SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
DEPARTMENT OF POWER

EFFECT OF LOAD VARIATION ON STEAM UNIT

تأثير اختلاف الحمل علي وحدة البخارية

A project Submitted in Partial Fulfillment for the Requirements of the Degree B.Eng.(Honor) In Mechanical Engineering

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October 2017

الآيـة

قال تعالي:

{قُلِ انظُرُواْ مَاذَا فِي السَّمَاوَاتِ وَالأَرْضِ وَمَا تُغْنِي الآيَاتُ وَالنُّذُرُ عَن قَوْمٍ لاَّ يُؤْمِنُونَ }

التوبة الآية (101)

A word of thanks and fulfillment.

The candles that melted in pride……...

To illuminate every step in our path……..

To overcome every obstacle ahead……..

They were messengers for science and ethics……….

Thank you everyone………

Can someone to thank Sun for she lit the world……..

But I'll try reply part of returning to be as humane upstairs before….

I was professionally thank and honour and appreciation for

Dr. Tawfiq Ahmed Gamal to Gallic Golden advice guidance and patience is nice all the friendliness

respect for science and knowledge Castle Sudan University of science and technology, Faculty of engineering.

All due honour and discretion of the Mechanical Engineering Department-Department capability.

And sincere thanks and appreciation to all employees at the Naval Station. Particularly efficient and operational sections for their ability to provide all the information and assistive devices. And in particular,

Eng. Zaheer Mohamed AL Sheikh.

We also thank the National Center of control to make artificial limbs in what we are.

Dedication

A research into the cupcake is the dedication to our leader and teacher of good human Messenger of Allah Mohamed, Allah bless him

Handed over to the stake of his heart. ….

It has protected me with his wisdom and gave to his affection.

And held me with his heart and his soul.

To sighing and feed me. And usury.

Here's my dad ". Mommy and Daddy dearest to my brothers and my family and dear friends.

ABSTRACT:-

The steam power plant generally is assemblies of systems convert chemical energy of the (coal, oil, gas) into mechanical energy in a turbine and transmission to generate electricity.

The load on a power station varies from time to time due to uncertain demands of the consumers and is known as variable load on the station.

Most equipment we produce today uses this energy because it's easy generate and transform from one kind of energy to another also we can control it, power parameters effect on equipment electrical while the frequency is raise the equipment motion high speed (vibrations) and when frequency is little the equipment no motion let the power convert to thermal energy **.**

The objective of this study is to identify Reasons of load variation, Unit component effect when load variation occurs their effect per thermal efficiency, Steady working of steam unit under variable load and operation of steam unit to yield electricity.

In this project, studied important parts in steam power plant and the effect of load variation on the thermal station in general, and especially the units of the Boiler and turbine , this study implemented in Bahri thermal power station(Unit Six).

The main problem to be studied in this project represented in is the effect of load variation on some components of the thermal unit and efficiency of its components The efficiency of the boiler and the turbine was calculated and found to vary with the load variation for reasons to be highlighted later.

The most important recommendations of this study Use simulations programs to find the Momentariness of efficiency, Calculate the boiler efficiency by indirect method, Enter the pressure less heaters in turbine efficiency calculate, Calculate the average to values which is taken form history data.

ملخص الدراسة

محطة توليد الطاقة البخارية عموما هي مجموعة نظم تحول الطاقة الكيميائية في (الفحم والنفط والغاز) الي طاقة ميكانيكية في التوربين وتنقل لتوليد الكهرباء.

الحمل على محطة القدرة يختلف من وقت لآخر بسبب الطلبات غير المحددة من المستهلكين ويعرف باسم الحمل متغير على المحطة.

معظم المعدات التي ننتجها اليوم تستخدم هذه الطاقة، تأثر عوامل القدرة على الأجهزة الكهربائية فعندما يزيد التردد تزيد سرعة حركة هذه الأجهزة (الاهتزازات) وعندما يقل التردد تقل سرعة حركتها و قد تنعدم وبالتالي تحولت الطاقة الكهربائية الي طاقة حرارية.

الهدف من هذه الدراسة هو التعرف على أسباب اختلاف الحمل، تأثير بعض مكونات الوحدة عندما يتغير الحمل التأثير محسوب بالكفاءة ، عمل مستقر لوحدة البخار تحت حمل متغير وتشغيل وحدة البخار لإنتاج الكهرباء.

في هذا المشروع، تم دراسة الأجزاء مهمة في محطة توليد القدرة البخارية وتأثير اختلاف الحمل على المحطة البخارية بشكل عام، وخاصة وحدتي الغلاية والتوربين، وقد نفذت هذه الدراسة في محطة بحري الحرارية (الوحدة السادسة).

المشكلة الرئيسية التي يتم دراستها في هذا المشروع تتمثل في تأثير اختلاف الحمل على بعض مكونات الوحدة البخارية وكفاءة تلك المكونات ,تم حساب كفاءتي الغلاية والتوربين وتبين أنها تختلف مع اختلاف الحمل لأسباب يتم إلقاء الضوء عليها لاحقا.

أهم التوصيات من هذه الدراسة استخدام برامج المحاكاة للحصول على الكفاءة اللحظية، حساب كفاءة الغلاية بالطريقة غير المباشرة، إدخال سخانات الضغط المنخفض في حساب كفاءة التوربين .

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Chapter One

(Introduction)

Introduction

1.1 General overview:-

The steam power plant generally is assemblies of systems convert chemical energy of the (coal, oil, gas) into mechanical energy in a turbine and transmission to generate electricity, i.e., power with Economy and requirements. The power plant itself must be useful economically and environmental Friendly to the society. The power plants consists of pump, boiler, turbine and condenser .Also its consists to some equipment which is increasing the efficiency.
The load on a power station varies from time to time due to uncertain demands of the consumers and is known as variable load on the station. When the load changes, the frequency of the system also varies. A power station is designed to meet the load requirements of the consumers.

1-2 problem statement:-

The load variation effect on Electrical Network steady this always cause blackout on the plant, or the work become unsteady especially in the summer season.

1.3 Importance of the project:-

In all the world the supply electrical energy must be stable (constant parameters). Most equipment we produce today uses this energy because it's easy generate and transform from one kind of energy to another also we can control it, power parameters effect on equipment electrical while the frequency is raise the equipment motion high speed (vibrations) and when frequency is little the equipment no motion let the power convert to thermal energy **.**

1.4 Objectives of the project:-

- Reasons of load variation
- Unit component effect when load variation occurs their effect per thermal efficiency.
- Steady working of steam unit under variable load.
- operation of steam unit to yield electricity.

1.5 Methodology:-

In order to reach to the objectives of our project, collected data from the scientific references and scientific websites on the Web and Obtained on Basic data from Bahri power thermal station, and then through the analysis and calculations for different values by Matlab program , and then showed the effect of load variation on the station in general and, some of its components especially.

1.6 Project Layout :-

This research is divided into five chapters. Chapter 1 addresses the general background, declaration of the problem statement and discussion of the objectives and importance of project. Chapter 2 presents the literature survey; with focus on variable load. This chapter also reviews the previously published works of researchers related to this study. Chapter 3 explains the methodology by taken basic data from Bahri thermal station. Chapter 4 is showing the results obtained from the station and compared with ideal values and used matlab program. Chapter 5 is included the Conclusion and Recommendation.

Chapter Two

(Theoretical Study & Previous Study)

Theoretical Study:-

2.1 Preface:-

Thermal power generation plant or thermal power station is the most conventional source of electric power. Thermal power plant is also referred as coal thermal and steam turbine power plant[1].

a plant designed to convert the heat from the combustion of a fuel into mechanical energy by means of steam. Mechanicalenergy is generally not the end product of a steam power plant but is transformed by electric generators into electric power,which is then transmitted to consumers.[2]

The main components of a thermal/steam power plant are: Pump, boiler, steam turbine, condenser and generator.[3]

The theory of thermal power station or working of thermal power station is very simple. A power generation plant mainly consists of alternator runs with help of steam turbine. The steam is obtained from high pressure boilers .the steam is produced in high pressure in the steam boiler due to burning of fuel (pulverized coal) in boiler furnaces. This steam is further supper heated in a super heater. This supper heated steam then enters into the turbine and rotates the turbine blades. The turbine is mechanically so coupled with alternator that its rotor will rotate with the rotation of turbine blades. After entering in turbine the steam pressure suddenly falls and corresponding volume of the steam increases. After imparting energy to the turbine rotor the steam passes out of the turbine blades into the condenser. In the condenser the cold water is circulated with the help of pump which condenses the low pressure wet steam. This condensed water is further supplied to low pressure water heater where the low pressure steam increases the temperature of this feed water, it is again heated in high pressure [1].

Power plant has advantages like Fuel used is cheaper, Smaller space is required compared to hydro power plant, Economical in initial cost compared to hydro plants and running costs are less compared to gas plants or diesel plants.[4]

And Disadvantages Thermal plant are less efficient than diesel plants Starting up the plant , bringing into service takes more time, Cooling water required is more and Space required is more And others.[5]

Fig(2.1) shows the main parts of the steam power plant.

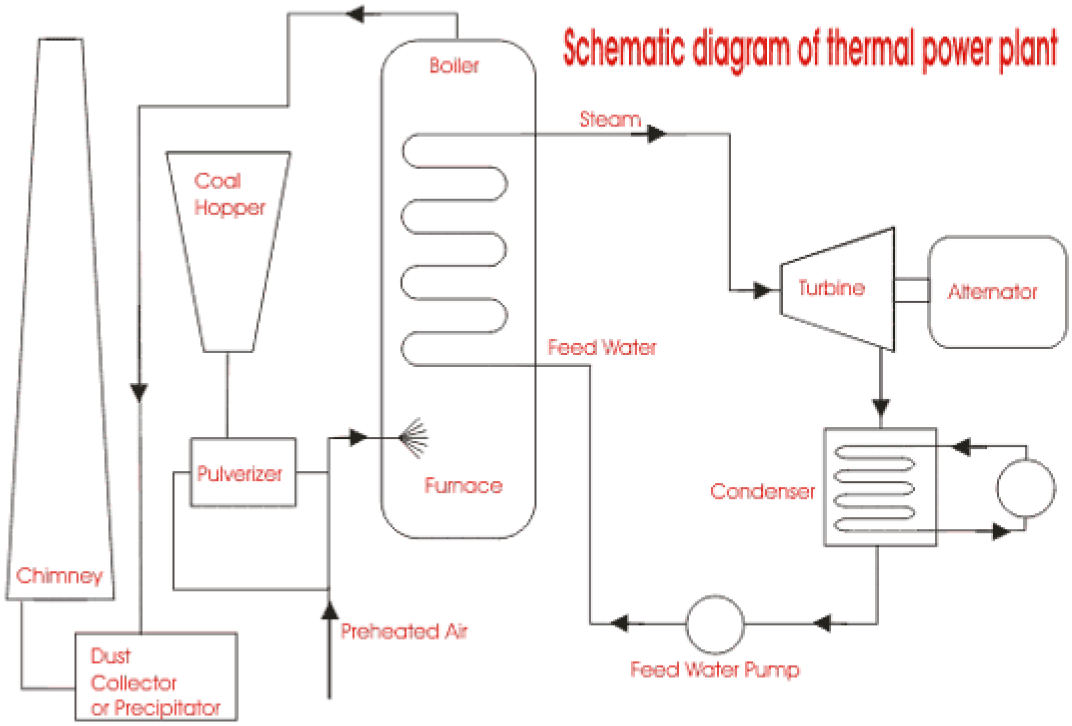


Figure 2.1: Diagram of the steam power plant

•The main parts of the steam power plant :-

2.2 The Generator:-

Synchronous generators convert mechanical power to electrical power. [6]

The rotational speed must remain constant to maintain a steady frequency. At speed, rotor poles turn in synchronism with the stator rotating electromagnetic poles, torque being transmitted magnetically across the “air gap” power angle, lagging in generators.

The rotating rotor pole magnetism generates voltage in the stator winding which delivers power to an electric load. The characteristics of all synchronous machines when their stator terminals are short-circuited are Similar. [7]

A direct current (DC) is applied to the rotor winding of a synchronous generator to produce the rotor magnetic field. A prime mover rotates the generator rotor to rotate the magnetic field in the machine. A three-phase set of voltages is induced in the stator windings by the rotating magnetic field. The rotor is a large electromagnet. Its magnetic poles can be *salient* (protruding or sticking out from the surface of the rotor). [8]

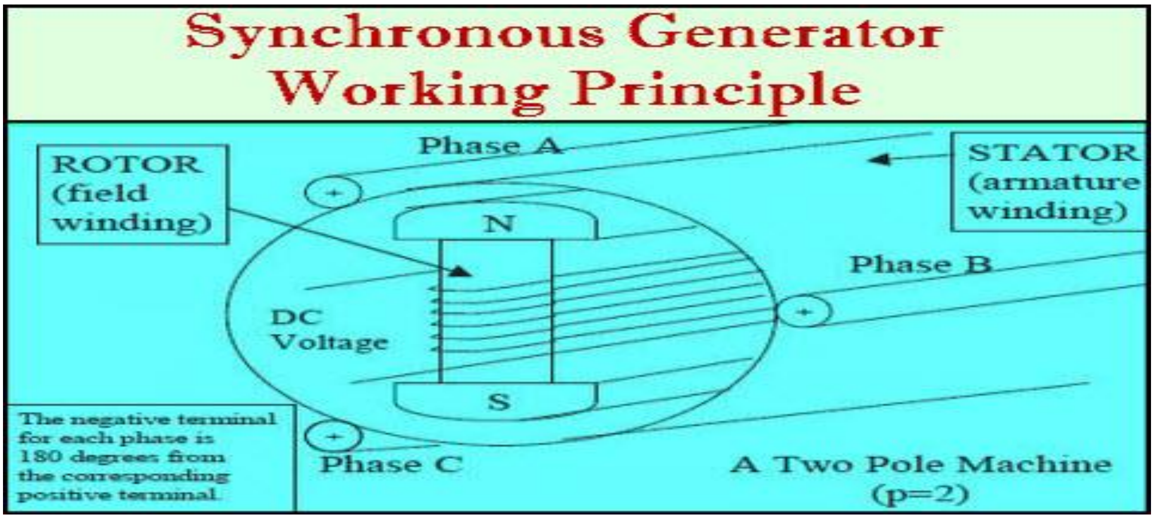


Figure 2.2: synchronous generator

2.2.1 Field Excitation and Exciters:-

Generators require direct current to energize its magnetic field. The DC field current is obtained from a separate source called an exciter. [9]

- There are two common approaches to supplying this dc power:

1. Supply the dc power from an external dc source to the rotor by means of slip rings and brushes.

2. Supply the dc power from a special dc power source mounted directly on the Shaft of the synchronous generator. [7]

On larger generators and motors, brushless exciters are used to supply the dc field current to the machine. A brushless exciter is a small ac generator with its field circuit mounted on the stator and its armature circuit mounted on the rotor shaft. The three-phase output of the exciter generator is rectified to direct current by a three-phase rectifier circuit also mounted on the shaft of the generator, and is then fed into the main dc field circuit. By controlling the small dc field current of the exciter generator (located on the stator), it is possible to adjust the field current on the main machine without slip rings and brushes. [7]

