.177
22	14:50	101.246	152.993	235.177	36.863	153.049	213.234	35.406
23	14:55	101.186	152.661	235.273	36.665	151.969	213.293	34.857
24	15:00	100.958	153.833	235.241	36.665	153.727	213.11	35.169

Table (4 -5) Total combustion air measuring values

Total air Combustion						
No.	**Time**	**Load (MW)**	**Primary air**	**Secondary air right side**	**Secondary air left side**	**Total air**
1	13:05	101.018	16.599	153.757	153.727	324.083
2	13:10	101.018	16.605	153.757	153.727	324.089
3	13:15	101.064	16.579	153.833	153.727	324.139
4	13:20	101.064	16.599	153.833	153.727	324.159
5	13:25	101.064	16.599	153.833	153.727	324.159
6	13:30	101.064	16.569	153.833	153.727	324.13
7	13:35	100.958	16.702	153.833	153.727	324.262
8	13:40	100.958	16.726	153.833	153.727	324.286
9	13:45	100.958	16.696	153.833	153.727	324.256
10	13:50	100.958	16.935	153.97	153.355	324.261
11	13:55	101.018	16.905	153.97	153.355	324.23
12	14:00	101.231	16.798	153.827	154.914	325.539
13	14:05	101.338	16.896	153.207	153.563	323.666
14	14:10	101.475	16.778	154.455	155.926	327.159
15	14:15	101.094	16.687	153.793	152.428	322.908
16	14:20	101.064	16.737	154.087	153.933	324.757
17	14:25	101.155	16.737	153.806	153.992	324.535
18	14:30	101.246	16.615	152.993	153.049	322.657
19	14:35	101.246	16.613	152.993	153.049	322.655
20	14:40	101.140	16.763	154.213	153.872	324.848
21	14:45	101.140	16.792	154.213	153.872	324.877
22	14:50	101.246	16.635	152.993	153.049	322.677
23	14:55	101.186	16.617	153.274	153.465	323.356
24	15:00	100.958	16.598	153.833	153.727	324.158

4.5 Burners wind box pressure measurement

The flowing table is measuring values of combustion air pressure (**mbar**) in burner wind box recorded during the trial run commissioning period readings were taken every five minutes for two hours when the unit in full load (100 MW) by the installed pressure transmitter in each burner and according to measured values we obtain that distribution of the combustion air on the burners is equalize or convergent. The main function of these pressure transmitters to confirm that the sufficient pressure to help pushing fuel into the furnace get good combustion and perfect fire performance, combustion air pressure measuring values in each burner shown on table (4- 6).

4.6 Fuel Oil parameter measurement

The fuel oil which is used in our objective boiler is heavy fuel oil or furnace oil which is a fraction obtained from petroleum distillation (residual product) with high viscosity (mm2/s or (cSt)) so fuel oil must be heated to decrease viscosity (at temperature 50 C◦ viscosity is about 700 mm2/s and at 100 C◦ is about 55 mm2/s), also for atomizing fuel steam pressure of air pressure used around (8 to 11 bar). The supply fuel oil flow measured in ton per hour (T/h) and the flowing table recorded when the unit in full load (100 MW), supply oil parameters measuring values shown on table (4 -7).

Table (4 -6) combustion air pressure measuring values in each burner

		Burner A	**Burner B**	**Burner C**	**Burner D**	**Burner E**	**Burner F**	**Burner G**	**Burner H**
No.	**Time**								
1	13:05	34.662	46.458	34.526	33.327	33.344	33.202	33.37	33.19
2	13:10	34.662	46.458	34.526	33.327	33.344	33.202	33.37	33.19
3	13:15	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
4	13:20	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
5	13:25	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
6	13:30	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
7	13:35	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
8	13:40	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
9	13:45	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
10	13:50	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
11	13:55	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
12	14:00	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19
13	14:05	35.076	50.212	34.806	33.964	33.822	33.434	33.786	33.606
14	14:10	34.601	38.919	34.452	33.681	33.458	33.245	33.357	33.336
15	14:15	34.741	62.116	34.73	33.86	33.745	33.412	33.666	33.474
16	14:20	34.865	61.485	34.775	33.665	33.67	33.309	33.515	33.501
17	14:25	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
18	14:30	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
19	14:35	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
20	14:40	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
21	14:45	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
22	14:50	34.989	61.489	34.95	33.957	33.715	33.52	33.713	33.609
23	14:55	34.851	55.577	34.603	33.676	33.441	33.244	33.403	33.27
24	15:00	34.585	46.458	34.526	33.327	33.344	33.143	33.37	33.19

