SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF POST GRADUATE STUDIES

Effect of Operating Conditions on Thermal Efficiency of Khartoum North Power Station

تأثير ظروف التشغيل على الفعالية الحرارية لمحطة كهرباء الخرطوم بحري

This thesis is a partial fulfillment of the degree of M.Sc. of Science in Mechanical Engineering (Power)

By

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الآيـة

قال تعالي:

((أتونى زبر الحديد حتى إذا ساوى بين الصدفين قال إنفخوا حتى إذا جعله ناراً قال أتونى أفرغ عليه قطراً (96) فما أسطعوا أن يظهروه وماإستطعوا له نقباً (97)))

صدق الله العظيم

سورة الكهفالآيـ (96) – (97) ـات

Dedication

To whom covered me with their completely welfare

My parents

To whom supported & helped me during my studying years

My generous teachers

To whom   associated and shared with me studying classes

My brothers …. Sisters…. Nobel friends

Special thanks to Eng. Zuhier Mohammed Elshaikh Dafalla

Acknowledgement

We thank (Allah) for giving us the power & strength to complete this project Our deepest thanks to:

Dr. Abdallah Mokhtar &Mechanical school teachers

Abstract:

The aim of this research is to know the operating conditions and its factors that affect thermal efficiency due to the low efficiency of thermal stations and excessive consumption of fuel and its main objective is to increase efficiency and thus reduce fuel consumption and selecting the best factors affecting efficiency. This research explained the relationship between the most important variables in efficiency This research explained the importance of generating electricity and methods of generation and focused on steam stations, parts and important components

This research also included the studies conducted in this field. Readings were taken from Khartoum north power station. Results were obtained and the relationship between the variables was explained by charts and figures with MATLAB software. I have recommended some important recommendations which in turn can increase the efficiency of the course.

التجريدة:

هـدف هـذا البحـث الـى معرفـة ظـروف التشـغيل وعواملـه التـي تـؤثر فـي الكفـاءة الحراريـة وترجـع اهميتـه الـى انخفـاض كفـاءة المحطـات الحراريـة والاسـتهلاك الزائـد للوقـود فهـدفهاه الاساسـيان همـا زيـادة الكفـاءة وبالتـالي تقليـل اسـتهلاك الوقـود واختيـار افضـل العوامـل المـؤثرة فـي الكفـاءة واوضـح هـذا البحـث العلاقـة بـين اهـم المتغيـرات فـي الكفـاءة واوضـح هـذا البحـث اهميـة توليـد الطاقـة الكهربائيـة وطـرق توليـدها وركـز علـى المحطـات البخاريـة والاجـزاء والمكونـات المهمـة بـين ايضـا هـذا البحـث الدرسـات التـي اجريـت فـي هـذا المجـال تـم اخـذ قـراءات مـن محطـة كهربـاء الخرطـوم بحـري الحراريـة وتـم الحصـول علـى نتـائج ووضـحت العلاقـة بـين المتغيـرات بمخططـات وارقـام عـن طريـق برنـامج المـاتلاب وقـد اوصـيت بـبعض التوصـيات المهمـة التـي بـدورها يمكـن ان تزيد كفاءة الدورة.

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List of Symbols

Symbol	**Description**	**Unit**
MW	Mega watt	
η_{total}	Overall efficiency	-
h_4	Total heat out from boiler	kJ
m_f	fuel burning rate	kg/sec
CV	caloric value of fuel	MJ/kg
η_{boiler}	boiler (steam generator) efficiency	-
m_s	Steam flow from boiler	Kg/sec
h_1	Enthalpy value enter turbine	kJ/kg
h_2	Enthalpy value out from turbine	kJ/kg
$\eta_{turbine(mech)}$	Turbine efficiency	-
$\eta_{generator}$	Generator efficiency	-
$\square_{leakage}$	Leakage efficiency	-
$\square_{radiation}$	Radiation efficiency	-
$\square_{turbine}$	Turbine efficiency	-
$\square_{transformer}$	Transformer efficiency	-
η_{aux}	Auxiliary efficiency	-
C	Fixed heat	kJ/hr
m	Incremental heat	kJ/kWhr
$\square_{work\ power}$	Generator efficiency	-
cw1	Cooling water inlet temperature	^oC
cw2	Cooling water outlet temperature	^oC
$\square_M$	Mechanical efficiency	-
$\square_{EFP}$	Electrical feed pump motor efficiency	-
$\square_E$	Electrical feed pump motor efficiency	-
cw	Cooling water temperature rise	^oC
heat19	actual heat rejected	kW
m_4	actual cw flow	kg/s
lmtd	Design log mean temperature difference	-
lmtd2	New log mean temperature difference	-
cw3	Temp rise	^oC

cw4	Temp of cw outlet during change load	^{o}C
sent1	Total energy sent out	MW
lmtd3	New log mean temperature difference	-
eff14	Target thermal efficiency corrected to CW condition (theoretical efficiency)	-
heat26	Heat for generation including starts	GJ
eff20	Target thermal efficiency at actual condition including starts	-
eff22	Efficiency at actual temp	-
loss2	Loss due heater out of service	-
eff23	Efficiency loss due heater out of service	-
cont2	%CO2 percentage	-
eff24	Change in boiler efficiency	-
eff25	Unit thermal efficiency due change in excess air	-
eff26	Unit thermal efficiency due temp difference	-
loss3	Loss due change in temp difference	-
gen1	Total generated load	
aux1	Aux power used (boiler and turbine)	MW
aux2	General services aux power	MW
aux3	Off load power consumption at (cold warm hot) type of operation	MW
aux4	Target total aux power	MW
aux5	Actual aux power used	MW
aux6	Difference in aux power	MW
heat27	Difference in heat input	GJ
eff27	Efficiency at gain or loss when use actual aux power	-

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CHAPTER ONE

Introduction

CHAPTER ONE

Introduction

1-1Introduction:

Power station running costs can be grouped into three categories (fuel materials good services, salaries and wages) less than half the heat in the fuel is converted to electricity and the loss to the condenser accounts for more heat than does the electrical output. There are some engineers whose full time job it is to monitor the performance of the plant, to make recommendations for improvements and to keep the station management fully aware of undesirable trends. Each month, station returns are submitted to regional headquarters detailing the efficiency achieved and the magnitude of the losses sustained. Carnot (1796-1832) developed profound abstract ideas about thermodynamics .in particular he conceived the idea of a perfectly insulated frictionless heat engine. All of its heat is received at an upper temperature and reject at a constant temperature. The compression and expansion of the steam is isentropic and the heat acceptance and rejection is isothermal. The Rankine cycle is very useful as a means of determining the ultimate performance of plant working between particular heat input and rejection temperatures. However, the theoretical cycle upon which actual steam plant is based is that devised by Rankine in Rankine the condensation of steam is continued to completion rather than the impractical partial condensation assumed in the Carnot cycle. Each modification to the basic cycle has result in improvement efficiency. The best Rankine cycle efficiency is lower than Carnot cycle. the improvement on Rankine cycle in by reheating and feed heating by increasing the temperature inlet to the turbine. [1]

The Rankin steam power cycle is one of the most important cyclic processes used in industry. The efficiency of electrical power generation has been increased in the last few years due to process optimization. Nowadays a total efficiency of approx. 38%. For this reason, the steam power cycle plays an important role in engineering education. The objective of this research is to show the operation variables effect on efficiency into manual calculation of Steam Power Plant Cycle efficiency and to optimize to get the biggest possible Efficiency, making changes in the feed variables of the cycle. [1]

1-2 Problem Statement:

The stations suffer from low efficiency and plenty of many operation variable effect on thermal efficiency which is difficult to select the best??All station concentrate on the overall efficiency. the effect of any parameter in efficiency not cleared it cleared after any period until occurring steady state it took time it different from variable to variable. this research involves all the parameter and its relation with efficiency and any parameter effect alone on thermal efficiency.

1-3 Objectives:

- The effect of variation of operation parameters on efficiency.
- select the best parameter to get high efficiency.
- determine the efficiency and performance of Steam power plant.

1-4 Methodology:

- Study the theoretical side of the Steam cycle power plants.
- Review literature to explore different calculation methods and compare/evaluate these methods

- Select variables affecting efficiency.
- Collect design and actual operation data.
- Choose the equations to be used in the calculation of thermal efficiency, enter all data and obtain desired results by analytical methods.

1-5 Expected result:

- Determine the values of operation variables and parameters to achieve optimum efficiency.
- Recommended actions to maximize efficiency.
- **1-6 Times**

Introduction	From Nov 2016 to dec2016
Theoretical framework andliterature review	From Oct 2016 to dec2016
Description of methodAnalytical method	From |Oct 2016 to Jan 2017
Calculations and result discuss	From Dec 2016 to Jan 2017
Conclusions recommendation	April 2017

1-7 Field of study:

The field of study in Khartoum North Power Station in unit 1 steam turbine

CHAPTER TWO

Theoretical framework and Literature Review

CHAPTER TWO

Theoretical framework and Literature Review

2-1Theoretical framework

2-1-1Concept of power plant

A power plant is assembly of systems or subsystems to generate electricity, i.e., power with economy and requirements. The power plant itself must be useful economically and environmental friendly to the society. While the stress is on energy efficient system regards conventional power systems *viz.*, toincrease the system conversion efficiency. A power plant may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated. The type of prime move determines, the type of power plants. The major power plants, which are: -

1. Steam power plant
2. Diesel power plant
3. Gas turbine power plant
4. Nuclear power plant
5. Hydroelectric power plant

The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plantsare called THERMAL POWER PLANT**,** because these convert heat into electric energy. [3]

2-1-2 Steam power plant:

A steam power plant continuously converts the energy stored in fuel (coal, oil, natural gas) into shaft work and ultimately into electricity. The working fluid is water which is some times in the liquid phase and sometimes in the vapor phase during its cycle of operation. Figure illustrates a fossil fueled power plant as a bulk energy converter from fuel to electricity using water as working medium. energy released by the burning of fuel is transferred to water in the boiler (to generate steam at a high pressure and temperature, which then expands in the turbine (T) to a low pressure to produce shaft work. The steam leaving the turbine is condensed into water in condenser where cooling water from a river or sea circulates carrying a way the heat released during a condensation. the water condensate is then fed back to the boiler by pump(P), and the cycle goes on repeating itself. The working substance, water, thus follows along the B T C P path of the cycle interacting externally as shown [2]