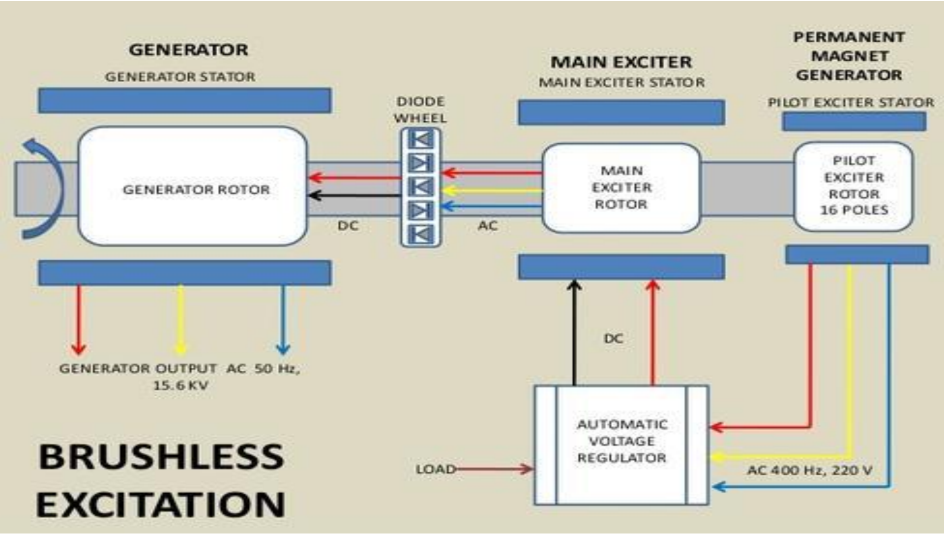


Figure 2.3: brushless excitation

To make the excitation of a generator *completely* independent of any external power sources, a small pilot exciter is often included in the system. [7]

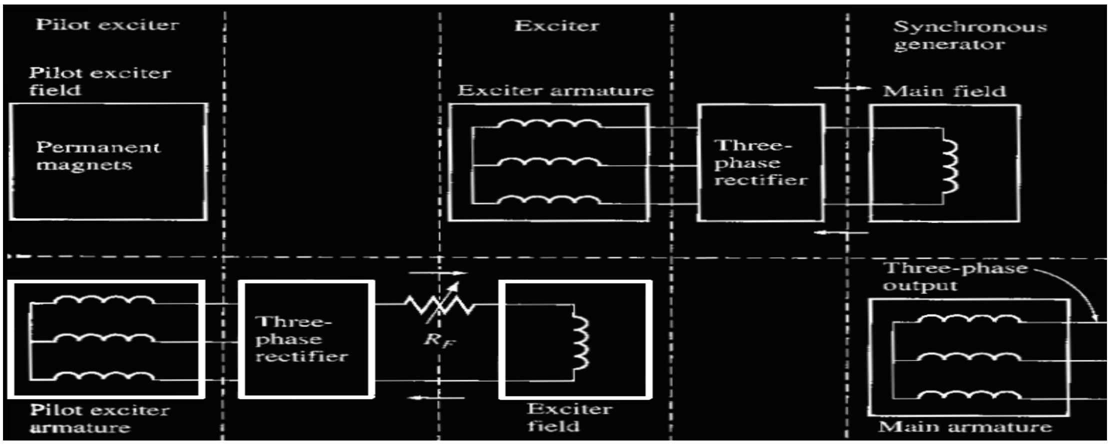


Figure 2.4: A brushless excitation scheme that includes a pilot exciter. The permanent magnets of the pilot exciter produce the field current of the exciter, which in turn produces the field current of the main machine.

2.2.2 Eddy current:

Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. They can be induced within nearby stationary conductors by a time-varying magnetic field created by an AC electromagnet or transformer.[10]

The induced eddy currents also generate a magnetic force that opposes the motion, making it more difficult to move the conductor across the magnetic field.[11]

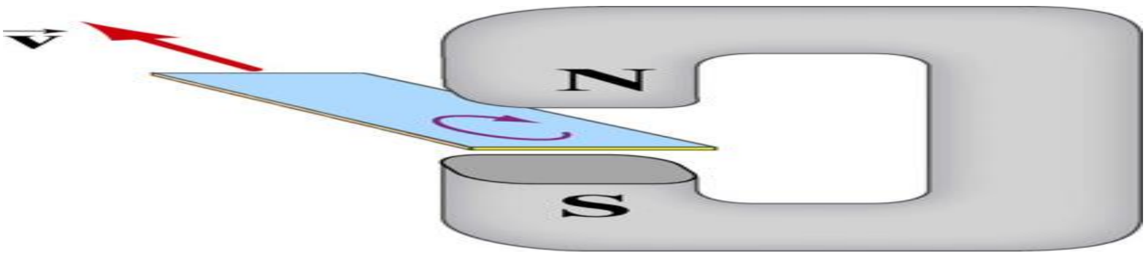


Figure 2.5: eddy current

The electrical frequency of synchronous generators is synchronized (locked in) with mechanical rote of rotation of the magnetic fields is related to the stator electrical frequency.

2.2.3 The Active and Reactive power :-

The power which is actually consumed or utilized in an AC Circuit is called True power or **Active Power** or real power. It is measured in kilo watt (kW) or MW. It is the actual outcomes of the electrical system which runs the electric circuits or load.[12]

The powers that continuously bounce back and forth between source and load is known as reactive Power ,Power merely absorbed and returned in load due to its reactive properties is referred to as reactive power.[13]

The reactive power is measured in kilo volt ampere reactive (kVAR) or (MVAR).[12]

2.3 The turbine:-

2.3.1 General definition:-

A Steam Turbine is a mechanical device that extracts thermal energy from pressurized steam and transforms it into mechanical work. The basic parts of stream turbines are blades and rotors. A set of blades is known as a stage. They also have steam inlets (usually a set of nozzles) and outlets. Two independent mechanisms, known as governors, are used to ensure safe operation of the turbine. [14]

2.3.2types of Turbine:-

- **The Two Types of Steam Turbines**

The modern steam turbine can be divided into two types, impulse and reaction turbines.

- **Impulse Turbines:-**

In this type of turbine the superheated steam is projected at high velocity from fixed nozzles in the casing. When the steam strikes the blades (sometimes called buckets), it causes the turbine shaft to rotate. The high pressure and intermediate pressure stages of a steam turbine are usually impulse turbines.

- **Reaction turbines:-**

In this type of steam turbine the steam passes from fixed blades of the stator through the shaped rotor blades nozzles causing a reaction and rotating the turbine shaft. The low pressure stage of a steam turbine is usually a reaction type turbine. This steam having already expanded through the high and intermediate stages of the turbine is now of low pressure and temperature, ideally suited to a reaction turbine[15]

2.3.3 Steam turbine governing:

Steam turbine governing is to ensure that the turbine speed constant irrespective of steam turbine load conditions. The steam turbine governor controls the steam entry to the turbine to maintain the steam turbine speed.[16]

Governing system of the turbine does the following functions:

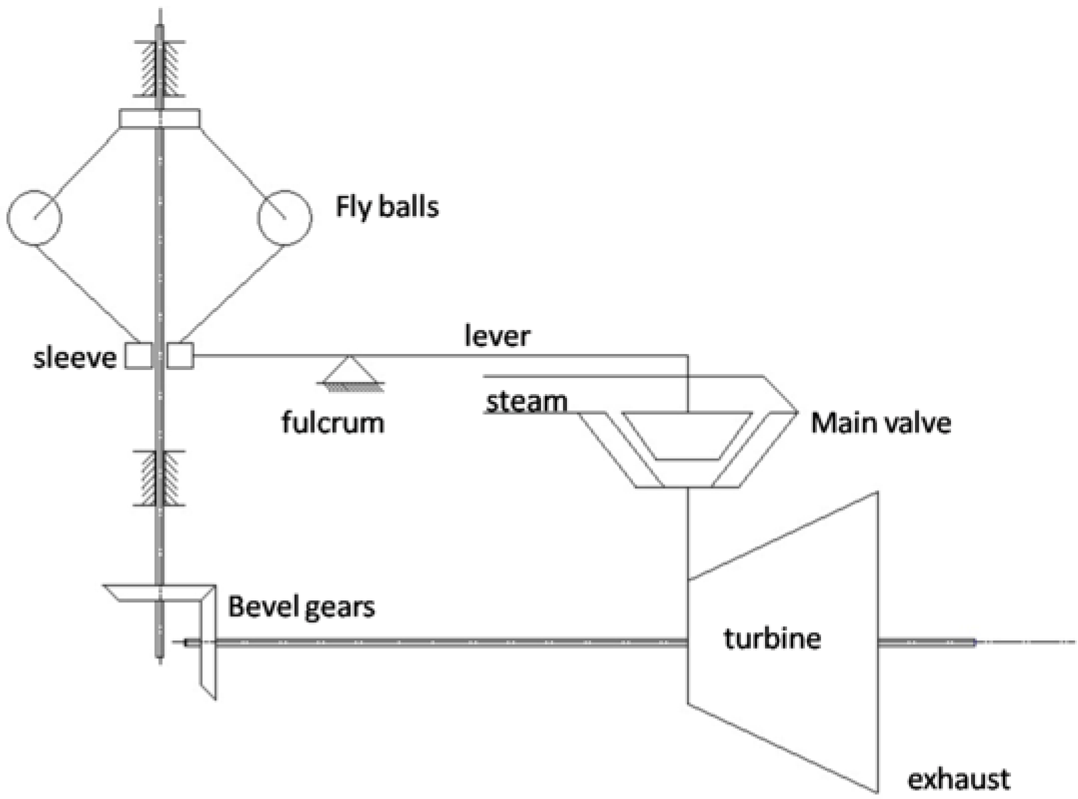
- Controls the turbine speed during start-up or in no load condition to permit the unit to be synchronized with the grid.
- Controls the turbine load when running in parallel with the grid/generating sets.
- All protective functions to ensure the safe operation of the unit[17]

The principle methods of steam turbine governing are as follows:

- Nozzle Governing
- Throttle Governing
- By-pass governing[15]

•Throttle Governing:

In this case of governing mechanism, the mass flow rate is controlled by throttling the steam by means of control value. The control value position will be adjusted to allow the required steam for turbine operation. Here the controlling parameter can be turbine speed and load. With latest technologies steam generator pressure control is also incorporated in governing control system. This is more important in nuclear power plants where constant steam pressure is essential for efficient operation.[17]



Figure(2.6) : Throttle Governing

•Nozzle Governing:

Nozzle governing is an alternative efficient method of steam turbine governing. Simple schematic of nozzle governing of steam turbine are shown in below figure. In this method of governing, the nozzles are grouped together as 3 or 5 and the supply of steam through this nozzles are controlled by regulating valves. Under full full load conditions all the regulating valves of nozzles are fully open. When the load on turbine changes or deviates from the design valve, the supply of steam through one or some group of nozzles are regulated or fully closed to maintain the speed of the turbine.

Nozzle governing control can be only applied to the first stage of a turbine. It is suitable for impulse turbines and larger units which have impulse state followed by an impulse reaction stage. In this there will be a steam pressure drop at first stage outlet to second stage because of the nozzles cut down.

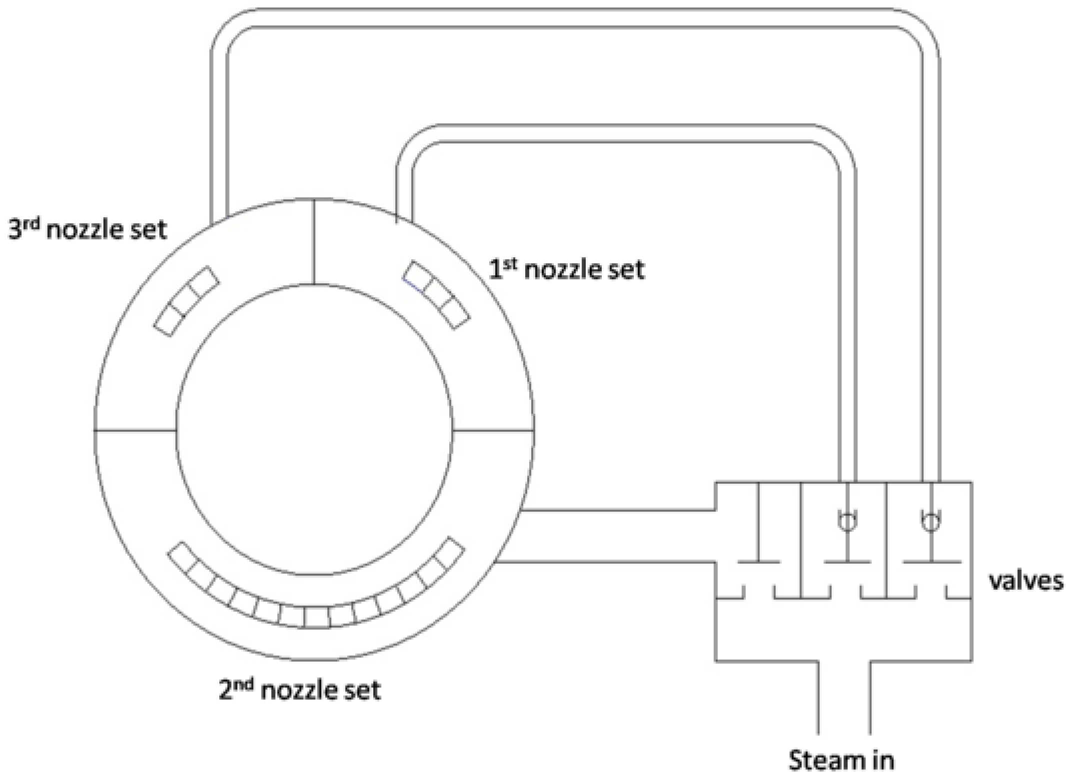


Figure 2.7: Nozzle Governing

•By-pass Governing:

The above two methods of steam turbine governing i.e. nozzle governing and throttle governing controls the steam at inlet of the first stage or high pressure stage of turbine. When the load is greater than desired load, the additional steam required could not pass through the first stage since additional nozzles are not available. Bypass regulation governing, the steam is by-passed through a valve to the lower stage turbines which results in increasing the turbine power. Once the bypass valve opens it is under control of turbine governor to control the speed of the turbine. Because if it not controlled by the governor it may allow more steam to lower stage which results in increase in turbine speed.[15]