Table (4 -7) supply oil parameters measuring values

Heavy fuel oil parameter						
No.	**Time**	**Load (MW)**	**Flow** (T/h)	**Pressure Bar**	**Temp** (C◦)	**Viscosity mm2/s (cSt)**
1	13:05	101.018	27.728	12.978	131.344	127.65
2	13:10	101.018	27.719	12.984	131.249	127.64
3	13:15	101.064	27.719	12.984	131.249	127.64
4	13:20	101.064	27.719	12.984	131.249	127.63
5	13:25	101.064	27.719	12.984	131.249	127.64
6	13:30	101.064	27.719	12.984	131.249	127.62
7	13:35	100.958	27.734	12.984	131.181	127.62
8	13:40	100.958	27.728	12.984	131.181	127.63
9	13:45	100.958	27.728	12.984	131.181	127.62
10	13:50	100.958	27.722	12.975	131.181	127.62
11	13:55	101.018	27.722	12.975	131.181	127.64
12	14:00	101.231	27.798	13.009	131.100	127.61
13	14:05	101.338	27.731	13.021	131.086	127.72
14	14:10	101.475	27.728	13.012	131.615	127.57
15	14:15	101.094	27.717	13.039	132.387	126.89
16	14:20	101.064	27.711	13.042	132.821	126.76
17	14:25	101.155	27.711	13.042	132.821	126.77
18	14:30	101.246	27.714	13.042	132.862	126.75
19	14:35	101.246	27.714	13.042	132.862	126.76
20	14:40	101.14	27.789	13.03	132.889	126.73
21	14:45	101.14	27.789	13.03	132.889	126.72
22	14:50	101.246	27.714	13.042	132.862	126.74
23	14:55	101.186	27.795	13.055	132.008	126.97
24	15:00	100.958	27.728	12.984	131.181	127.64

4.7 Burners Oil consumption measurement

The flowing table is measuring values of oil flow ton per hour (T/h) recorded during the trial run commissioning period readings were taken every five minutes for two hours when the unit in full load (100 MW) by the installed flow meter in each burner and according to measured values we obtain that oil consumption on the burners is equalize or around. The main function of these flow meters to confirm that the cleanness of burner gun to get perfect performance, oil flow measuring values in each burners shown on table (4 -8).

4.8 Air fuel ratio

A Stoichiometric AFR has the correct amount of air and fuel to produce a chemically complete, the air fuel ratio is one of the boiler stop condition when it will be less than the setting value.

The flowing table is calculation values of air to fuel ration on DCS taken every five minutes for two hours for comparing with previse ration, air –fuel ratio measuring values shown on table (4 -9).

4.9 Oxygen content

One of the good fire indictor is oxygen content in outlet of the boiler flue gas, during the combustion process; NOx is one of the primary pollutants emitted into the atmosphere because of high temperatures and the availability of oxygen and nitrogen from both the air and fuel, the peak flame temperature by reducing the oxygen concentration.

Combustion efficiency is a measure of the chemical energy available in fuel that is liberated by the combustion process. Quantifying combustion efficiency involves determining by losses from unburned carbon and hydrocarbons in the flue gas (CO).