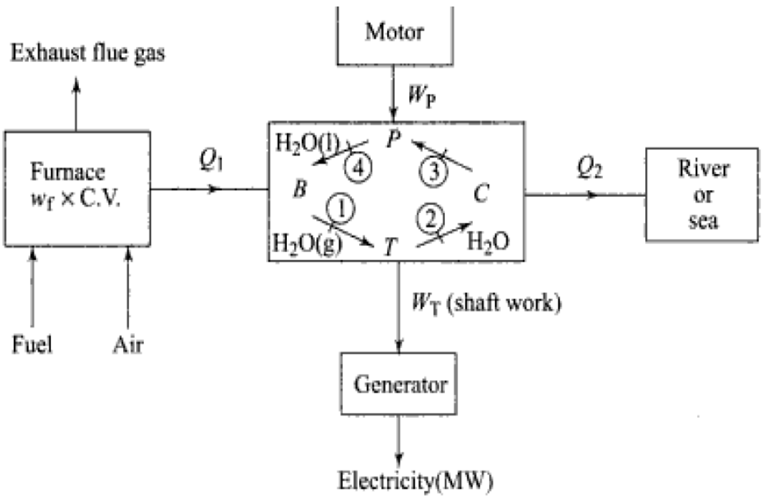


Figure 2.1 Steam power plant – bulk energy converter from fuel to electricity

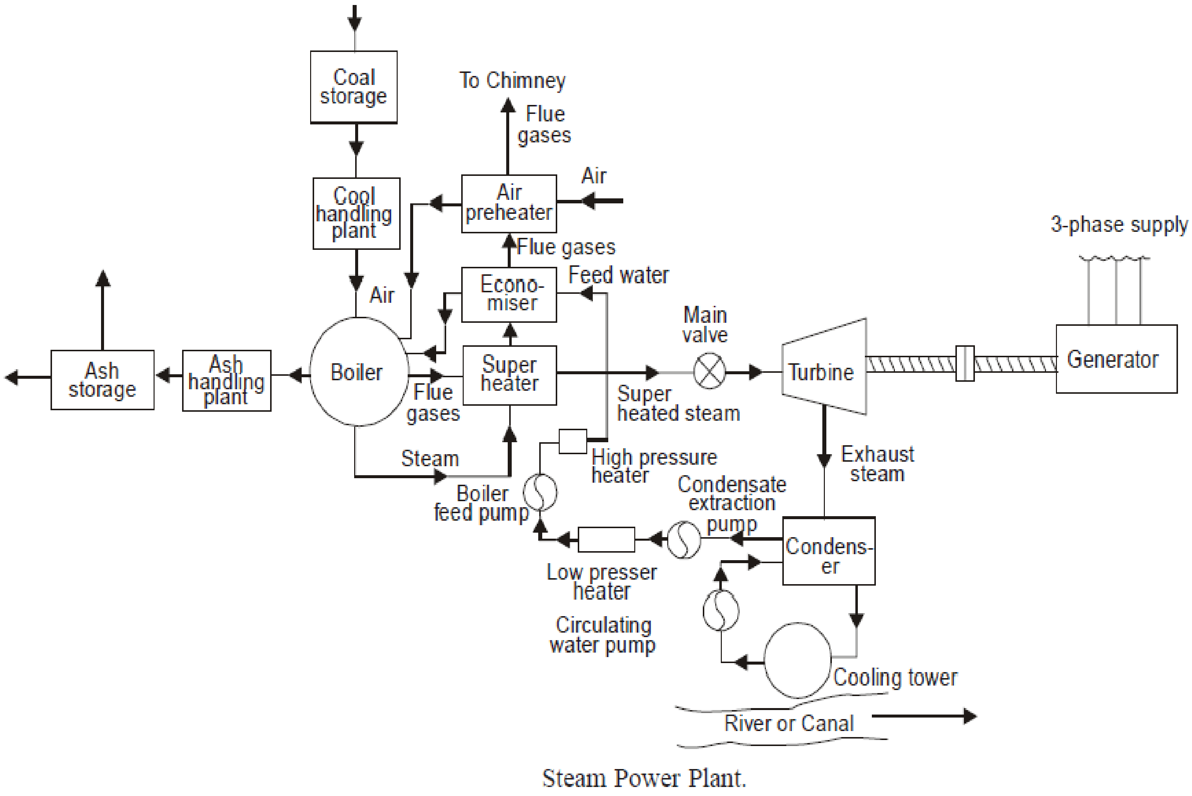


Figure 2.2 Steam power plant components

2-1-3 Analysis of Regenerative Cycle (feed heating)

The process of extracting steam from the turbine at certain points during its expansion and using this steam for heating for feed water is known as Regeneration or Bleeding of steam. The arrangement of bleeding the steam at two stages is shown in Fig below. [3]

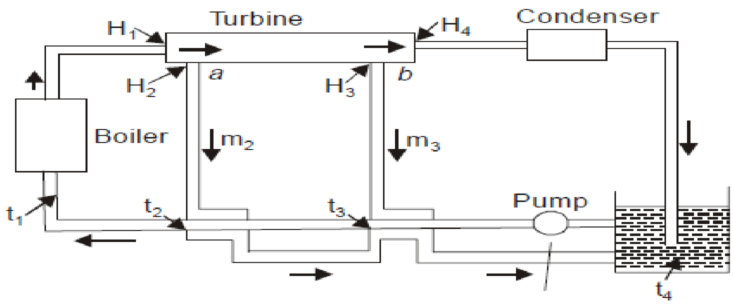


Figure 2.3 Regenerative Cycle (feed heating)

2-2 Theory and description of plant (Overview of KNPS):

The Khartoum North Power Station of Sudan is located at northeast of North Khartoum Industrial Area in Khartoum suburb to provide power for national public, industrial and civil use. Phase I consists of one set of 33MW steam turbine generator unit to energize the existing BLUE NILE power system via 110KV transmission line. Phase II consists of 2 expanded 66MW steam turbine generator units to energize via another 110KV transmission line. This project is the expanded phase III including two sets of 100MW steam turbine generator units and two sets of 420T oil-fired boilers, therefore, the installed gross capacity of the plant is

386MW（2×33MW+2×60MW+2x100MW）.

2-3 effect of variation of operation parameter on efficiency

2-3-1 Steam condition on thermal condition on thermal efficiency of steam power plant:

The variation of Rankine efficiency with the inlet steam pressure at a constant steam temperature 470 ^{o}C and three condenser pressure is shown in figure below .it is seen that for inlet steam pressure above 100bar, there is a continuing but degreasing rate of improvement of cycle efficiency the increase in steam pressure is limited by consideration of mechanical stresses and the ensuing higher cost of equipment. The figure also demonstrates that there is a considerable improvement in cycle efficiency with decrease of condenser pressure. [2]

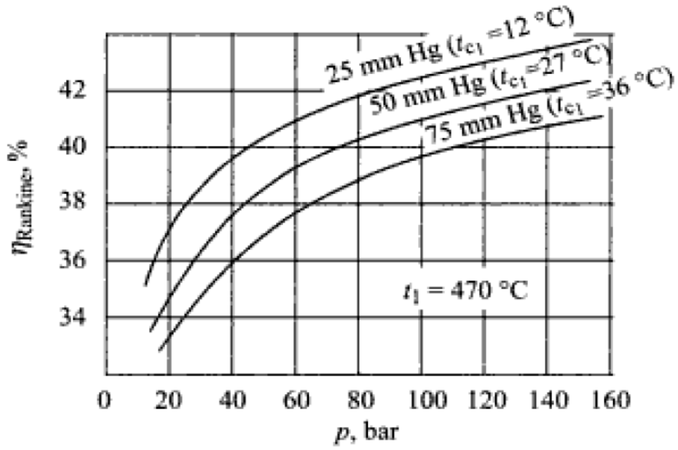


Figure 2.4 : Effect of inlet steam pressure(P_i) and condenser pressure on Rankine efficiency with constant inlet steam temperature of 470°C

2-3-2 Effect of superheat:

The effect of increasing the initial temperature at constant pressure on cycle efficiency is shown in figure. when the initial state changes from 1 to 1' ,T_{m1} between1 and 1' is higher than T_{m1} between 4 and 1. Son the increase in the superheat at constant pressure increase the mean temperature of heat addition and hence, the cycle efficiency. Moreover, with increase in superheat, the expansion line of steam in the turbine shifts to the right, as a result of which the quality of steam at turbine exhaust increase and performance of the turbine improves, as explained later. if hot flue gas is the primary fluid or heat source for steam generation in the power cycle the use of super heat also reduces the thermal irreversibility. [2]