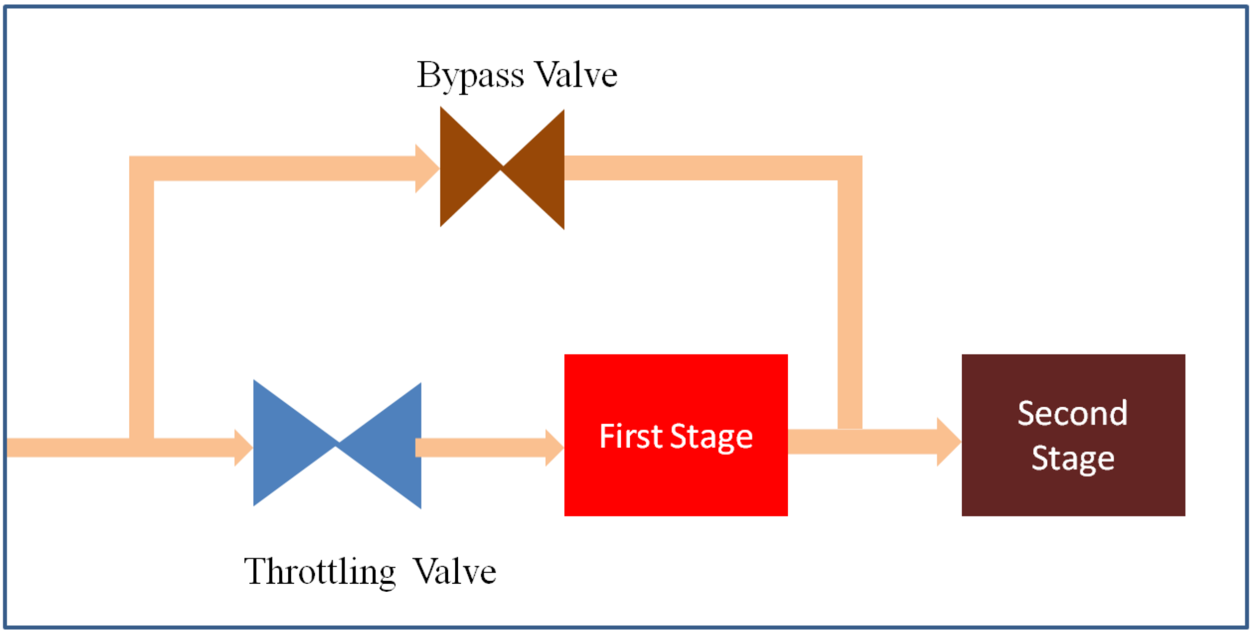


Figure 2.8: By-pass Governing

•Electro hydraulic governor- As it name indicate it has electrical sensing and hydraulic controlling. In electro hydraulic governing all transducers are electrical/electronic components. The acquired signals (of control valve lift, speed ,load& initial pressure etc..) are processed electronically and processed signal is introduced at a suitable point in the hydraulic circuit through a electro-hydraulic converter which is used as a connecting link between the electronic modules and valve actuators. Hydraulic signal before application to control valves servomotors is suitably amplified. EHG consists of three control loops for speed, load and pressure. EHG optimizes the turbine life by conservative operation with the aid of TSE. Actual speed of the turbine is measured by using hall probes. Speed regulation (Droop) can be changed from 2.5% to 8% in a step of 0.5% even when the machine runs on load. The usual setting of droop in EHG is 5%.Speed regulation (Droop) can be changed from 2.5% to 8% in a step of 0.5% even when the machine runs on load. The usual setting of droop in EHG is 5%[18]

2.3.4 Efficiency of steam turbine:-

The **efficiency** of any turbine or engine can be defined as its ability to convert the input energy into useful output energy .

An ideal turbine with 100% efficiency is the one which converts all its input energy into output work without dissipating energy in the form of heat or any other form. But in the real world, it is not possible to build a turbine with 100% efficiency because of friction in the parts of turbines, heat loss, and other such losses.[19]

Turbine efficiencies are in the range(31.00 to 41.90%) as compared to the design range of(34.80–43.97%).[20]

2.4 The Steam generator(Boiler):-

2.4.1. What is steam boiler?

A boiler can be defined as a closed vessel in which water or other fluid is heated under pressure. This fluid is then circulated out of the boiler for use in various processes or power generation. In the case of power generation steam is taken out of the steam boiler at very high pressure and temperature. Boiler classification can be based on many factors like usage, fuel fired, fuel firing system, type of arrangement etc. Commonly known types are pulverized coal fired boilers, fluidized bed boilers, super critical boilers, oil and gas fired boilers. All cater to industrial and power generation. [21]

2.4.2 Types of Boiler:

There are mainly two types of boiler – water tube boiler and fire tube boiler.

• Water Tube Boiler:-

It consists of mainly two drums, one is upper drum called steam drum other is lower drum called mud drum. These upper drum and lower drum are connected with two tubes namely down-comer and riser tubes .

Water in the lower drum and in the riser connected to it, is heated and steam is produced in them which comes to the upper drums naturally. In the upper drum the steam is separated from water naturally and stored above the water surface. The colder water is fed from feed water inlet at upper drum and as this water is heavier than the hotter water of lower drum and that in the riser, the colder water push the hotter water upwards through the riser. So there is one convectional flow of water in the boiler system. [22]

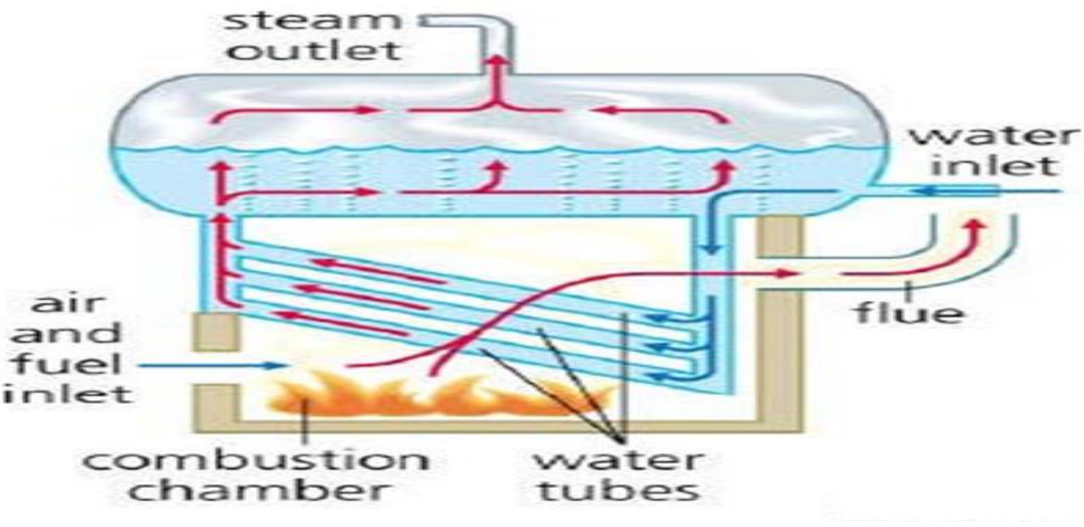


Figure 2.9: water tubes Boiler

• Fire Tube Boiler:-

As it indicated from the name, the fire tube boiler consists of numbers of tubes through which hot gasses are passed. These hot gas tubes are immersed into water, in a closed vessel. Actually in fire tube boiler one closed vessel or shell contains water, through which hot tubes are passed. These fire tubes or hot gas tubes heated up the water and convert the water into steam and the steam remains in same vessel. As the water and steam both are in same vessel a fire tube boiler cannot produce steam at very high pressure. Generally it can produce maximum 17.5 kg/cm^2 and with a capacity of 9 Metric Ton of steam per hour.[1]

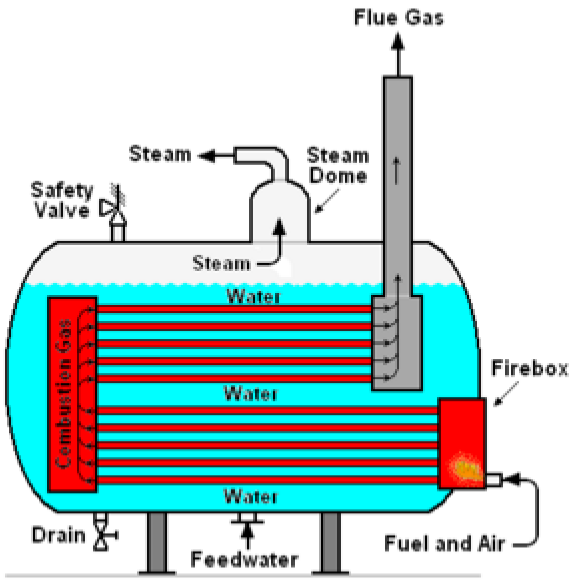


Figure 2.10: Fire Tube Boiler

2.4.3 Boiler components:-

2.4.3.1 Drum:-

The steam drum is primary used on water tube boilers and HRSGs. It contains internals such as the a**gglomerators** and the cyclone separators, chevrons, demister pads, and any combination thereof. The primary function of the steam drum is separate water from steam which prevents carryover of the condensate into to the steam header (phase separation). [23]

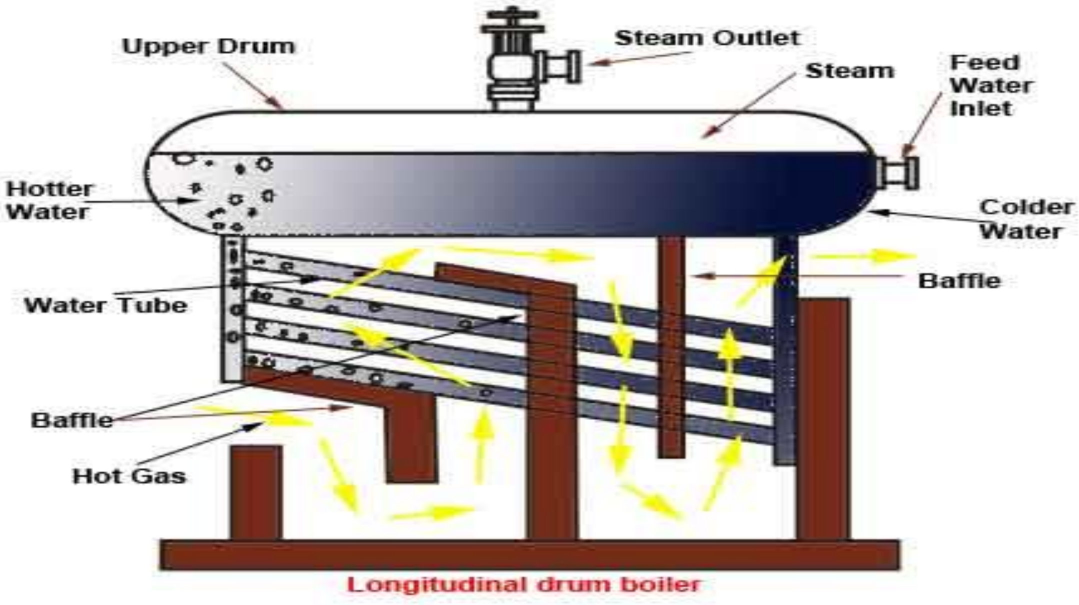


Figure 2.11: longitudinal drum boiler

2.4.3.2 Burners:-

Boiler burners are the functional component of boilers that provide the heat input by combustion of a fossil fuel, including natural gas, with air or oxygen. They are available either as part of the boiler package from the manufacturer, as stand-alone products for custom installations, or as replacement products. [24]

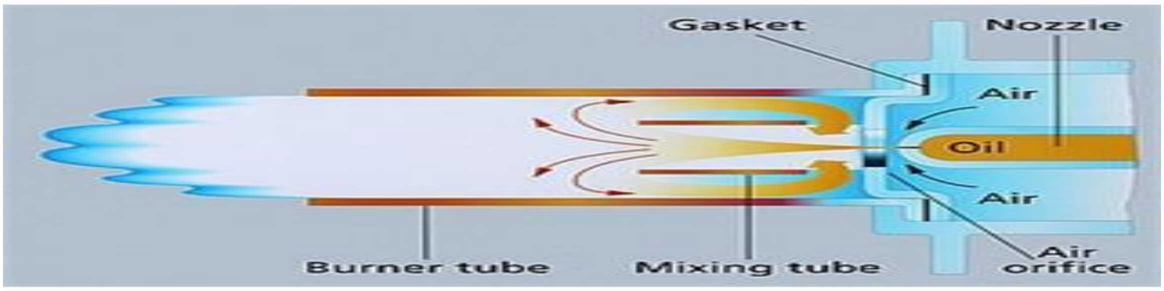


Figure 2.12: **Burners**

2.4.3.3 Furnace (combustion chamber):-

The heat required for producing steam in a boiler is generated at boiler furnace by combustion of fuel. [1] Contains the combustion gases and then directs those gases to the heating surfaces of the boiler. [24]

2.4.3.4 Air preheater:-

Air preheat is use to preheat the air. It is preheated by the exhaust gases of boiler. So it also increase efficiency of boiler. The heated air enters into boiler,

Today we have discussed about what is a boiler and parts of a boiler.

2.4.3.5 Economizer:-

Economizer is use to preheat water before it enter into boiler drum. The economizer uses the heat of flue gases to preheat the water. The flue gases coming out from boiler, first passes through economizer and then to atmosphere. It increases the efficiency of boiler.

2.4.3.6 Super heater:-

The steam generate by the boiler is saturated steam. If this steam is use in turbine, it may cause corrosion. So the steam is superheated before taken out for process work. This is done by super heater.

2.4.3.7 Attemperator:-

Temperature control is usually achieved by admitting a fine spray of water into the steam line through what is called an attemperator or DE super heater, which is typically located between the primary and secondary super heaters. [25]

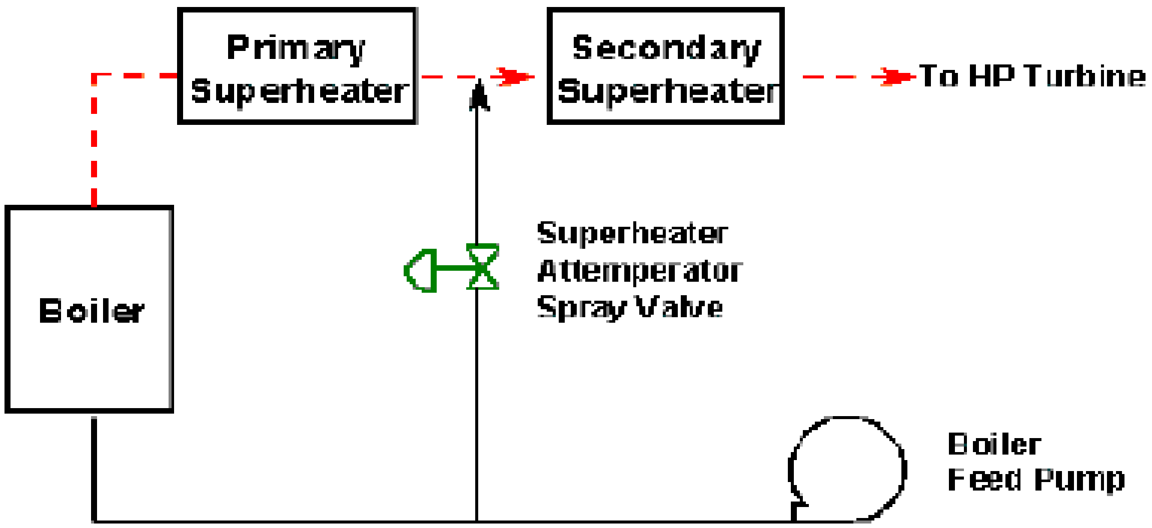


Figure 2.13: attemperator

2-5 Feed pump:-

Feed pump is use to pump the water in boiler for continuous working. The feed pump is run by the electricity or by a steam turbine. The steam use to drive the turbine taken by the boiler itself, which increase the boiler efficiency.