Table (4 -8) oil flow measuring values in each burners

No.	Time	Burner A	Burner B	Burner C	Burner D	Burner E	Burner F	Burner G	Burner H	Total flow
1	13:05	3.511	3.506	3.448	3.466	3.442	3.505	3.485	3.318	27.681
2	13:10	3.514	3.511	3.452	3.466	3.442	3.507	3.483	3.319	27.694
3	13:15	3.513	3.508	3.456	3.471	3.441	3.507	3.483	3.319	27.698
4	13:20	3.513	3.509	3.449	3.471	3.442	3.506	3.485	3.322	27.697
5	13:25	3.511	3.508	3.449	3.470	3.443	3.507	3.484	3.322	27.694
6	13:30	3.512	3.508	3.450	3.470	3.443	3.507	3.483	3.321	27.694
7	13:35	3.512	3.507	3.450	3.469	3.442	3.506	3.483	3.322	27.691
8	13:40	3.509	3.508	3.451	3.469	3.443	3.506	3.482	3.323	27.691
9	13:45	3.510	3.509	3.451	3.470	3.443	3.507	3.483	3.323	27.696
10	13:50	3.510	3.510	3.452	3.471	3.442	3.507	3.483	3.322	27.697
11	13:55	3.509	3.509	3.452	3.471	3.442	3.508	3.483	3.322	27.696
12	14:00	3.509	3.508	3.451	3.478	3.450	3.506	3.485	3.319	27.706
13	14:05	3.508	3.508	3.451	3.480	3.449	3.506	3.485	3.322	27.709
14	14:10	3.508	3.509	3.452	3.477	3.449	3.508	3.484	3.322	27.709
15	14:15	3.511	3.509	3.452	3.473	3.448	3.506	3.485	3.323	27.707
16	14:20	3.511	3.510	3.449	3.473	3.447	3.507	3.483	3.321	27.701
17	14:25	3.509	3.510	3.449	3.471	3.448	3.507	3.483	3.321	27.698
18	14:30	3.510	3.511	3.450	3.470	3.448	3.506	3.483	3.319	27.697
19	14:35	3.510	3.509	3.450	3.469	3.449	3.506	3.482	3.320	27.695
20	14:40	3.508	3.508	3.451	3.469	3.450	3.508	3.483	3.320	27.697
21	14:45	3.508	3.509	3.450	3.470	3.450	3.509	3.484	3.322	27.702
22	14:50	3.509	3.511	3.449	3.470	3.449	3.510	3.485	3.322	27.705
23	14:55	3.509	3.510	3.449	3.471	3.448	3.510	3.485	3.323	27.705
24	15:00	3.510	3.510	3.451	3.471	3.449	3.510	3.483	3.319	27.703

Table (4 -9) air –fuel ratio measuring values

Air -Fuel ratio before and after Primary air					
No.	**Time**	**Load (MW)**	**Air Fuel ratio Before**	**Air Fuel ratio After**	**Diff**
1	13:05	101.018	11.517	11.688	0.171
2	13:10	101.018	11.533	11.692	0.159
3	13:15	101.064	11.021	11.694	0.673
4	13:20	101.064	11.343	11.695	0.352
5	13:25	101.064	11.384	11.695	0.311
6	13:30	101.064	11.465	11.694	0.229
7	13:35	100.958	11.707	11.692	-0.015
8	13:40	100.958	11.467	11.695	0.228
9	13:45	100.958	11.375	11.694	0.319
10	13:50	100.958	11.38	11.697	0.317
11	13:55	101.018	11.309	11.696	0.387
12	14:00	101.231	11.353	11.711	0.358
13	14:05	101.338	11.253	11.672	0.419
14	14:10	101.475	11.354	11.799	0.445
15	14:15	101.094	11.272	11.651	0.379
16	14:20	101.064	11.357	11.72	0.363
17	14:25	101.155	11.396	11.712	0.316
18	14:30	101.246	11.216	11.643	0.427
19	14:35	101.246	11.316	11.643	0.327
20	14:40	101.14	11.399	11.691	0.292
21	14:45	101.14	11.372	11.691	0.319
22	14:50	101.246	11.284	11.643	0.359
23	14:55	101.186	11.339	11.634	0.295
24	15:00	100.958	11.394	11.691	0.297