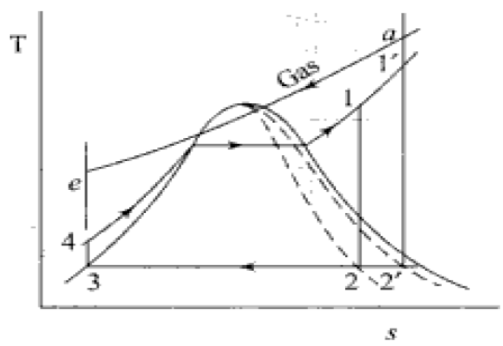


Figure 2.5: Effect of superheat on the mean temperature of heat addition

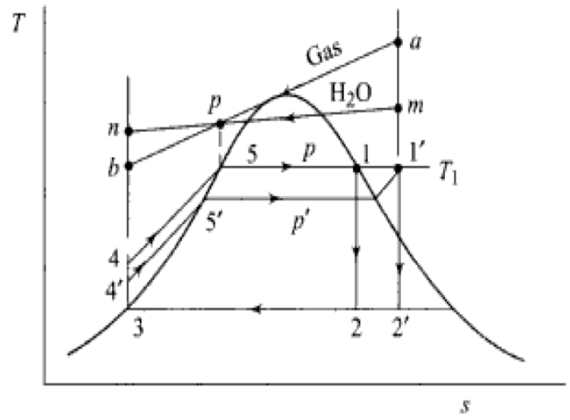


Figure 2.6: Effect of superheat

An increase in inlet steam temperature, i.e. an increase in superheat at constant inlet steam pressure and condenser pressure gives a steady improvement in cycle efficiency and lowers the heat rate due to the increase in T_{m1}.Raising the inlet steam temperature also reduces the wetness of the steam in the later stages of the turbine and improves the turbine internal efficiency. [2]

2-3-3 Reheat effect :

The net output of the plant increases with reheat. weather the cycle efficiency improves with reheat. [2]

2-3-4 Feed water Heaters:

Feed water heater are of two types, viz, open heaters and closed heaters. in an open or contact type heater, the extracted steam is allowed to mix with feed water and both leave heater at common temperature figure below no (A). in aclosed heater, the fluids are kept separate and are not allowed to mix together. Closed heater are shell and tube heat exchanger where the feed water flows through the tubes and the extracted steam condenses outside the tubes in the shell. The heat released by condensation is transferred through the walls of tubes. the condensate (saturated water at the steam extraction pressure), sometimes called heater drip, then passes through a trap into the next lower pressure heater.This, to some extent, reduces the steam required by that heater.

The trap passes only liquid and no vapor. the drip from the lowest pressure heater could similarly be trapped to the condenser, but this would be throwing away energy to the condenser cooling water. to avoid this, waste, adrip pump feeds the drip directly into the feed water stream. [2]

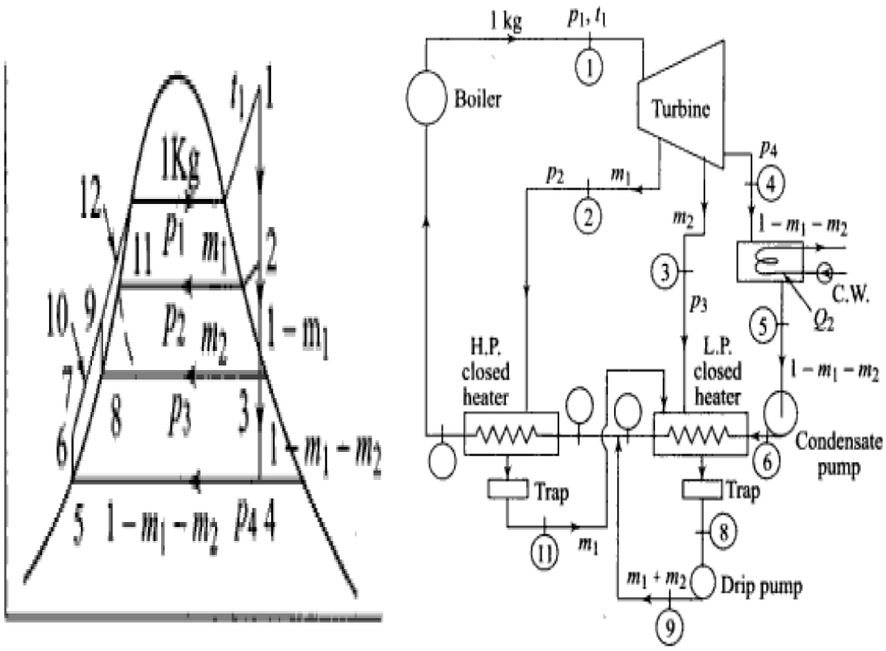


Figure 2.7: Regenerative feed water heating with two closed heaters

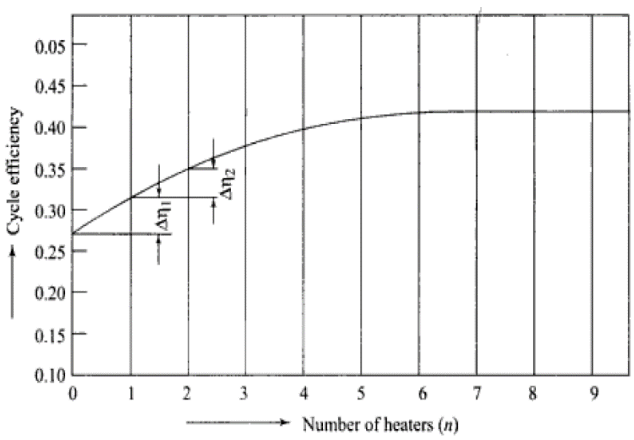


Figure 2.8 : Efficieency gain (Δη) succcessively diminishes with the increse in number of heaters

2-4 Literature Review:

Prateek Bhardwaj was studied Kota thermal power plant and was used and got high benefit from waste heat in condenser during phase change by nano material because it improved heat transfer the energy was obtained from condenser waste heat by using thermoelectric generator the efficiency increased about 3.3% from 37% to 40.32% the load increased to 228.86 MW from 210 MW. [5]

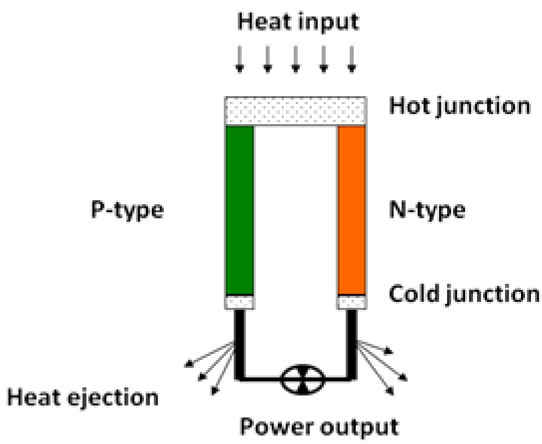


Figure 2.9: Thermoelectric generator structure.