2.6 Condensers:-

The condenser reduces the backpressure, thereby increasing the output and efficiency of the turbine. The condensed steam becomes excellent feed water and is returned to the boiler. The vacuum created in the condenser depends on the cooling water temperature entering the condenser, the effectiveness of the air-removal devices, and many other factors.

The steam condenser is one of the essential components of all modern steam power plants.

- **Steam condenser are of two types:**

2.6.1 Surface condenser

In surface condensers there is no direct contact between the steam and cooling water and the condensate can be re-used in the boiler: In such condenser even impure water can be used for cooling purpose whereas the cooling water must be pure in jet condensers. Although the capital cost and the space needed is more in surface condensers but it is justified by the saving in running cost and increase in efficiency of plant achieved by using this condenser. [26]

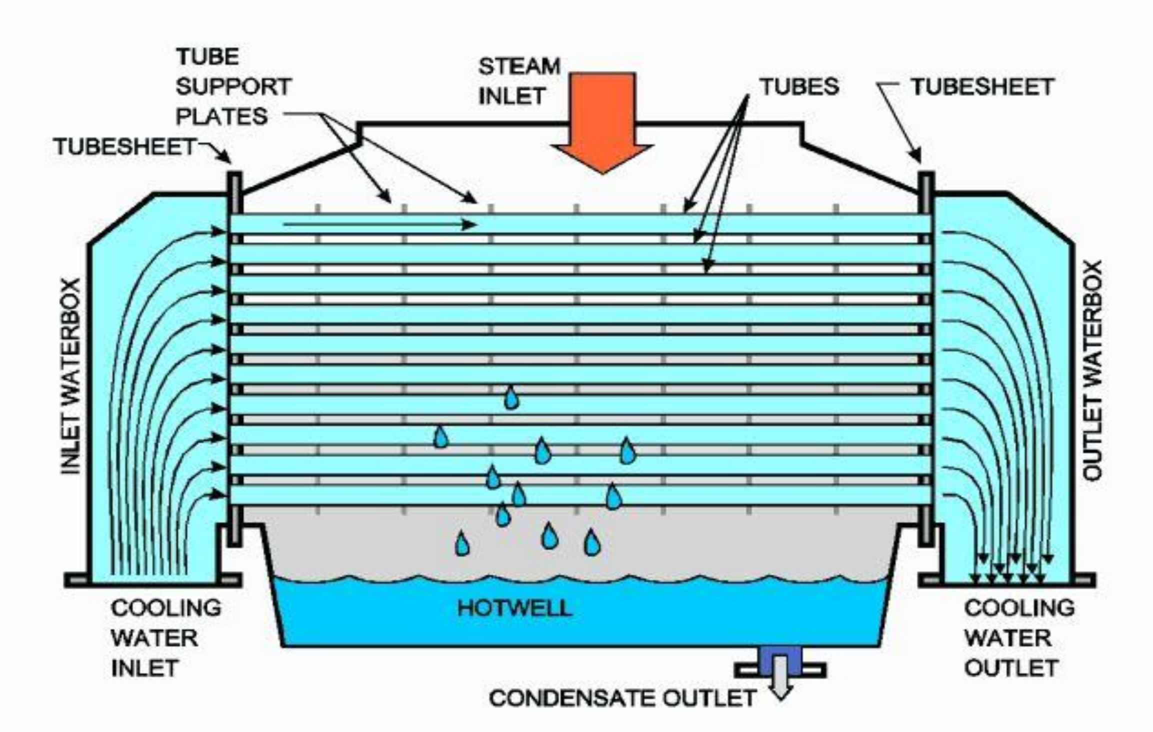


Figure 2.14: surface condenser

2.6.2 Jet condenser:-

Jet condensers have direct contact between steam and cooling fluid thereby causing contamination of condensate.

Due to direct contact of two fluids the circulating water requirement is much less in jet condenser as compared to other types of condensers. Space requirement and size of condenser etc. are also less with jet condensers. Surface condenser is advantageous over direct contact type condensers because any type of cooling fluid can be used in it and also there is no scope of contamination etc.[27]

2.7 The Blackout:-

A blackout = a power outage. This state means the loss of the electricity supply to a part of the power system or to whole power system.

The blackout in the power system can cause:

• power system equipment damage,

• heavy economical losses,

• jeopardy of economy functioning,

• life paralysis in stricken parts of country.

It is necessary to notice that everyone is dependent on reliable and quality power supply. Several power system blackouts became in the world of late years. Causes of these disturbances were various – technical, bad weather, human failing.[28]

2.8 Tripping:-

"Tripping" generally means an immediate, emergency shutdown. It's also not clear from your post if you are referring to an immediate, emergency shutdown or an orderly shutdown.[29]

2.8.1 TURBINE TRIP CONDITIONS:-

- 3 OUT OF 4 GOVERNOR VALVES TRIPPED:
  Failure of HP Governor Valves stops steam admission to HP

Turbine. Admission of steam thru' single Governor Valve will result in non-uniform temperature distribution within the Turbine which may result in distortion of blades, rotor.

- **MAIN STEAM PRESSURE LOW:**

  Will produce undue stress on Turbine blades due to Reduction of "available enthalpy" (reduction in input conditions).Usually a Trip is preceded by an "de-loading of turbine" as per Turbine manufacturer recommendation.

- Main Steam Temperature Low:

  Will produce undue stress on Turbine blades due to reduction of "available enthalpy" (reduction in input conditions).

2.8.2 Master Fuel Trip:-

- All FD Fans off:

  Will result in in-sufficient air for the combustion process and the fuel cannot burn.

- All ID Fans off:

  Will result in uncontrolled furnace pressurization.

- Furnace pressure very high /low:

  Will result in explosion or implosion of the furnace resulting in mechanical deformity.

- Drum level very high / low:

  High: Will result in Flooding of super heaters causing

  a- carryover of dissolved solids and hence deposition downstream effecting heat transfer

  b- fall of steam temperature and quenching of Turbine

  Low: Will result in starvation of water in the furnace tubes which will lead to tube metal overheating as no cooling medium is present.[30]

2.9 Previous study:-

2.9.1 The load variation:-

Today's interconnected power systems supply a variety of loads depending upon the consumer's demands. These demands, of course, vary constantly which leads to the variable loading of the system and all its consequences.

Load following power plants run during the day and early evening. They either shut down or greatly curtail output during the night and early morning, when the demand for electricity is the lowest. The exact hours of operation depend on numerous factors. One of the most important factors for a particular plant is how efficiently it can convert fuel into electricity. The most efficient plants, which are almost invariably the least costly to run per kilowatt-hour produced, are brought online first. As demand increases, the next most efficient plants are brought on line and so on. The status of the electrical grid in that region, especially how much base load generating capacity it has, and the variation in demand are also very important. An additional factor for operational variability is that demand does not vary just between night and day. There are also significant variations in the time of year and day of the week. A region that has large variations in demand will require a large load following or peaking power plant capacity because base load power plants can only cover the capacity equal to that needed during times of lowest demand.[31]

2.9.2 Effects of Variable Loading On Power System:-

Variation in loading has certain undesirable effects, the most appreciable of which are given below:

- **Generation of power becomes costly:**

For obvious reasons of optimum operation, alternators are designed in such a way that maximum efficiency occurs at (or very close to) their rated capacity. Hence, when the load varies and becomes low, the alternator will not be loaded up to its rated capacity and its working efficiency is reduced. This consequently increases the cost of production.

- **Difficulty in controlling the system:**

When the load changes, the frequency of the system also varies. For proper operation, the frequency must be within the permissible limits.

In order to keep the frequency within limits, additional control equipment's are required. Such equipment's increase the cost and complexity of the system.

- **Requirement of additional equipment:**

As explained above, variable loading necessitates the use of speed governors, voltage and frequency sensors, microcontrollers and other closed loop control equipment's to exert control over the system and maintain all parameters within permissible ranges.

- **Increased losses**

Due to variation in loading conditions, various machines like transformers, electronic devices and other machines show increased losses due to magnetization characteristics, saturation and variation in parameters. This decreases the overall efficiency of the system. [32]

2.9.3 Effect of load variation on generation parameters:-

When the load changes, the frequency of the system also varies. For proper operation, the frequency must be within the permissible limits. (Generally ± 3% deviation is permissible, i.e. 48.5 Hz to 51.5 Hz in case of system frequency of 50Hz.) , The power system frequency is directly related to the rotational Speed of the generators supplying the system, In order to keep the frequency within limits, additional control equipment's are required. Such equipment's increase the cost and complexity of the system.[33]

Voltage fluctuations due to random load variation are amongst the most important Voltage Fluctuations can be described as repetitive or random variations of the voltage Envelope due to sudden changes in the real and reactive power drawn by a load. The characteristics of voltage fluctuations depend on the load type and size and the power system capacity. Illustrates an example of a fluctuating voltage waveform. The voltage waveform exhibits variations in magnitude due to the fluctuating nature or intermittent operation of connected loads. The frequency of the voltage envelope is often referred to as the flicker frequency. Thus there are two important parameters to voltage fluctuations, the frequency of fluctuation and the magnitude of fluctuation. Both of these components are significant in the adverse effects of voltage fluctuations. [34]

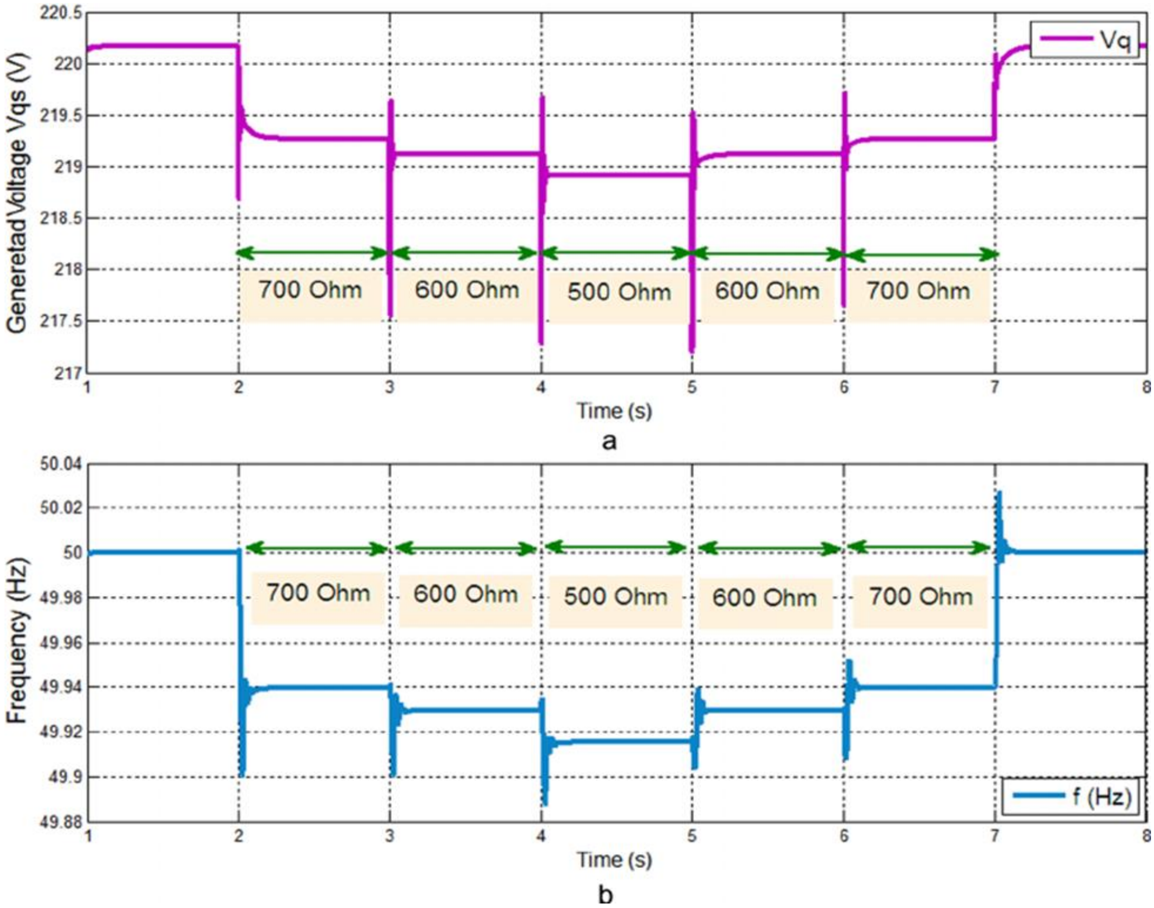


Figure 2.15: the relation between generated voltage and time (A), frequency and time (B)

The proposed load voltage control strategy is based on the action of the static synchronous Compensator (STATCOM) which can not only provide the necessary reactive power but also may enhance the load ability.[35]

The software PSCAD/UMTDC is used to simulate different set of load parameters.

2.9.4 Variation in Boiler Efficiency with Load:-

It is a general observation that boiler efficiency tends to decrease as the boiler load decreases. Both practically and theoretically, for any boiler, the efficiency is highest at maximum load conditions. At part loads, considerable drop in the boiler efficiency is noticed. This article briefly explains why efficiency of a boiler drops down when it is operated at part loads.

Reasons for drop in boiler efficiency at low/part loads:-

- **Radiation losses :**

The boiler is designed to transfer a specific amount of heat through the designed surface area. For this the fuel should be fired at the specified rate. Radiation losses depend on the heat transfer area. Heat transfer area is constant for a given boiler and hence, remains constant at different load conditions. This implies that some part of the generated heat is always lost as radiation losses. Therefore when the boiler is operated at lower loads, lesser amount of fuel is fired. As a result, lesser amount of heat is generated. But some part (Which is constant) is going to be lost. Hence radiation losses increase at lower loads

- **Low Fire Operation:**

During the operation at lower loads the combustion is less efficient. This is because of the increased oxygen % in the flue gases. Generally the oxygen % is 2-3% greater at low fire operation than what at high fire. Thus the oxygen % rises above the ideal 3-3.5% and efficiency drops

- **Start up and shut down losses:**

Start up and shut down losses are mandatory in every boiler. Burners are incorporated with pre- purge and post-purge which actually is a safety measure.

During start-up, the burner does not start firing immediately. Instead it purges air for a period of 30 seconds before the actual atomization. The purpose of Pre-purge is to blow away the residual exhaust flue gases that exist in the furnace and the boiler tubes since the boiler is shut down. Similarly a post purge cycle is carried out after the shut down. These purging cycles blow away hot flue gases which actually is a loss. This problem gets aggravated when boiler is operated on lower loads. The reason for this is, if the loads drop below the turn-down ratio, the burner trips and the boiler shuts down. Occurrence of such situations can be brought down if the loads are higher and do not fluctuate.