Table (4 -10) measuring values of oxygen content

Boiler outlet flue gas O2 capability					
No.	**Time**	**Load (MW)**	**before PA**	**after PA**	**Diff**
1	13:05	101.018	0.02	0.009	0.011
2	13:10	101.018	0.029	0.011	0.018
3	13:15	101.064	0.019	0.011	0.008
4	13:20	101.064	0.019	0.011	0.008
5	13:25	101.064	0.017	0.011	0.006
6	13:30	101.064	0.017	0.011	0.006
7	13:35	100.958	0.019	0.009	0.01
8	13:40	100.958	0.017	0.009	0.008
9	13:45	100.958	0.019	0.009	0.01
10	13:50	100.958	0.019	0.011	0.008
11	13:55	101.018	0.017	0.011	0.006
12	14:00	101.231	0.017	0.011	0.006
13	14:05	101.338	0.018	0.009	0.009
14	14:10	101.475	0.019	0.009	0.01
15	14:15	101.094	0.017	0.013	0.004
16	14:20	101.064	0.018	0.009	0.009
17	14:25	101.155	0.013	0.009	0.004
18	14:30	101.246	0.013	0.011	0.002
19	14:35	101.246	0.011	0.011	0
20	14:40	101.14	0.013	0.009	0.004
21	14:45	101.14	0.013	0.009	0.004
22	14:50	101.246	0.011	0.011	0
23	14:55	101.186	0.011	0.011	0
24	15:00	100.958	0.011	0.009	0.002

4.10 Exhaust temperature

In particularly corrosive environments such as those where low-temperature flue gas is present, corrosion-resistant materials are sometimes specified to minimize or avoid corrosion damage, in the flowing table we observe flue gas temperature reduced about 4 degree averages in the chimney, measuring values of flue gas outlet temperature shown on Table (4 -11).

4.11 Boiler vibration

Boiler nose caused combination of vibration humming from the air trapped within the boiler.

Boiler vibration is reduced due to primary air adding when the secondary damper openings due to the air flow.

4.12 Summary

From the recoded data and comparison between the new measuring parameters values and previse values appear that indications of enhancing happen as follow:

- The air – fuel ratio increasing value 0.673 than the previse value,
- Decreasing of outlet gas temperature in one to six degree for the previse value,
- Also Oxygen content in out let gas was decrease between the range 0.002 and 0.011 from the previse values
- No abnormal sound happen during burners startup and vibration minimize about 0.213mm/s form the previse value.

Table (4 -11) measuring values of flue gas outlet temperature

Boiler outlet flue gas Temp.					
No.	**Time**	**Load (MW)**	**Before PA**	**After PA**	**Diff**
1	13:05	101.018	141.5	138.01	3.47
2	13:10	101.018	142.34	136.07	6.27
3	13:15	101.064	140.63	134.17	6.46
4	13:20	101.064	140.43	132.88	7.54
5	13:25	101.064	140.2	132.85	7.35
6	13:30	101.064	139.65	135.99	3.66
7	13:35	100.958	138.38	137.76	0.62
8	13:40	100.958	139.43	138.24	1.19
9	13:45	100.958	140.27	139.5	0.77
10	13:50	100.958	144.69	138.59	6.1
11	13:55	101.018	143.73	137.74	5.99
12	14:00	101.231	143.65	139	4.65
13	14:05	101.338	142.52	140.44	2.08
14	14:10	101.475	143.12	141.27	1.85
15	14:15	101.094	143.9	142.15	1.75
16	14:20	101.064	143.22	142.55	0.67
17	14:25	101.155	144.07	142.52	1.55
18	14:30	101.246	142.87	143.09	-0.22
19	14:35	101.246	142.68	139.5	3.18
20	14:40	101.14	142.61	138.95	3.66
21	14:45	101.14	142.42	138.46	3.96
22	14:50	101.246	142.3	138.44	3.86
23	14:55	101.186	141.6	137.02	4.58
24	15:00	100.958	140.39	136.48	3.91