Darshan H Bhalodiawas used first law of thermodynamics and identified losses and made maximization performance of 25MW plant at Sauken Ltd overall efficiency was calculated and boiler efficiency was calculated by indirect method by losses way it was 79.4 % and losses 20.6 %. the turbine efficiency was calculated it was 33.57% and generator efficiency (98%).The power plant overall efficiency was 26.2%. [6]

H.Hussain was worked in Kuwait power plant (Rankine cycle) analyzed and enhanced the efficiency it was resulted inlet temperature and pressure more active on turbine affected in work power and thermal efficiency the peak efficiency occurred at reheating inlet pressure between 10% and 20 % the thermal efficiency increased from 42.7 % to 44% and the load decreased boiler energy consumption from 2,731 kJ/kg to about 2,414.5 kJ/kg. [7]

Amir Vosough was presented the effect of condenser pressure effect in performance and thermal efficiency and found energy loss to environment about 2126 KW exergy destruction was found 86.27%, condenser and stack gas 13.73% efficiency was calculated 38.39% exergy efficiency was calculated 45.85%. It was showed that condenser pressure an important parameter effect on power plant thermal efficiency and output power. It was found that about 60.86 % of an input energy lost to environment the exergy lost in boiler was 86.271% of the fuel exergy input. Exergy destroyed at condenser was 13.22%. Exergy efficiency was found 38.39%.[8]

Anjali T H was used energy and exergy analysis the first law and second law of thermodynamics and identified magnitude and location of losses and tried to maximized the performance of 15 MW and was evaluated the boiler and turbine and condenser efficiencies the comparison between first law and second law were made.It was discovered that improvement of efficiency by proper maintenance and it was discovered the factors affected on thermal efficiency such as fuel used for combustion, type of boiler varying load power plant. [9]

Table 2.1: efficiencies and second low

Component	η_i(%)	η_{ii}(%)	Energy loss kW	Exergy loss kW
Boiler	80	58.19	15826.41	19688.057
Turbine	21	82	48546.82	2775
condenser	82	32	3034.15	894.64

Adeyinka O Adeoye used second law mass, energy balance and using exergy efficiency of 75 MW power plant experimental dataand calculated overall efficiency during condenser pressure it was showed that increase environment temperature increased thermal exergy efficiency and deceased the condenser pressure increased and decreased the efficiency and increased heat rejection of condenser. it was discovered the increasing the reference environment temperature increased efficiency and increased power output to reduce the loss of heat loss and energy consumption. [10]

Alpesh V Mehtam was used first law analysis and used it to calculate efficiency for Gandhinagar coal fired unit 4 (210 MW) Thermal Power Station (GTPS). boiler efficiency was calculated by indirect method and estimated losses in boiler. Efficiency analysis was used to calculate overall thermal efficiency boiler efficiency was 86.84 % losses 13.16% the highest heat losses 5.29% occurs due to the exhaust gas. steam turbine efficiency 43.5% and generator efficiency 98%the overall efficiency was37.01%. [11]

Muhib Ali Rajber studied the impact of operating parameters on performance were studied net power output, energy efficiency and exergy efficiency are considered as performance parameters of the plant whereas, condenser pressure, main steam pressure and main steam temperature are nominated as operating parameters the output power was 186.5 MW energy efficiency was 31.37% exergy efficiency was 30.41%. it was found condenser was contributed major share in total energy loss(68.7%) followed by boiler was (21.8%). The major exergy destructing was found in boiler 350MW(82.11%), turbine 43.1 MW (10.12%) condenser 12 MW (5.74%). It was found the increasing in main steam pressure and temperature and decrease condenser pressure was improved the efficiency. [12]

Ch.Kiran Kumar studied Kothagudem 500 MW thermal power station was studied coal flow , air gas flow , excess air , oxygen in flue gas , heat transfer , auxiliary power consumption the overall performance evaluation overall efficiency , boiler efficiency , boiler feed water efficiency , pump efficiency air compressor efficiency, evaporation losses and blow down losses of cooling tower etc. it was found serval factors affecting in boiler efficiency (fuel on boiler dry and wet flue gas loss combustion characteristics, the start-up and the shut-down losses, the radiation losses and the heat losses due to hydrogen in fuel, moisture in fuel, carbon monoxide in fuel are explained . it was found boiler loss The boiler losses were (Dry flue gas loss, due to moisture present in fuel, due to hydrogen present in fuel, due to moisture present in air, Un burnt carbon loss, Total Un account loss). the boiler loss reduced when caloric value of coal was high and flue gas outlet between 140 to 150 ^{o}C excess air 3.5% of oxygen excess. [13]