At the low load conditions, all of the above 3 parameters come into the picture which in turn bring down the boiler efficiency. To ensure that boiler operates at high efficiencies, it should always be operated at full load conditions.[36]

2.9.5 Energy, exergy and exergoeconomic analysis of a steam power plant: A case study.

The objective of this paper is to perform the energy, exergy and exergoeconomic analysis for the Hamedan steam powerplant. In the first part of the paper, the exergy destruction and exergy loss of each component of this power plant isestimated. Moreover, the effects of the load variations and ambient temperature are calculated in order to obtain a good insight into this analysis. The exergy efficiencies of the boiler, turbine, pump, heaters and the condenser areestimated at different ambient temperatures. The results show that energy losses have mainly occurred in the condenserwhere 306.9MW is lost to the environment wh/ile only 67.63MW has been lost from the boiler. Nevertheless, theirreversibility rate of the boiler is higher than the irreversibility rates of the other components. It is due to the fact thatthe combustion reaction and its high temperature are the most significant sources of exergy destruction in the boilersystem, which can be reduced by preheating the combustion air and reducing the air–fuel ratio. When the ambienttemperature is increased from 5 to 241C, the irreversibility rate of the boiler, turbine, feed water heaters, pumps and thetotal irreversibility rate of the plant are increased. In addition, as the load varies from 125 to 250MW (i.e. full load) theexergy efficiency of the boiler and turbine, condenser and heaters are increased due to the fact that the power plant is -designed for the full load. In the second part of the paper, the exergoeconomic analysis is done for each component ofthe power plant in order to calculate the cost of exergy destruction. The results show that the boiler has the highest cost of exergy destruction. In addition, an optimization procedure is developed for that power plant. The results show that by considering the decision variables, the cost of exergy destruction and purchase can be decreased by almost 17.11%.[37]

Table (2.1): The relation between previous study and a project

Previous study name	**Approximating**	**The Different**
The load variation	Load changing between time to time	It used kilowatt per hour, project used efficiency.
Effects of Variable Loading On Power System	External effect of load variation on steam unit	The external generally and calculation the efficiency.
Effect of load variation on generation parameters	Limit of frequency	Externals effect of frequency variation on all the equipment.
Variation in Boiler Efficiency with Load	Calculate the limit of boiler efficiency.	Externals Boiler trips
Energy, exergy and exergoeconomic analysis of a steam power plant: A case study.	The decision variables are selected as extraction pressure and extraction mass flow rate For each feed water heater.	Extraction pressure and extraction mass flow rate for each feed water heater under variable load and used efficiencies.

2.10he equations of efficiency in thermal power plant:-

2.10.1 Isentropic Efficiency of turbine :-

$\eta_t = W_a/W_s=(h_4-h_c)/(h_4-h_{c\,s})$ (2.1)

Where:

W_a≡ actual turbine work(kJ/kg) .

W_s≡ isentropic turbine work per(kJ/kg) .

h_4 ≡ enthalpy of dearator enter per(kJ/kg).

h_c ≡actual enthalpy at the input of condenser per(kJ/kg).

$h_{c\,s}$ ≡isentropic enthalpy at input of condenser per(kJ/kg).

2.10.2 Boiler efficiency:-

$\eta_b= \dot{m}_s(h1-h_{13})/\dot{m}_f\ GCV$ ……..…………………………. (2.2)

Where:

$\dot{m}_s$≡ amount of steam flow at the output the boiler per(kg/s).

$\dot{m}_f$≡ amount of fuel flow enter to the boiler per(kg/s).

h_1 ≡ enthalpy at input of the turbine per (kJ/kg).

h_{13} ≡ enthalpy at input of the boiler (kJ/kg).

GCV ≡gross calorific value of fuel(kJ/kg).

2.10.3 Turbine efficiency:-

$\eta_t = (\dot{m}_s(h1\text{-}h2)+\dot{m}_{s7}(h2\text{-}h3)+\dot{m}_{s6}(h3\text{-}h4)+\dot{m}_{s5}(h4\text{-}hc))/\dot{m}_s(h1\text{-}h13)$ …….. (2.3)

Where:

$\dot{m}_s$≡ amount of steam flow at enter of the turbine per (kg/s).

$\dot{m}_{s5}$≡ amount of steam flow at enter heater five(dearator) per (kg/s).

$\dot{m}_{s6}$≡ amount of steam flow at enter of HP heater six per (kg/s).

$\dot{m}_{s7}$≡ amount of steam flow at enter HP heater seven the turbine per (kg/s).

h_1 ≡ enthalpy at input of the turbine per (kJ/kg).

h_2 ≡ enthalpy at input of HP heater seven per(kJ/kg).

h_3 ≡ enthalpy at input of HP heater sixe per(kJ/kg).

h_4 ≡ enthalpy at input of dearator enter per(kJ/kg).

h_c ≡actual enthalpy at the input of condenser per(kJ/kg).

h_{13} ≡ enthalpy at input of the boiler (kJ/kg).[38]

Chapter Three

(Methodology)

3.1 Preface:

This chapter describes the approaches employed in this project, the objective of this project rounds around effect of load variation on thermal unit , in order to achieve the above target we simulates the turning process by applying the following steps in flow chart in figure. 3.1.

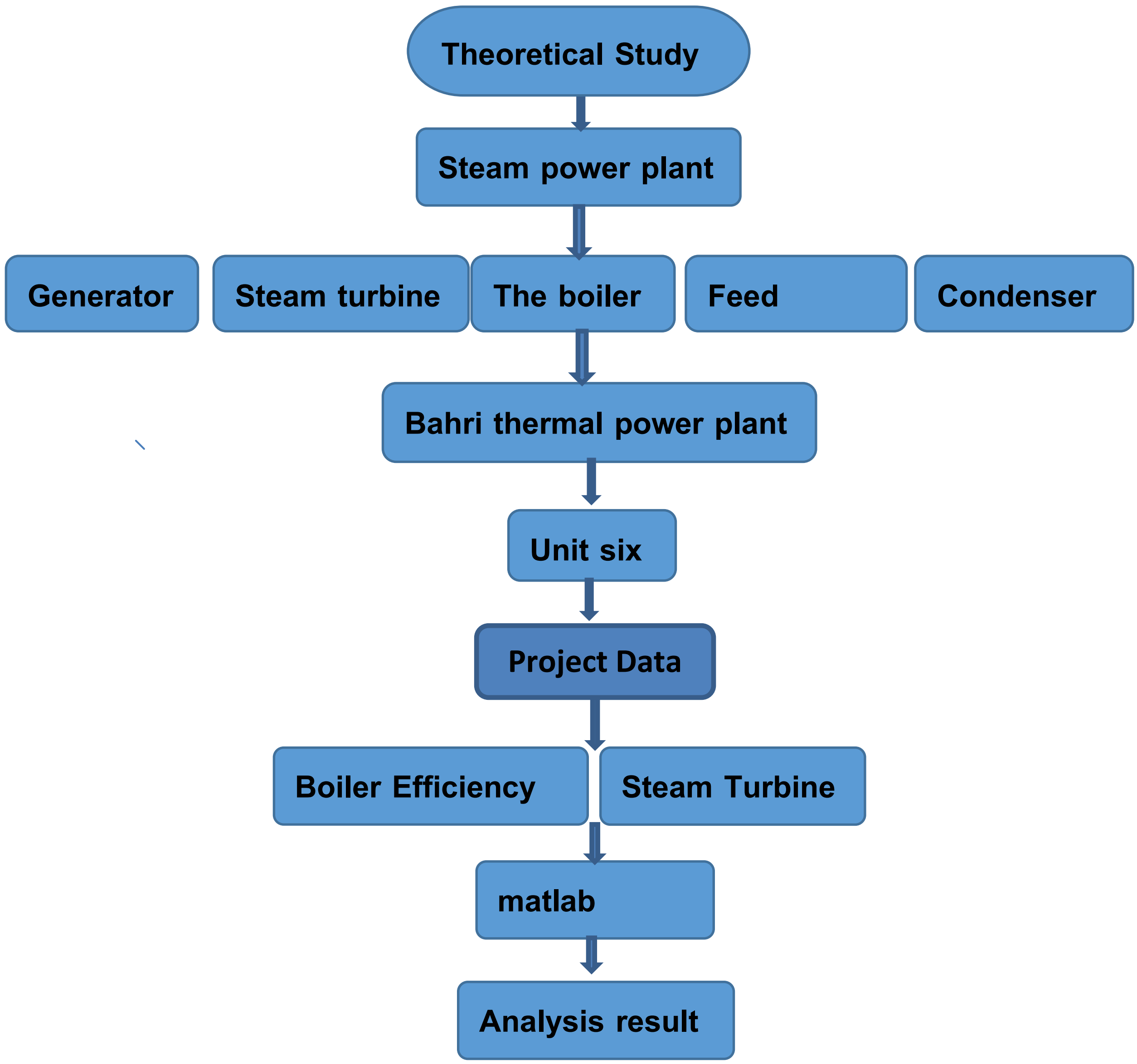


Figure 3.1:Flow-chart of the project methodology

3.2 Bahri thermal power plant

Bahri thermal power is considered one of the plants in the Sudan that supplies the electrical energy as it compensates the loss in the hydro power generation when water resources level decreases during summer period .Its consist of three phases any phase consists of two units:
Phase one feed the electrical cycle with 60MW.

Phase two feed the electrical cycle with 120MW.

Phase three feed the electrical cycle with 200MW.

All theunit working in Rankine cycle with regeneration.Bahri thermal power plant was founded on a location where it’s close to the water resource (riverside) and also had to close to the large load centers for an economic distribution and cost.

3.3 Phase three Unit (6):

3.3.1 Boiler unit:

Water tube Boiler, two forced dry fans (one to rune and anther to standby) to use air inter the boiler. Air preheater is use to preheat the air It is preheated by the exhaust gases of boiler. Two fuel oil storages and three feed oil pumps and electrical heaters also tube inside steam (to safe liquid oil) Economizer is use to preheat water before it enter into boiler drum. The economizer uses the heat of flue gases to preheat the water. Furnace at eight burners fore level and tube water three side surface. Drum to generate steam and two super heater guarantee superheated steam also Attemperator to Temperature control inlet turbine, for valves and fore governors to control quantity of a steam.

3.3.1.1 MCR:

Steam boilers rated output is also usually defined as MCR (Maximum Continuous Rating). This is the maximum evaporation rate that can be sustained for 24 hours and may be less than a shorter duration maximum rating

3.3.1.2 Boiler Rating :

Conventionally, boilers are specified by their capacity to hold water and the steam generation rate. Often, the capacity to generate steam is specified in terms of equivalent evaporation (kg of steam / hour at 100^oC). Equivalent evaporation- “from and at” 100^oC. The equivalent of the evaporation of 1 kg of water at 100^oC to steam at 100^oC.[39]

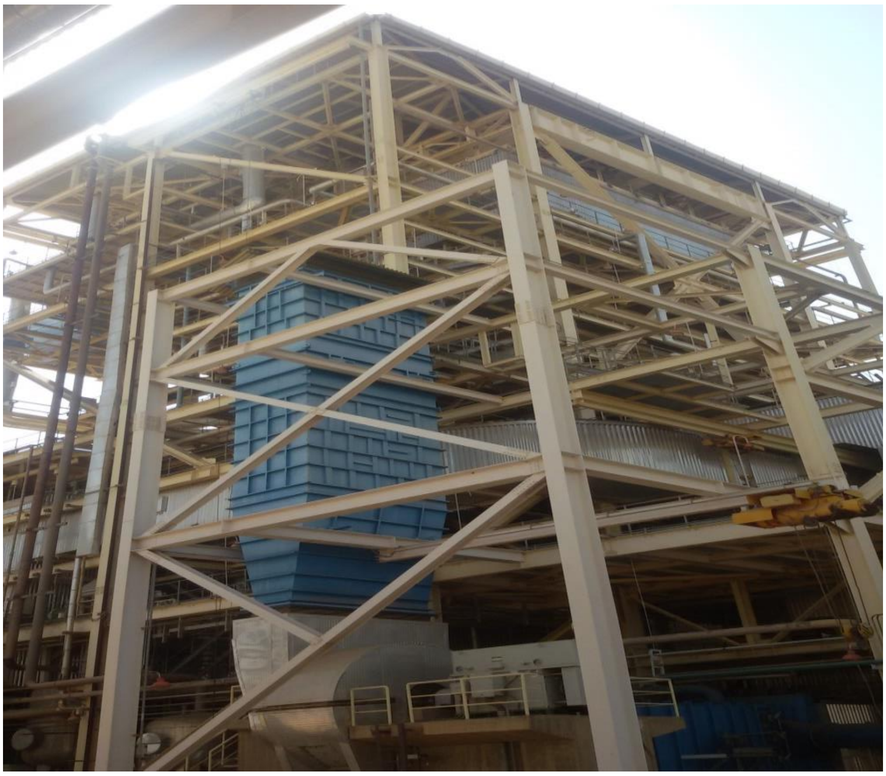


Figure 3.2:The boiler in unit six

3.3.2 Turbine unit:

Type of turbine (reaction -impulse turbine) and two stage turbine (high pressure - Low pressure) also seven heaters are Low pressure heaters (heater one, heater two, heater three and heater four) also deaerator (open feed heater) and High pressure heaters (heater six and heater seven).

Figure3.3: turbine in unit six

Figure 3.4: other side in turbine

3.3.2 Condenser unit:

Surface condenser at two Pasig also two condensate pumps (one to rune and anther to standby).

Figure3.5: surface condenser in unit six

3.3.4 Feed pump:

Two feed pumps (one to rune and anther to standby) canter fugal at variable Speed (variable pressure) to control pressure.

3.4 steady Procedure:

Went to central international control (soba) knew in it:

- Definition of load variation
- The plants open in network (substitute station).
- Steam power plant under control gradually.
- Limited of frequency allowed must be between (49 down, 51 up).

3.5 Project Data:

Our study cause in unit six the method which are used to bring data by return to operation department in Bahari power plant this department work to operate anything in the plant by using computer and manual operate its save history data because if any problem happen they can return for it .

We can limited our history loads per MW and read value of temperatures, pressures in the boiler and turbine enter and exit. Also we are read value of steam amount per (t/h) for boiler and turbine in anther hand also we are read value of fuel amount per (t/h).