Table (4 -12) measuring values of the vibration

Boiler Vibration					
No.	**Time**	**Load (MW)**	**before PA (mm/s)**	**after PA (mm/s)**	**Decreasing value**
1	13:05	101.018	0.247	0.162	-0.085
2	13:10	101.018	0.369	0.156	-0.213
3	13:15	101.064	0.201	0.15	-0.051
4	13:20	101.064	0.197	0.18	-0.017
5	13:25	101.064	0.195	0.156	-0.039
6	13:30	101.064	0.198	0.156	-0.042
7	13:35	100.958	0.174	0.156	-0.018
8	13:40	100.958	0.192	0.159	-0.033
9	13:45	100.958	0.195	0.154	-0.041
10	13:50	100.958	0.191	0.151	-0.04
11	13:55	101.018	0.198	0.157	-0.041
12	14:00	101.231	0.201	0.16	-0.041
13	14:05	101.338	0.273	0.162	-0.111
14	14:10	101.475	0.229	0.168	-0.061
15	14:15	101.094	0.223	0.171	-0.052
16	14:20	101.064	0.218	0.171	-0.047
17	14:25	101.155	0.218	0.169	-0.049
18	14:30	101.246	0.215	0.175	-0.04
19	14:35	101.246	0.195	0.162	0.067
20	14:40	101.14	0.193	0.165	0.072
21	14:45	101.14	0.192	0.166	0.074
22	14:50	101.246	0.196	0.165	0.069
23	14:55	101.186	0.188	0.165	0.077
24	15:00	100.958	0.184	0.163	0.079