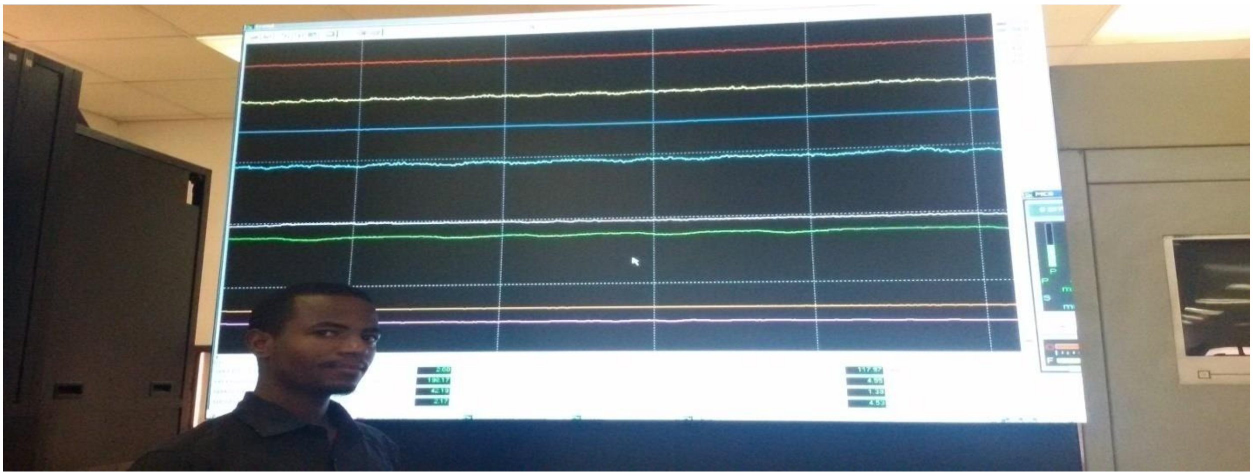


Figure3.6:carve of characteristics operation

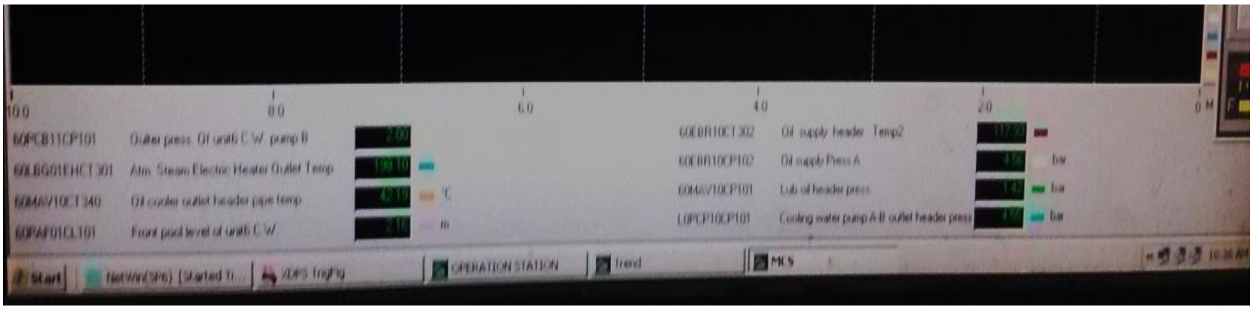


Figure3.7: Reading of some characteristics operation

Table(3.1): Basic data at load 20.24MW

Components unit	Pressure per bar	Temperature per ^{0} C
Boiler inlet	29.21	75.95
Boiler outlet	25.54	525.86
Inlet feed heater 7	9.28	289.14
Inlet feed heater 6	5.26	209.7
Inlet feed heater 5 (open feed heater)	2.45	141.46
Inlet condenser	0.12	41.72

Table(3.2): Basic data at load 40 MW

Components unit	Pressure per bar	Temperature per ^{0} C
Boiler inlet	44.23	195.94
Boiler outlet	39.11	557
Inlet feed heater 7	11.37	320.9
Inlet feed heater 6	6.380	255.8
Inlet feed heater 5 (open feed heater)	3.645	168.6
Inlet condenser	0.1009	42.7

Table(3.3): Basic data at load 65.32 MW (blackout)

Components unit	Pressure per bar	Temperature per ^{0} C
Boiler inlet	81.01	209.09
Boiler outlet	72.62	533.47
Inlet feed heater 7	18.01	383.71
Inlet feed heater 6	10.21	309.83
Inlet feed heater 5 (open feed heater)	4.91	241.34
Inlet condenser	0.12	42.36

Table (3.4): Basic data at load 65.32 MW

Components unit	Pressure per bar	Temperature per ^{0}C
Boiler inlet	73.08	210.72
Boiler outlet	65.8	534.51
Inlet feed heater 7	12.66	404.24
Inlet feed heater 6	10.48	336.41
Inlet feed heater 5 (open feed heater)	7.92	259.32
Inlet condenser	0.15	47.75

Table(3.5): Basic data at load 87.12 MW

Components unit	Pressure per bar	Temperature per ^{0}C
Boiler inlet	78.46	213
Boiler outlet	67.44	532.01
Inlet feed heater 7	20.28	402.9
Inlet feed heater 6	12.06	317
Inlet feed heater 5 (open feed heater)	5.89	257.4
Inlet condenser	0.16	49.22

Table(3.6): Basic data at load 110 MW

Components unit	Pressure per bar	Temperature per ^{o} C
Boiler inlet	93.4	232
Boiler outlet	88.26	535.4
Inlet feed heater 7	30.99	389.4
Inlet feed heater 6	17.6	314.4
Inlet feed heater 5 (open feed heater)	9.474	241.3
Inlet condenser	0.11	41.5

3.5.1 Boiler Efficiency by Direct Method:-

This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula (2.2)

By this method we are calculate the efficiency of boiler directly to put the values which are bring them from the plant in equation(2.2) exit the result .
The enthalpy value read from steam table. and value of GCV is constant its equal 44160 .

- **From steam table and interpolation:-**

Table (3.7) basic input data of efficiency boiler

NO	$\dot{m}_s$(kg/s)	$\dot{m}_f$(kg/s)	H (kJ/kg)	h (kJ/kg)	Load (MW)
1	33.61	2.860	3519.00	893.015	20.24(steady state)
2	45.94	3.553	3577.00	306.170	40.00(steady state)
3	70.490	4.611	3488.91	873.996	65.32(black out)
2	76.080	5.200	3498.65	880.810	65.32(steady state)
3	80.714	5.531	3490.19	893.015	87.12(steady state)
6	112.41	6.789	3475.00	966.000	110.0(steady state)

3.5.2 Turbine efficiency:

We are calculate the turbine efficiency by reading the amount of steam and the steam regeneration by heaters in high pressure turbine once not in low pressure turbine we assume this values in last is in pressure condenser because its very small pressure and usually could not measure. We are used the equation (2.1) for calculate enthalpy in exit of turbine value and equation (2.3) to calculate the efficiency of turbine.

The enthalpy value read from steam table.

Table (3.8): amount of steam inter feed heaters

Unit load per MW	Amount of steam In heater 7 kg/s	Amount of steam In heater 6 kg/s	Amount of steam in heater 5(open heater)
20.24	1.29	1.24	1.052
40	1.9156	1.8	1.539
65.32(blackout)	3.4	3.122	2.61
65.32	3.67	3.37	2.81
87.12	4.381	3.92	3.186
110	5.33	4.72	3.8

Table (3.9): amount of steam after heaters

Load	(steam rate after Heater seven) $\dot{m}_{s7}$	(steam rate after Heater six) $\dot{m}_{s6}$	(steam rate after Heater five) $\dot{m}_{s5}$
20.24MW	33.61-1.29=32.32	32.32-1.24=31.08	31.08-1.052=30.03
40.00MW	39.044	32.534	26.994
65.32BMW	67.090	63.968	61.358
65.32MW	72.410	69.040	66.230
87.12MW	76.333	72.413	69.227
110.0MW	107.08	102.36	98.560

Table (3.10) : the enthalpy of heaters and condenser

Load	h_7	h_6	h_5	h_c
20.24 MW	3030.000	2874.900	2756.850	2279.549
40.00 MW	3092.390	2967.990	2795.360	2290.500
65.32 BMW	3215.040	3071.600	2942.800	2328.050
65.32 MW	3272.800	3128.190	2972.650	1984.070
87.12 MW	3253.520	3083.400	2973.020	2350.210
110.0 MW	3188.000	3050.000	2913.000	2464.710

3.7 Programs used in the project:

• Matlab:

MATLAB offers an intuitive language for expressing problems and their solutions both mathematically and visually.

data calculated by matlab program. Chosen matlab because it’s very quickly to analysis and calculate data which is given from bahari thermal power plant.

We entered the equation and variables to known in program data and saved in it after that we entered the values of variable; matlab lonely calculated the value and give us the result and plot curves.

• Excel:

We also used excel program to drew the carve between load and efficiency. Excel program is one of application use to solve numerical calculation by put it in tables, carves and shapes to explain the relationship between them like our cause.

CHAPTER FOUR

(Calculation & discussion)

4.1 Calculation:

In case one to use equation (2.2) at simple calculation:

Basic data (from Bahri at 110MW):-

$\dot{m}_s$=404.65 t/h = 112.41kg/s, $\dot{m}_f$=24.44 t/h=6.79kg/s, T_1=230.5^{0}C P_1=93.5 bar, T_2=535 C, P2=88.26 bar, T3=377.5^{0}C, P_3=26.99 bar, T_4=304.7^{0}C

P_4=14.95 bar, T_5=233.0 ^{0}C, P_5=8.084 bar.

From steam table and interpolation:-

@ T_1=230.55C h = C_p*T_1= 4.19*230.55= 966 KJ/Kg.

@ [p=88.26bar, t=535^{0}C] on superheated h_1=3475 KJ/Kg

@ [p=26.99bar, t=377.5^{0}C] on superheated h_2=3188KJ/Kg

@ [p=14.95bar, t=304.7^{0}C] on superheated h_3=3050KJ/Kg

@ [p=8.08bar, t=233.0^{0}C] on superheated h_4=2913KJ/Kg,

S_4=S_5 =7.7675KJ/Kg. K, @ P_5=101 mbar, S_{fg}=7.494KJ/Kg .K

S_f=.651KJ/Kg .K, h_{fg}=2391.8KJ/Kg, h_f=192.5KJ/Kg.

X=[7.7675-.651]/7.494=0.95.

h_{cs}=192.5+.95*2391.8=2464.71KJ/Kg.

Boiler efficiency (η) = [(112.41*(3475-966))/ (6.79*44160)]*100

Boiler efficiency (η) = 94.060%

In case final to use equation (2.3) at simple calculation:

Turbine efficiency(η)=[(112.41*(3475-3188) +107.08*(3188-3050)+102.36*(3050-2913)+98.56*(2913-2464.710))/(112.41*(3475 966))]*100

Steam Turbine efficiency (η) = 37.45%

- **The result given by matlab program:**

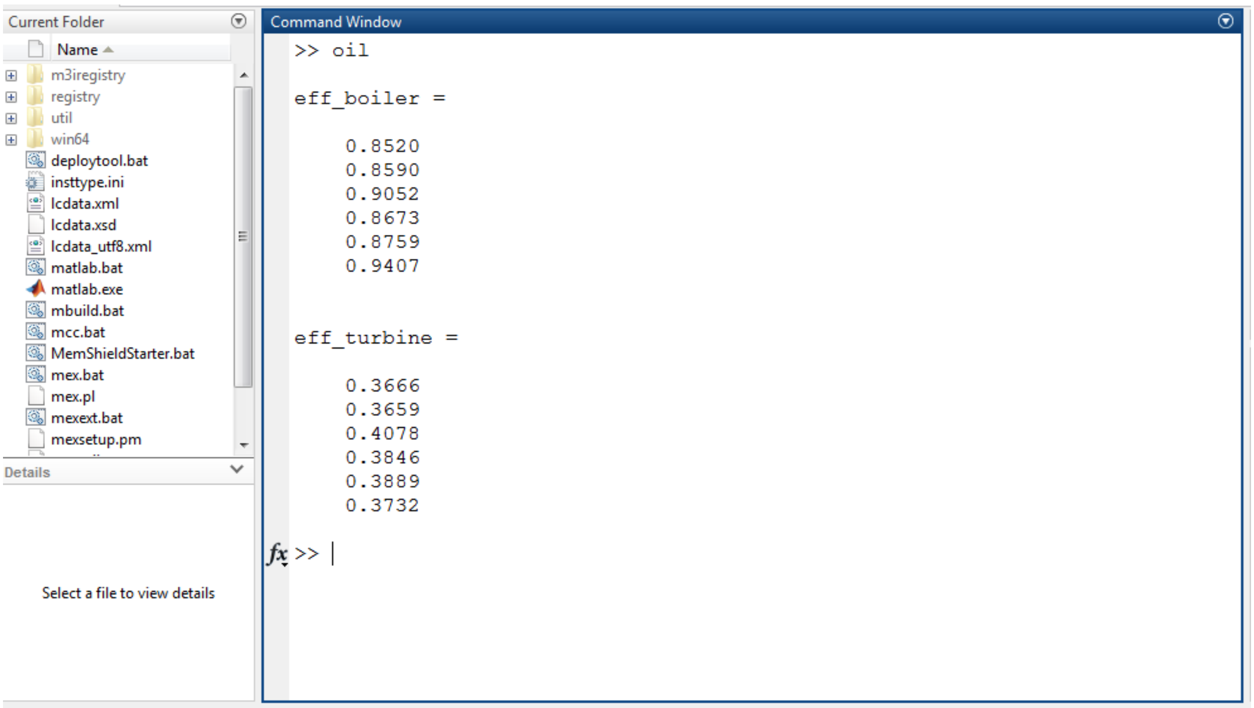


Figure 4.1: boiler and turbine efficiency

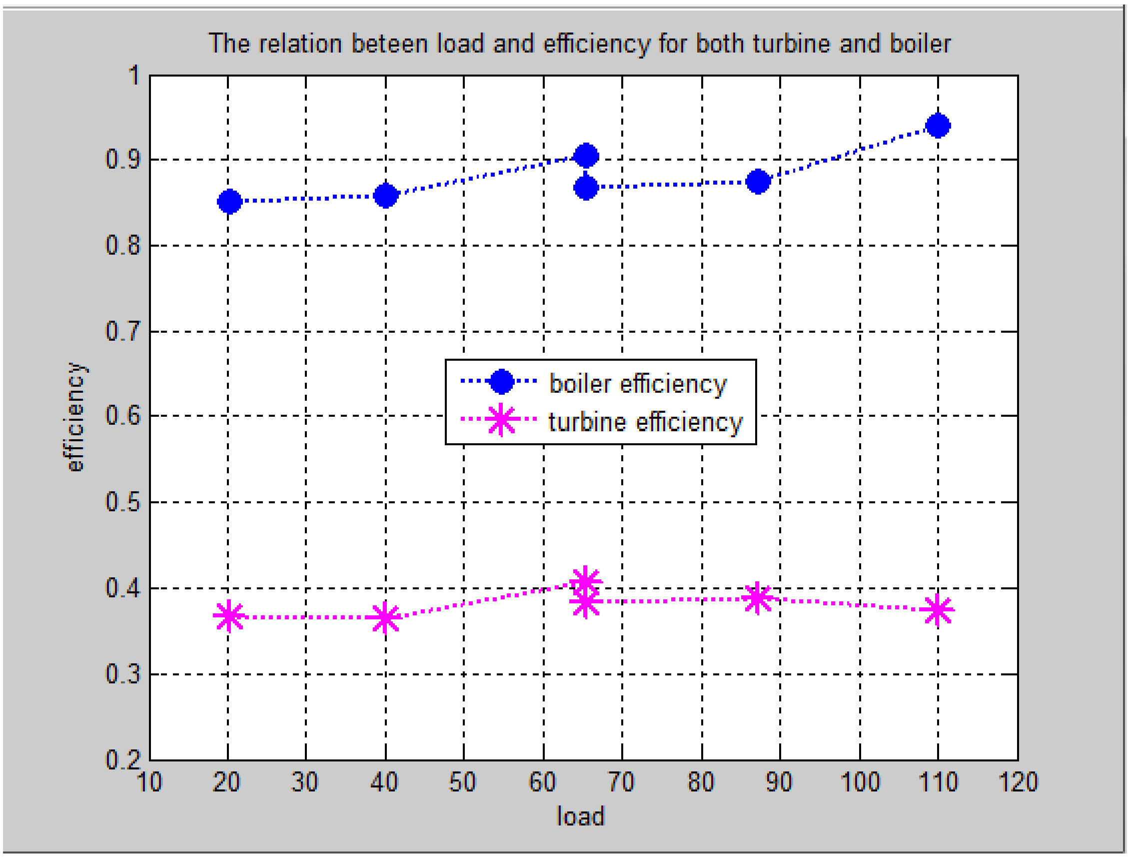


Figure 4.2: relationship between efficiency and load

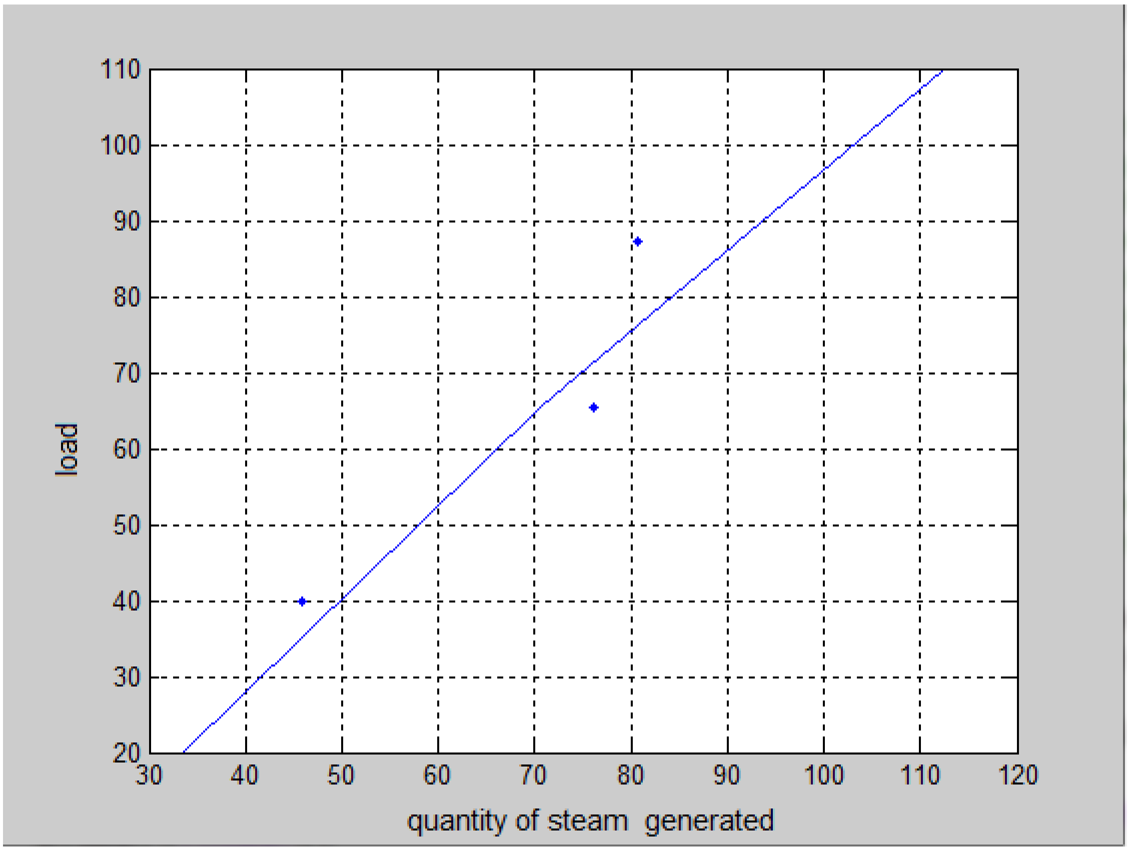


Figure 4.3: The relationship between steam generation and load

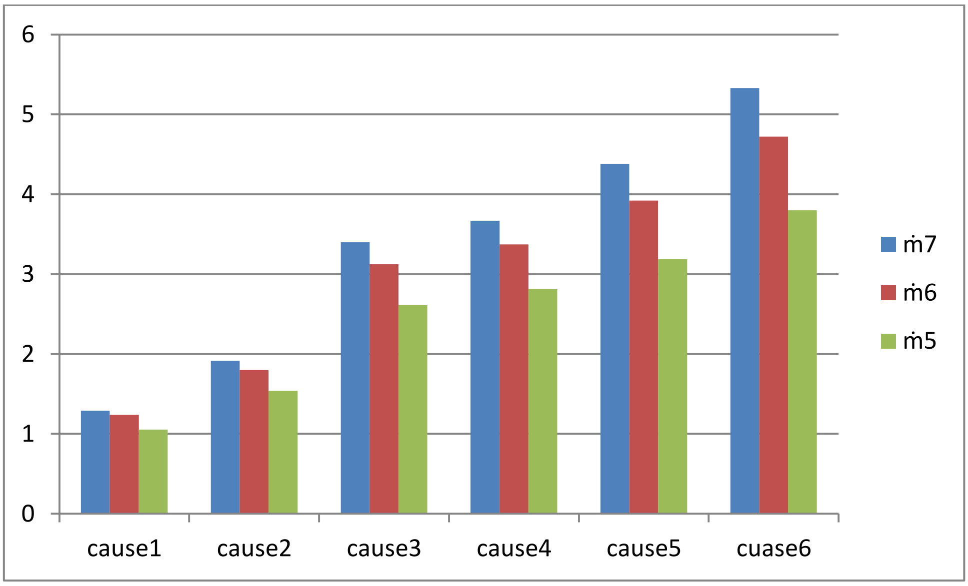


Figure 4.4: the curve between amount of steam and load

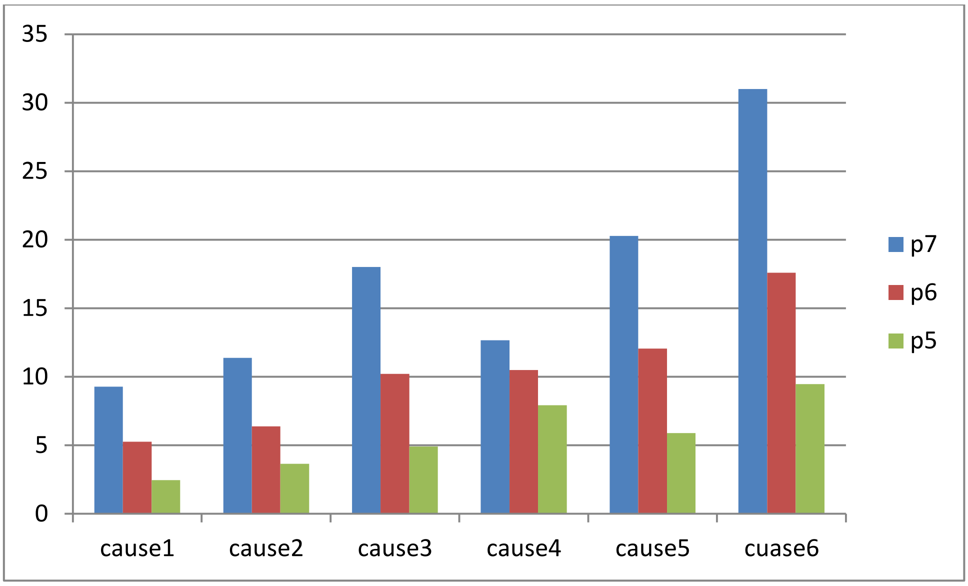


Figure 4.5: curve between heaters pressure and load

4.2 Discussion:

4.2.1 boiler efficiency:

From the result noted the boiler efficiency generally increased typically increased the load. and Increase the load led to increase steam generates also Extraction pressure and extraction mass flow rate for each feed water increase on case load increase.

- Cause one (20.24MW) efficiency boiler little because startup is began and steam flow little, fuel flow also little, some of burners open.
- Cause two (40MW) noted that the efficiency of boiler increase than cause one because the load increased.
- Cause three (65.32MW- blackout) this result taken before the blackout happened for some fraction of seconds although the parameters not stable and try to return to their natural position we could see the efficiency very high comparison to steady state in same load.

- Cause four (65.32MW) in this load the efficiency of boiler high gradually comparison between the other cause before accept cause three.
- Cause five (87.12MW) this also new cause verified increase load work on increase the efficiency of boiler.
- Cause six(110MW) in this cause the efficiency of boiler is maximum limit for ever because this maximum load could generated in unit six.

We noted that all the result located in the standard limit in paragraph (2.9.4)

4.2.2 steam turbine efficiency:

From the above curve in figure(4.2) we note that when increasing the load increases the efficiency in a steady state and also note that in case of Blackout the efficiency varies from a steady state in the same load due to the failure to achieve a steady state before the Blackout, because the other parameters included in the calculation of efficiency may vary and therefore the efficiency varied **.**

We noted that all the result located in the standard limit in paragraph (2.3.4)

4.3 Externals:

4.3.1 Trips:

Trips which is occurs in Bahri power plant:

- Bending in turbine shaft:

This cause occurs because the lubricant oil is stopped to flow, for this reason the friction is become more than limits after that the shaft is bending.

- The blade is breaking:

  Blade breaking because the level of condenser water become more than level

- Occurrence slot in boiler tube:

The pressure high become more than limit level also safety valve not operate and caused slots. This slots working for boiler pressure losses by leaking the steam.

4.3.2 Surge:

Surge is low in the electrical current because there is big load inter in the electrical network suddenly.

This big load work on turbine trip but governors inter more steam to meet this increase load and work to balancing the frequency after that current stable.

This external could see it if you are open your lamp you watch suddenly light is become low and return to stable, this mean surge.

4.3.3 Blackout:

A blackout refers to the total loss power to an area and is the most severe from power outage that can occur.

Outage may last from a few minutes to few weeks depending on the nature of blackout and the configurations of the electrical network.

Generally black out can occur if there is over load or under load.

4.4 Reason of load variation:

4.4.1 External reasons:

External reasons means the load which is inter the electrical network or outer network

- Load Inter to electrical network:

Such as Giad furnace (40 MW) if this furnaceinter suddenly the network without plant known it can causes load variation in network.

- load out from electrical network:

This occurs if this furnace out(40MW) suddenly or high voltage tower fill down suddenly.

4.4.2 Internal reasons:

Internal reason a cause happen in a plant work to decrease the load or increase the load not under control.

4.4.2.1 decrease the load:

1. One forced fan out.

2. Pressure less in the fuel supply.

4.4.2 Increase the load:

- ❖ Condenser pressure less.

Chapter 5

(Conclusion & recommendation)

Conclusion and recommendation

❖ Conclusion

- In the boiler efficiency raise to 95% in steam power plant depend on natural operate. in our cause Bahri in unit six we found the efficiency of boiler between(85-95)% is result been like this because boiler operate depend on type of fuel, ideal natural operate and amount of steam losses in auxiliary.
- The standard turbine efficiency which is work in thermal steam power plant depending on paragraph (2.3.4). In Bahri power plant we are calculate the steam turbine efficiency in phase three which is largest phase in the plant(110MW).we found steam turbine efficiency between (31-35)% because some of equipment not work automatically also pressure less heaters not work, for this we saw the load variation not effect in thermal unit parameter accept in life time of turbine by operating to full load sometime and small load for other time. In the anther hands load variation suddenly and more blackout effect in life turbine.
- We found the reason of load variation on thermal unit is internal reason and external reason which explain paragraph (4.4).

❖ Recommendation

- Use simulations programs to find the Momentariness of efficiency.
- Calculate the boiler efficiency by indirect method.
- Enter the pressure less heaters in turbine efficiency calculate.
- Calculate the average to values which is taken form history data.

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Appendix

With matlab program:

>>Clc, clear

1. A % flow rate steam generate on boiler or steam supply inlet turbine %

2. B % flow rate oil supply in boiler burners' %

3.C % outlet boiler or inlet turbine %

4. D %enthalpy of water inlet boiler %

5. E % flow rate steam supply after feedheater one %

6. F % flow rate steam supply after feedheater two %

7. G % flow rate steam supply inlet condenser %

8. I % enthalpy of steam inlet feedheater one %

9. J % enthalpy of steam inlet feedheater two %

10. K % enthalpy of steam inlet open feedheater %

11. L % enthalpy of steam inlet condenser %

12. M % load of unit %

13. A = [33.61; 45.94; 70.49; 76.08; 80.714; 112.41];

14. B = [2.86; 3.553; 4.611; 5.2; 5.531; 6.789];

15. C = [3519; 3577; 3488.91; 3498.65; 3490.19; 3475];

16. D = [893.015; 306.17; 873.996; 880.81; 893.015; 966];

17. E = [32.32; 39.044; 67.09; 72.41; 76.333; 107.08];

18. F = [31.08; 32.534; 63.968; 69.04; 72.413; 102.36];

19. G = [30.03; 26.994; 61.358; 66.23; 69.227; 98.56];

20. I = [3030; 3092.39; 3215.04; 3272.8; 3253.52; 3188];

21. J = [2874.9; 2967.99; 3071.6; 3128.19; 3083.4; 3050];

22. K = [2756.85; 2795.36; 2942.8; 2972.65; 2973.02; 2913];

23. L = [2279.549; 2290.5; 2328.05; 1984.07; 2350.21; 2464.71];

24. M = [20.24; 40; 65.32; 65.32; 87.12; 110];

25. Eff-boiler = [A.*[C-D]./[44160*B]

26. Eff-steam turbine = [A.*[C-I]+E.*[I-J]+F.*[J-K]+G.*[K-L]]./[A.*(C-D)]

27. Plot (M, eff-boiler, '.:', 'markersize', 30,' line width',2)

28. Hold on

29. Plot (M, eff-turbine, '*:', 'markersize', 13,' line width',2,'coler',[1 0 1])

30. Grid, axis([10 120 0.2 1])

31.Set (legend ('boiler efficiency','turbine efficiency'),'position'…
[0.39538095238092   0.486507936507937   0.276785714285714   0.1]

32. X labe1 ('load')

33. Y labe1 ('efficiency')

34. Title ('the relation between load and efficiency for bothturbine…

And boiler')