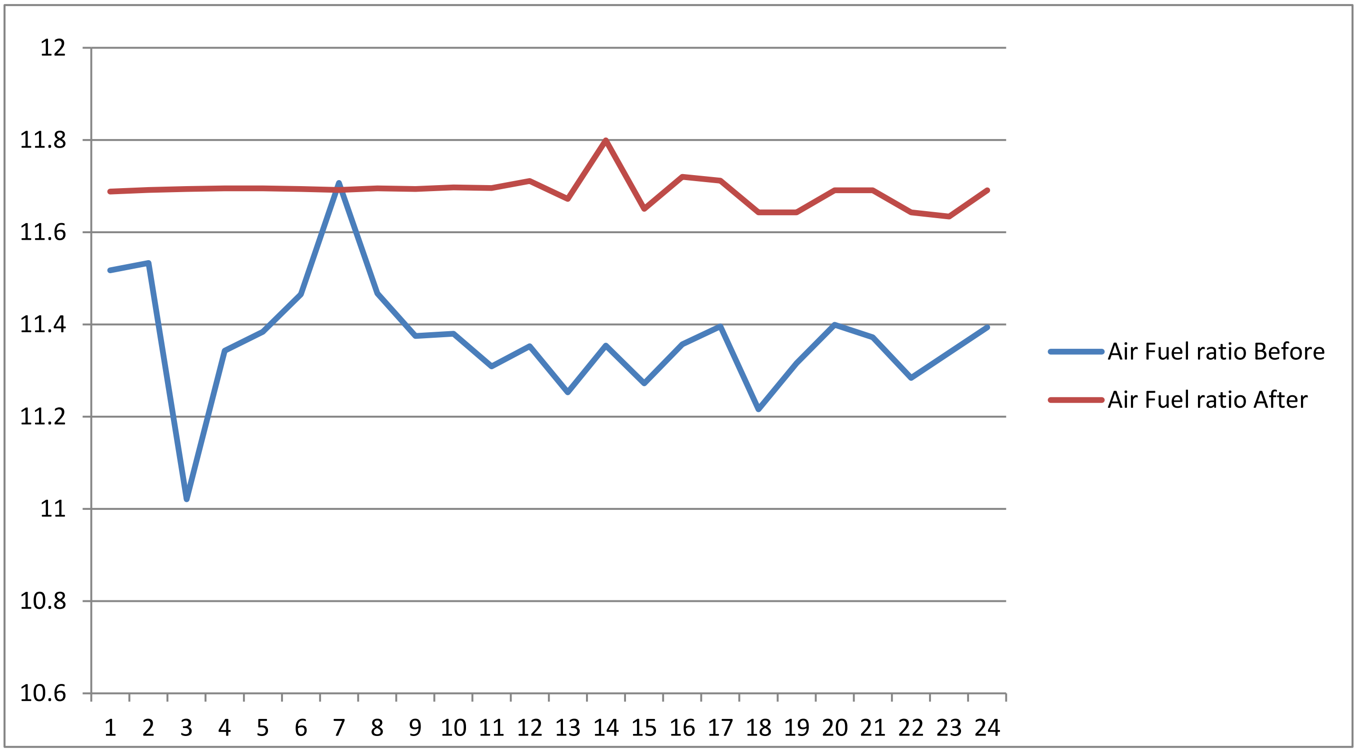

Figure (4-1) comparing carve of air fuel ratio

Reducing atmosphere less oxygen is available as necessary to burn all combustibles and air – fuel ratio increasing value 0.673 than the previse value. .

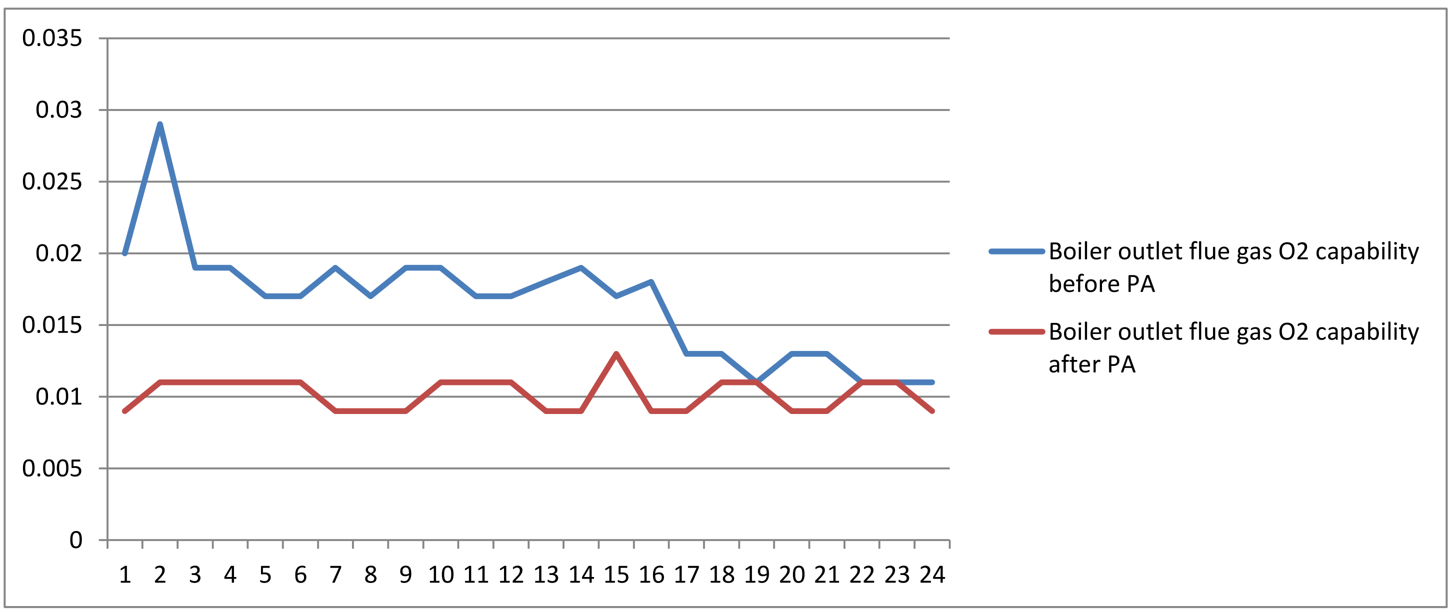

Figure (4-2) comparing oxygen content in outlet flue gas

Also Oxygen content in out let gas was decrease between the range 0.002 and 0.011 from the previse values.

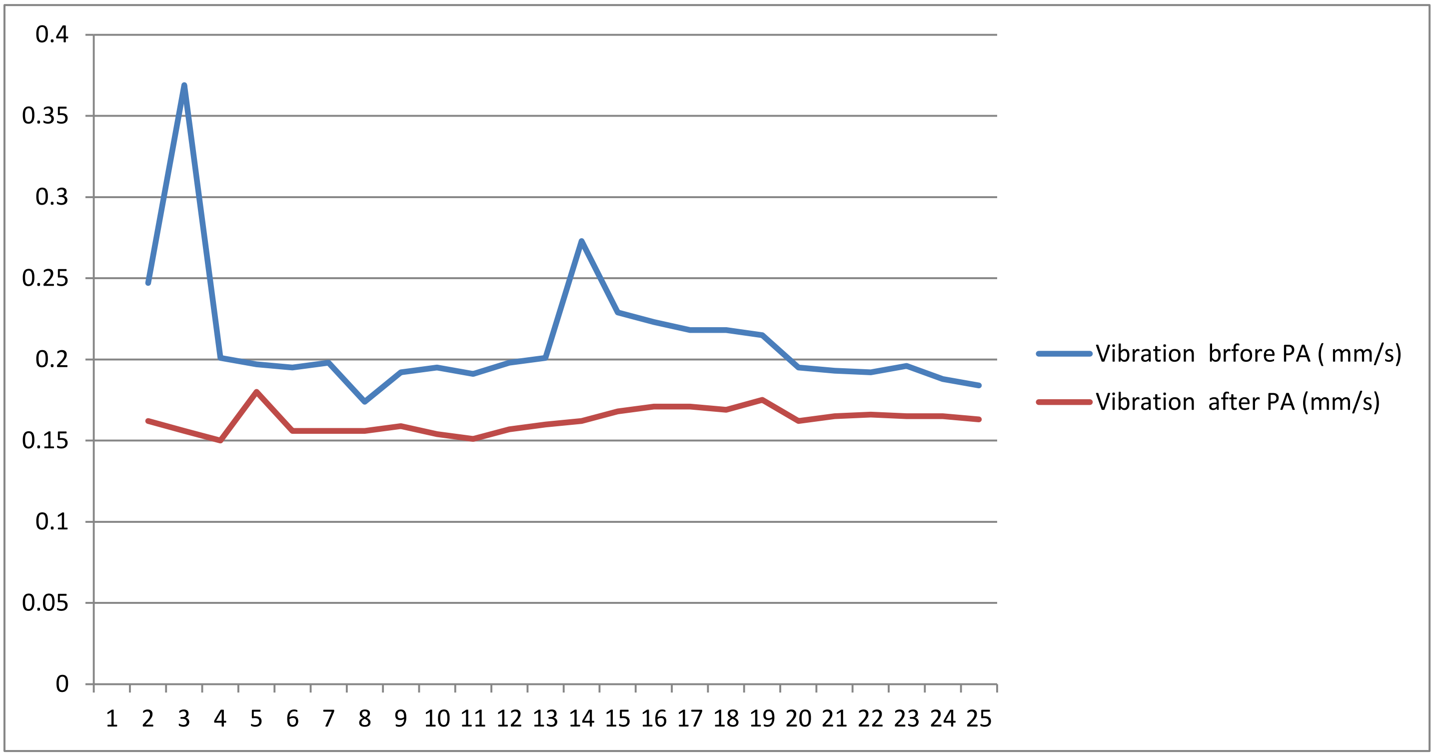

Figure (4-3) comparing boiler vibration

Vibration minimize about 0.213mm/s form the previse value.