35. Hold off

Table(5.1): saturated steam

Saturated Water and Steam (Pressure) Tables

Absolute pressure (bar)	*Temp. (°C)*	*Specific enthalpy (kJ/kg)*			*Specific entropy (kJ/kg K)*			*Specific volume (m^3/kg)*	
p	t_s	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	v_f	v_g
0.006113	0.01	0.01	2 501.3	2 501.4	0.000	9.156	9.156	0.0010002	206.14
0.010	7.0	29.3	2 484.9	2 514.2	0.106	8.870	8.976	0.0010000	129.21
0.015	13.0	54.7	2 470.6	2 525.3	0.196	8.632	8.828	0.0010007	87.98
0.020	17.0	73.5	2 460.0	2 533.5	0.261	8.463	8.724	0.001001	67.00
0.025	21.1	88.5	2 451.6	2 540.1	0.312	8.331	8.643	0.001002	54.25
0.030	24.1	101.0	2 444.5	2 545.5	0.355	8.223	8.578	0.001003	45.67
0.035	26.7	111.9	2 438.4	2 550.3	0.391	8.132	8.523	0.001003	39.50
0.040	29.0	121.5	2 432.9	2 554.4	0.423	8.052	8.475	0.001004	34.80
0.045	31.0	130.0	2 428.2	2 558.2	0.451	7.982	8.433	0.001005	31.13
0.050	32.9	137.8	2 423.7	2 561.5	0.476	7.919	8.395	0.001005	28.19
0.055	34.6	144.9	2 419.6	2 565.5	0.500	7.861	8.361	0.001006	25.77
0.060	36.2	151.5	2 415.9	2 567.4	0.521	7.809	8.330	0.001006	23.74
0.065	37.6	157.7	2 412.4	2 570.1	0.541	7.761	8.302	0.001007	22.01
0.070	39.0	163.4	2 409.1	2 572.5	0.559	7.717	8.276	0.001007	20.53
0.075	40.3	168.8	2 406.0	2 574.8	0.576	7.675	8.251	0.001008	19.24
0.080	41.5	173.9	2 403.1	2 577.0	0.593	7.636	8.229	0.001008	18.10
0.085	42.7	178.7	2 400.3	2 579.0	0.608	7.599	8.207	0.001009	17.10
0.090	43.8	183.3	2 397.7	2 581.0	0.622	7.565	8.187	0.001009	16.20
0.095	44.8	187.7	2 395.2	2 582.9	0.636	7.532	8.168	0.001010	15.40
0.10	45.8	191.8	2 392.8	2 584.7	0.649	7.501	8.150	0.001010	14.67
0.11	47.7	199.7	2 388.3	2 588.0	0.674	7.453	8.117	0.001011	13.42
0.12	49.4	206.9	2 384.2	2 591.1	0.696	7.390	8.086	0.001012	12.36
0.13	51.0	213.7	2 380.2	2 593.9	0.717	7.341	8.058	0.001013	11.47
0.14	52.6	220.0	2 376.6	2 596.6	0.737	7.296	8.033	0.001013	10.69
0.15	54.0	226.0	2 373.2	2 599.2	0.754 9	7.254 4	8.009 3	0.001014	10.022
0.16	55.3	231.6	2 370.0	2 601.6	0.772 1	7.214 8	7.986 9	0.001015	9.433
0.17	56.6	236.9	2 366.9	2 603.8	0.788 3	7.177 5	7.965 8	0.001015	8.911
0.18	57.8	242.0	2 363.9	2 605.9	0.803 6	7.142 4	7.945 9	0.001016	8.445
0.19	59.0	246.8	2 361.1	2 607.9	0.818 2	7.109 0	7.927 2	0.001017	8.027
0.20	60.1	251.5	2 358.4	2 609.9	0.832 1	7.077 3	7.909 4	0.001017	7.650
0.21	61.1	255.9	2 355.8	2 611.7	0.845 3	7.047 2	7.892 5	0.001018	7.307
0.22	62.2	260.1	2 353.3	2 613.5	0.858 1	7.018 4	7.876 4	0.001018	6.995
0.23	63.1	264.2	2 350.9	2 615.2	0.870 2	6.990 8	7.861 1	0.001019	6.709
0.24	64.1	268.2	2 348.6	2 616.8	0.882 0	6.964 4	7.846 4	0.001019	6.447

Table(5.2): superheated steam.

Superheated Steam at Various Pressures and Temperatures

↓p (bar) (t_s)	t (°C) →	50	100	150	200	250	300	400	500
	v	149.1	172.2	195.3	218.4	241.5	264.5	310.7	356.8
0.01	u	2445.4	2516.4	2588.4	2661.6	2736.9	2812.2	2969.0	3132.4
(7.0)	h	2594.5	2688.6	2783.6	2880.0	2978.4	3076.8	3279.7	3489.2
	s	9.242	9.513	9.752	9.967	10.163	10.344	10.671	10.960
	v	29.78	34.42	39.04	48.66	48.28	52.9	62.13	71.36
0.05	u	2444.8	2516.2	2588.4	2661.9	2736.6	2812.6	2969.6	3133.0
(32.9)	h	2593.7	2688.1	2783.4	2879.9	2977.6	3076.7	3279.7	3489.2
	s	8.498	8.770	9.009	9.225	9.421	9.602	9.928	10.218
	v	14.57	17.19	19.51	21.82	24.14	26.44	31.06	35.68
0.1	u	2443.9	2515.5	2587.9	2661.3	2736.0	2812.1	2968.9	3132.3
(45.8)	h	2592.6	2687.5	2783.0	2879.5	2977.3	3076.5	3279.6	3489.1
	s	8.175	8.448	8.688	8.904	9.100	9.281	9.608	9.898
	v		34.18	3.889	43.56	4.821	5.284	6.209	7.134
0.5	u		2511.6	2585.6	2659.9	2735.0	2811.3	2968.5	3132.0
(81.3)	h		2682.5	2780.1	2877.7	2976.0	3075.5	3278.9	3488.7
	s		7.695	7.940	8.158	8.356	8.537	8.864	9.155
	v		2.27	2.587	2.900	3.211	3.520	4.138	4.755
0.75	u		2509.2	2584.2	2659.0	2734.4	2810.9	2968.2	3131.8
(92.0)	h		2679.4	2778.2	2876.5	2975.2	3074.9	3278.5	3488.4
	s		7.501	7.749	7.969	8.167	8.349	8.677	8.967
	v		1.696	1.936	2.172	2.406	2.639	3.103	3.565
1.0	u		2506.2	2582.8	2658.1	2733.7	2810.4	2967.9	3131.6
(99.6)	h		2676.2	2776.4	2875.3	2974.3	3074.3	3278.2	3488.1
	s		7.361	7.613	7.834	8.033	8.216	8.544	8.834
	v			1.912	2.146	2.375	2.603	3.062	3.519
1.01325	u			2582.6	2658.0	2733.6	2810.3	2967.8	3131.5
(100)	h			2776.3	2875.2	2974.2	3074.2	3278.1	3488.0
	s			7.828	7.827	8.027	8.209	8.538	8.828
	v			1.285	1.143	1.601	1.757	2.067	2.376
1.5	u			2579.8	2656.2	2732.5	2809.5	2967.3	3131.2
(111.4)	h			2772.6	2872.9	2972.7	3073.1	3277.4	3487.6
	s			7.419	7.643	7.844	8.027	8.356	8.647

	v			0.960	1.080	1.199	1.316	1.549	1.781
2.0	u			2576.9	2654.4	2731.2	2808.6	2966.7	3130.8
(120.2)	h			2768.8	2870.5	2971.0	3071.8	3276.6	3487.1
	s			7.279	7.507	7.709	7.893	8.222	8.513
	v			0.764	0.862	0.957	1.052	1.238	1.424
2.5	u			2574.7	2655.7	2734.9	2813.8	2973.9	3139.6
(127.4)	h			2764.5	2868.0	2969.6	3070.9	3275.9	3486.5
	s			7.169	7.401	7.604	7.789	8.119	8.410
	v			0.634	0.716	0.796	0.875	1.031	1.187
3.0	u			2570.8	2650.7	2728.7	2806.7	2965.6	3130.0
(133.5)	h			2761.0	2865.6	2967.6	3069.3	3275.0	3486.1
	s			7.078	7.311	7.517	7.702	8.033	8.325
	v			0.471	0.534	0.595	0.655	0.773	0.889
4.0	u			2564.5	2646.8	2726.1	2804.8	2964.4	3129.2
(143.6)	h			2752.8	2860.5	2964.2	3066.8	3273.4	3484.9
	s			6.930	7.171	7.379	7.566	7.899	8.191

	v	0.425	0.474	0.523	0.570	0.617	0.664	0.711	0.804
5.0	u	2642.9	2723.5	2802.9	2882.6	2963.2	3045.3	3128.4	3299.6
(151.8)	h	2855.4	2960.7	3064.2	3167.7	3271.9	3377.2	3483.9	3701.7
	s	7.059	7.271	7.460	7.633	7.794	7.945	8.087	8.353
	v	0.352	0.394	0.434	0.474	0.514	0.553	0.592	0.670
6.0	u	2638.9	2720.9	2801.0	2881.2	2962.1	3044.2	3127.6	3299.1
(158.8)	h	2850.1	2957.2	3061.6	3165.7	3270.3	3376.0	3482.8	3700.9
	s	6.967	7.182	7.372	7.546	7.708	7.859	8.002	8.267
	v	0.300	0.336	0.371	0.406	0.440	0.473	0.507	0.574
7.0	u	2634.8	2718.2	2799.1	2879.7	2960.9	3043.2	3126.8	3298.5
(165.0)	h	2844.8	2953.6	3059.1	3163.7	3268.7	3374.7	3481.7	3700.2
	s	6.886	7.105	7.298	7.473	7.635	7.787	7.930	8.196
	v	0.261	0.293	0.324	0.354	0.384	0.414	0.443	0.502
8.0	u	2630.6	2715.5	2797.2	2878.2	2959.7	3042.3	3126.0	3297.8
(170.4)	h	2839.3	2950.1	3056.5	3161.7	3267.1	3373.4	3480.6	3699.4
	s	6.816	7.038	7.233	7.409	7.572	7.724	7.867	8.133

	v	0.230	0.260	0.287	0.314	0.341	0.367	0.394	0.446
9.0	u	2626.3	2712.7	2795.2	2876.7	2958.5	3041.3	3125.2	3297.3
(175.4)	h	2833.6	2946.3	3053.8	3159.7	3265.5	3372.1	3479.6	3698.6
	s	6.752	6.979	7.175	7.352	7.516	7.668	7.812	8.078
	v	0.206	0.233	0.258	0.282	0.307	0.330	0.354	0.401
10.0	u	2621.9	2709.9	2793.2	2875.2	2957.3	3040.3	3124.4	3296.8
(179.9)	h	2827.9	2942.6	3051.2	3157.8	3263.9	3370.7	3478.5	3697.9
	s	6.694	6.925	7.123	7.301	7.465	7.618	7.762	8.029
	v	0.132	0.152	0.169	0.187	0.203	0.219	0.235	0.267
15.0	u	2598.8	2695.3	2783.1	2867.6	2951.3	3035.3	3120.3	3293.9
(198.3)	h	2796.8	2923.3	3037.6	3147.5	3255.8	3364.2	3473.1	3694.0
	s	6.455	6.709	6.918	7.102	7.269	7.424	7.570	7.839
	v		0.111	0.125	0.139	0.151	0.163	0.176	0.200
20.0	u		2679.6	2772.6	2859.8	2945.2	3030.5	3116.2	3290.9
(212.4)	h		2902.5	3023.5	3137.0	3247.6	3357.5	3467.6	3690.1
	s		6.545	6.766	6.956	7.127	7.285	7.432	7.702
	v		0.0870	0.0989	0.109	0.120	0.130	0.140	0.159
25	u		2662.6	2761.6	2851.9	2939.1	3025.5	3112.1	3288.0
(223.9)	h		2880.1	3008.8	3126.3	3239.3	3350.8	3462.1	3686.3
	s		6.408	6.644	6.840	7.015	7.175	7.323	7.596
	v		0.0706	0.0811	0.0905	0.0994	0.108	0.116	0.132
30	u		2644.0	2750.1	2843.7	2932.8	3020.4	3108.0	3285.0
(233.8)	h		2855.8	2993.5	3115.3	3230.9	3344.0	3456.5	3682.3
	s		6.287	6.539	6.743	6.921	7.083	7.234	7.509
	v			0.0588	0.0664	0.0734	0.080	0.0864	0.0989
40	u			2725.3	2826.7	2919.9	3010.2	3099.5	3279.1
(250.4)	h			2960.7	3092.5	3213.6	3330.3	3445.3	3674.4
	s			6.362	6.582	6.769	6.936	7.090	7.369
	v			0.0453	0.0519	0.0578	0.0633	0.0686	0.0787
50	u			2698.0	2808.7	2906.6	2999.7	3091.0	3273.0
(263.9)	h			2924.5	3068.4	3195.7	3316.2	3433.8	3666.5
	s			6.208	6.449	6.646	6.819	6.976	7.259

60 (275.5)	v u h s			0.0362 2667.2 2884.2 6.067	0.0422 2789.6 3043.0 6.333	0.0474 2892.9 3177.2 6.541	0.0521 2988.9 3301.8 6.719	0.0567 3082.2 3422.2 6.880	0.0653 3266.9 3658.4 7.168
70 (285.8)	v u h s			0.0295 2632.2 2838.4 5.931	0.0352 2769.4 3016.0 6.228	0.0399 2878.6 3158.1 6.448	0.0442 2978.0 3287.1 6.633	0.0481 3073.4 3410.3 6.798	0.0557 3260.7 3650.3 7.089

↓*p (bar)* (t_s)	*t (°C)* →	*350*	*375*	*400*	*450*	*500*	*550*	*600*	*700*
80 (294.9)	v h s	0.02995 2987.3 6.130	0.03222 3066.1 6.254	0.03432 3138.3 6.363	0.03817 3272.0 6.555	0.04175 3398.3 6.724	0.04516 3521.0 6.878	0.04845 3642.0 7.021	0.05481 3882.4 7.281
90 (303.3)	v h s	0.0258 2956.6 6.036	0.02796 3041.3 6.169	0.02993 3117.8 6.285	0.03350 3256.6 6.484	0.03677 3386.1 6.658	0.03987 3511.0 6.814	0.04285 3633.7 6.959	0.04857 3876.5 7.222
100 (311.0)	v h s	0.02242 2923.4 5.944	0.02453 3015.4 6.089	0.02641 3096.5 6.212	0.02975 3240.9 6.419	0.03279 3373.7 6.597	0.03564 3500.9 6.756	0.03837 3625.3 6.903	0.04358 3870.5 7.169
110 (318.0)	v h s	0.01961 2887.3 5.853	0.02169 2988.2 6.011	0.02351 3074.3 6.142	0.02668 3224.7 6.358	0.02952 3361.0 6.540	0.03217 3490.7 6.703	0.03470 3616.9 6.851	0.03950 3864.5 7.120
120 (324.6)	v h s	0.01721 2847.7 5.760	0.01931 2958.9 5.935	0.02108 3051.3 6.075	0.02412 3208.2 6.300	0.02680 3348.2 6.487	0.02929 3480.4 6.653	0.03164 3608.3 6.804	0.03610 3858.4 7.075
130 (330.8)	v h s	0.01511 2803.3 5.663	0.01725 2927.9 5.859	0.01900 3027.2 6.009	0.02194 3191.3 6.245	0.0245 3335.2 6.437	0.02684 3469.9 6.606	0.02905 3599.7 6.759	0.03322 3852.3 7.033
140 (336.6)	v h s	0.01322 2752.6 5.559	0.01546 2894.5 5.782	0.01722 3001.9 5.945	0.02007 3174.0 6.192	0.02252 3322.0 6.390	0.02474 3459.3 6.562	0.02683 3591.1 6.712	0.03075 3846.2 6.994
150 (342.1)	v h s	0.01145 2692.4 5.442	0.01388 2858.4 5.703	0.01565 2975.5 5.881	0.01845 3156.2 6.140	0.02080 3308.6 6.344	0.02293 3448.6 6.520	0.02491 3582.3 6.679	0.02861 3840.1 6.957