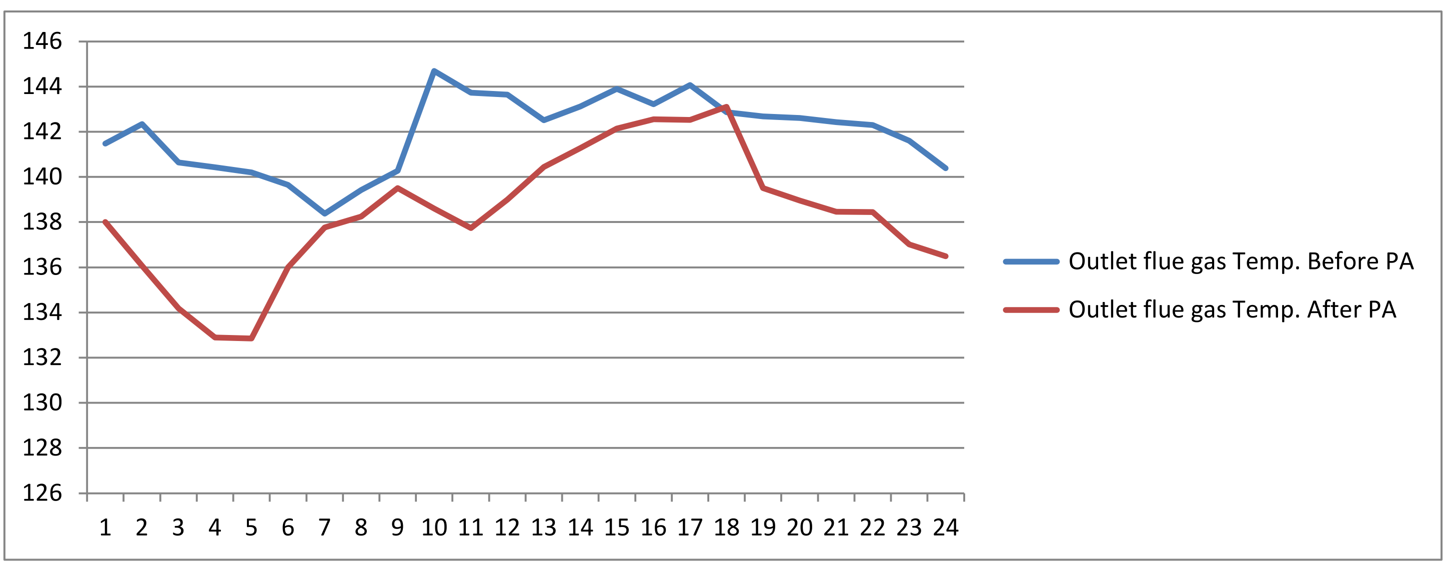

Figure (4-4) comparing boiler outlet flue gas temperature

Decreasing of outlet gas temperature in one to six degree for the previse value,

CHAPTER FIVE

CONCIUSSION AND RECONEDATION

5.1 Conclusion

In this project firing improved primary air system was installed on the boiler field to consummate with the existing secondary air system for combustion air to the boiler in Khartoum North Power Station KNPS – PH3 thermal power units.

The primary air system included two fans installed in parallel and also the bypass damper installed in parallel with fans and it will open when the boiler load is more than 50% of maximum continuous rate.

Oil flow meter installed for each burner for monitoring oil flow individually and insuring the performance and cleanness of the burner tip.

Pressure transmitter installed for each burner for monitoring air pressure at the burner combustion individually to confirm and insure the burners' performance

The fuel to air ratio was adjusted by calculation the total combustion air which is primary air flow adding to the existing secondary hot air flow.

The percentage ratio of primary air flow from the total combustion air flow under norm conditions or operating conditions is about eight percent (8%).

The table (4-2) is a summary detail of the total combustion air flow under normal operation and normal condition at 100% maximum continuous rate MCR calculation include total primary air flow and total secondary air flow when all burner in service and also when one burner out of service.

From the recoded data and comparison between the new measuring parameters values and previse values appear that indications of enhancing happen by air – fuel ratio increasing value 0.673 , decreasing of outlet gas temperature , Oxygen content in out let gas was decrease and vibration minimize about 0.213mm/s.

5.2 Recommendation

1. In primary air system control damper must be not fully close or in the minimum about 25%.
2. Burner purge must be done daily automatically
3. Fuel oil viscosity to be less than 110 cSt and viscosity meter to be install
4. Fuel oil temperature in range (120 C◦ to 125 C◦) in front of the boiler or near the burner control automatically.
5. The different pressure between atomizing pressure and fuel oil pressure at the burner in rage 1 to 1.5 bar and automatically tracing.

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Appendix