CHAPTER THREE

Methodology

CHAPTER THREE

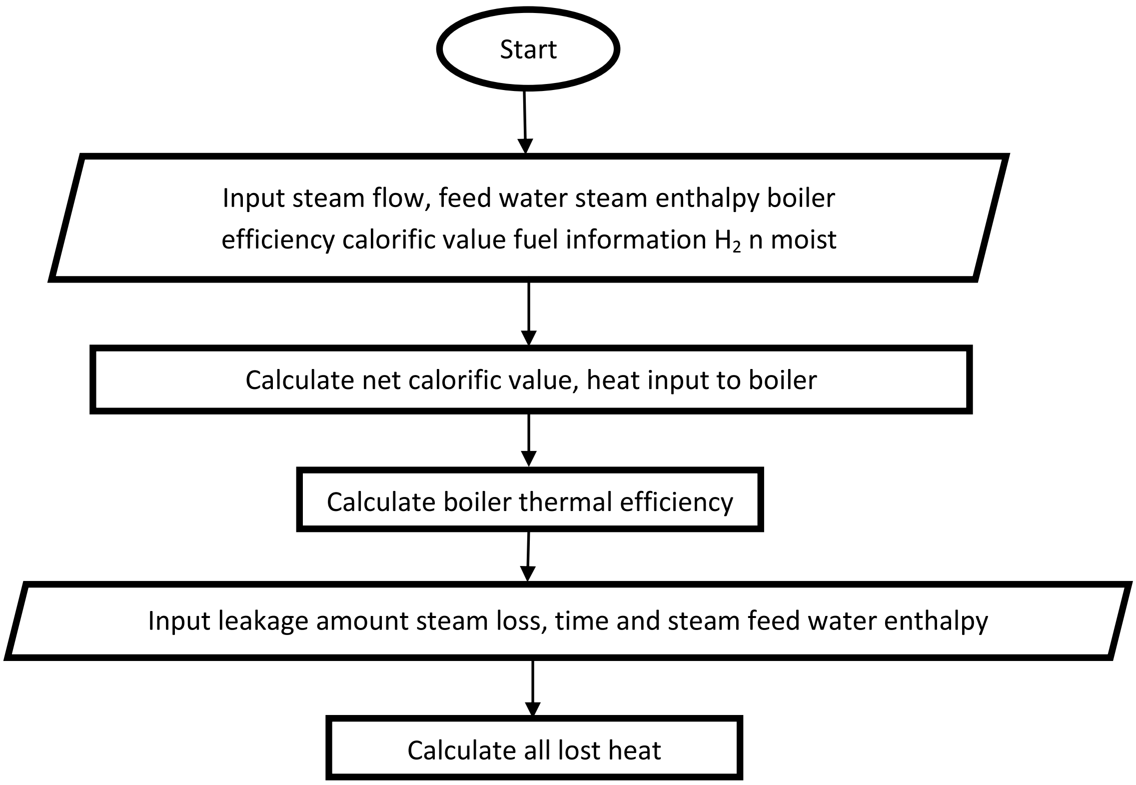
Methodology

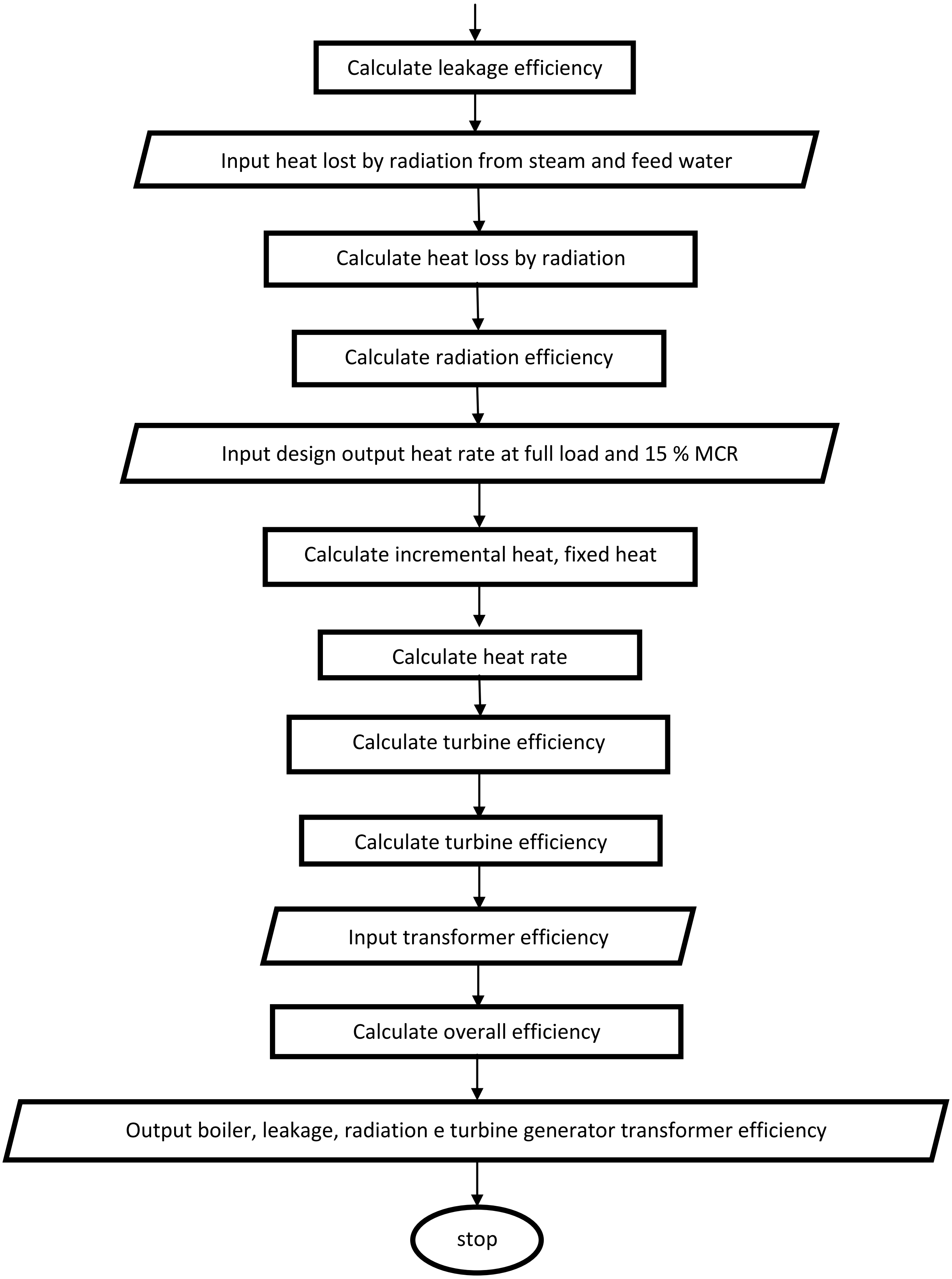
3-1 Methodology:

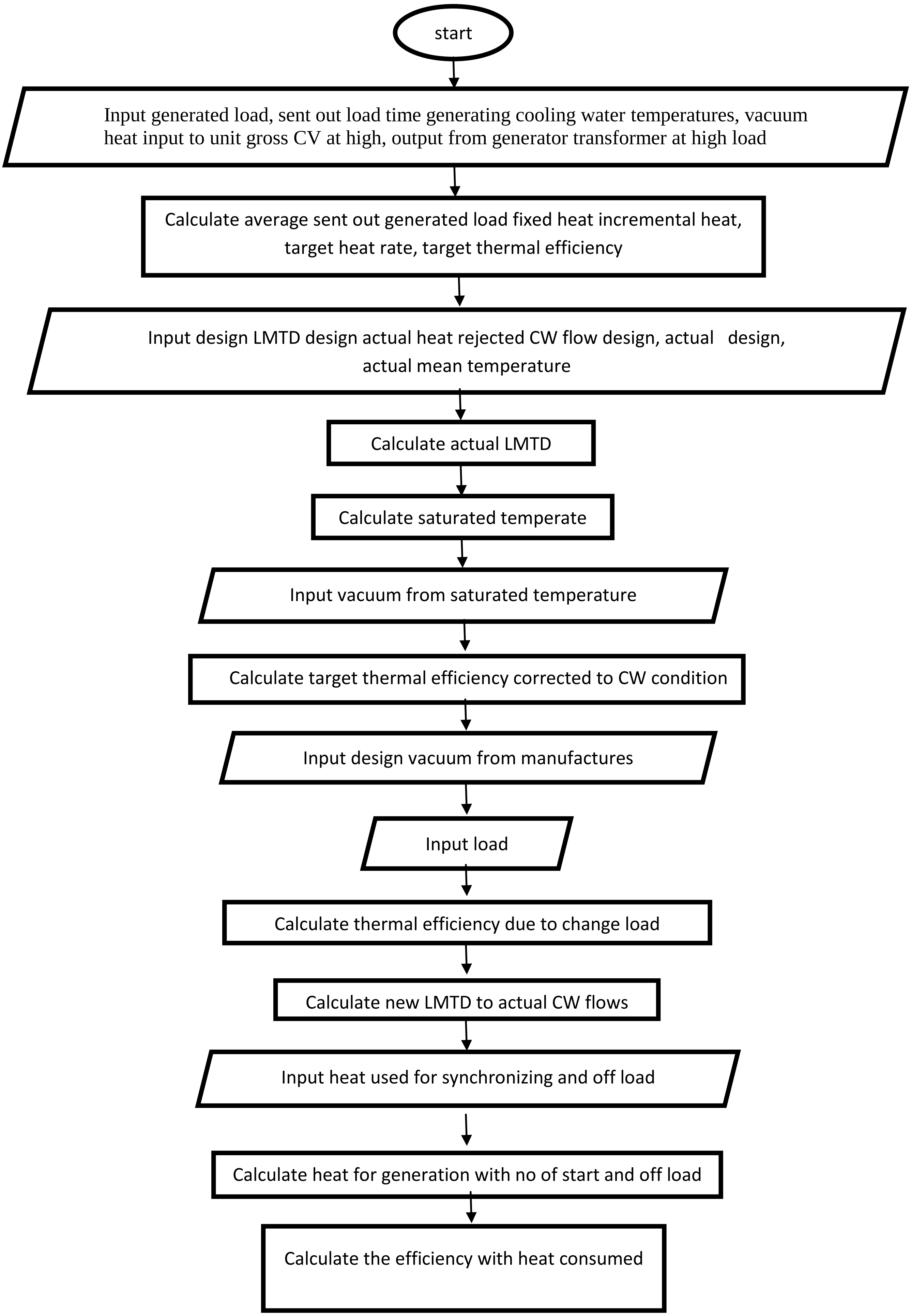
I calculated data from khartoum north power station and analysed by MATLAB programme to get all resultsbecause this programme is used for important project and it has high acuuracy in ressults I calculated boiler efficiency turbine efficiency and subsystem like auxilary steam change in vacuum and change in aux power consumption and other calculation for any operation paramter change with thermal efficiency Imade flow chart for these steps calculations. I made relation between these parameter with thermal efficiency with MATLAB figures to know any parameter change wuth efficiency . I discussed all results.

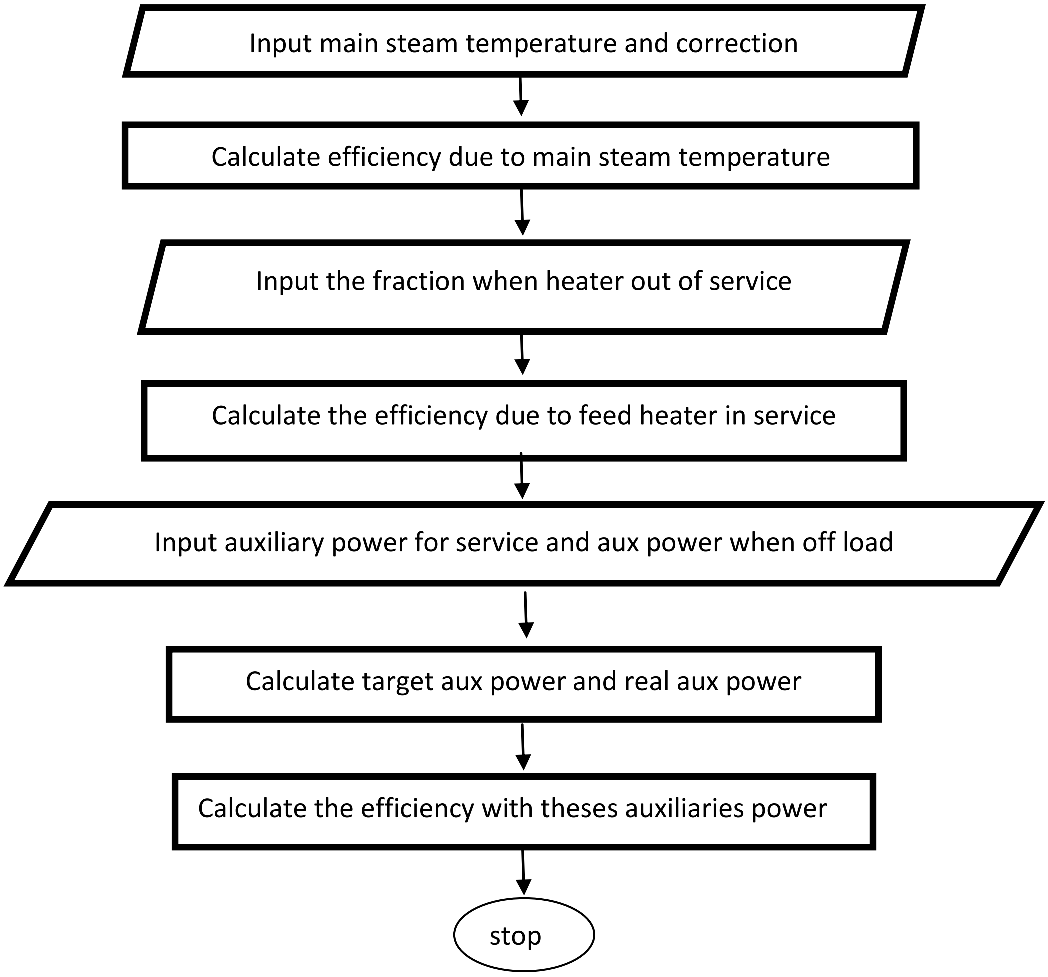
3-2 Flow charts:

It represent all or important equation that used in claculation for efficiency in MATLAB code. It has all equation and procedure.



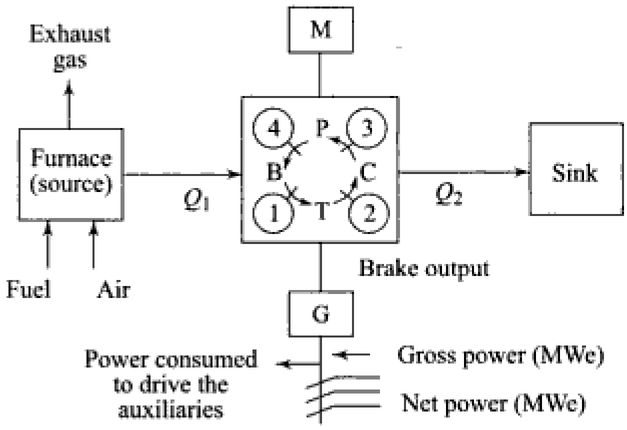

Calculate leakage efficiency
Input heat lost by radiation from steam and feed water
Calculate heat loss by radiation
Calculate radiation efficiency
Input design output heat rate at full load and 15 % MCR
Calculate incremental heat, fixed heat
Calculate heat rate
Calculate turbine efficiency
Calculate turbine efficiency
Input transformer efficiency
Calculate overall efficiency
Output boiler, leakage, radiation e turbine generator transformer efficiency
stop


start
Input generated load, sent out load time generating cooling water temperatures, vacuum heat input to unit gross CV at high, output from generator transformer at high load
Calculate average sent out generated load fixed heat incremental heat, target heat rate, target thermal efficiency
Input design LMTD design actual heat rejected CW flow design, actual design, actual mean temperature
Calculate actual LMTD
Calculate saturated temperate
Input vacuum from saturated temperature
Calculate target thermal efficiency corrected to CW condition
Input design vacuum from manufactures
Input load
Calculate thermal efficiency due to change load
Calculate new LMTD to actual CW flows
Input heat used for synchronizing and off load
Calculate heat for generation with no of start and off load
Calculate the efficiency with heat consumed


Input main steam temperature and correction
Calculate efficiency due to main steam temperature
Input the fraction when heater out of service
Calculate the efficiency due to feed heater in service
Input auxiliary power for service and aux power when off load
Calculate target aux power and real aux power
Calculate the efficiency with theses auxiliaries power
stop

3-3Efficiencies in steam power plant

A steam power plant is a bulk energy converter from fuel to electricity ffigure below the overall efficiency of a power plant is defined as :-



[2]

Figure 3.1 :A Power plant converts energy in fuel to electricity

$$\eta_{\text{overall}} = \frac{\text{powr availiable at generator terminals}}{\text{rate of energy releaased by the combustion of fuel}}$$

$$= \frac{MW \times 10^3}{w_f \times CV} \ldots\ldots (3.1)$$

Where w_f is, the fuel burning rate and CV is caloric value of fuel

The boiler (steam generator) efficiency is defend by

$$\eta_{\text{boiler}} = \frac{\text{rate of energy absorption by water to form steam}}{\text{rate of energy released by the combustion of fuel}} = \frac{ms(h_1 - h_4)}{m_f \times C.V} \ldots\ldots (3.2)$$

Where m_s is the steam generation rate

the mechanical efficiency of turbine will be

$$\eta_{\text{turbine(mech)}} = \frac{\text{brake out put of the turbine}}{\text{internal output of the turbine}} = \frac{\text{brake out put}}{\text{Ws (h1} - \text{h2)}} \ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

$$\eta_{\text{overall}} = \eta_{\text{boiler}} \times \eta_{\text{cycle}} \times \eta_{\text{turbine (mech)}} \times \eta_{\text{generator}} \ldots\ldots\ldots\ldots (3.4)$$

Therefor There is certain auxiliary equipment in the power plant like FD fan BFP CW P/P and so on which is driven by electricity taken from the generated power of the plant or grid. the net power transmitted from the generator will be the gross power producedminus the power consumed bythe internal auxiliaries of the plant. the efficiency of auxiliaries $\eta_{aux}$is given by

$$\eta_{\text{aux}} = \frac{\text{net power transmitted by the generator}}{\text{gross power produced by the plant}} \ldots\ldots\ldots\ldots\ldots...(3.5)$$

There for the overall efficiency of plant is product of live component efficiencies as given by

$$\eta_{\text{overall}} = \eta_{\text{boiler}} \times \eta_{\text{cycle}} \times \eta_{\text{turbine (mech)}} \times \eta_{\text{generator}} \times \eta_{\text{aux}} \ldots (3.6)$$

$$\text{heat output from boiler} = \text{main steam flow (main steam enthalpy} - \text{feed water enthalpy)} \ldots (3.7)$$

$$\text{heat input to boiler} = \frac{\text{heat output from boiler}}{\text{boiler thermal efficiency}} \ldots\ldots\ldots\ldots..(3.8)$$

$$\text{oil flow to boiler} = \frac{\text{heat input to boiler}}{\text{gross calorific value of fuel}} \ldots\ldots\ldots..(3.9)$$

$$\begin{aligned}&\text{net calorific value of fuel}\\ &\quad= \text{gross calofific value of fuel} - \text{oil flow to boiler}\\ &\quad* 1000(\text{number of hydrogen mole} * \text{hydrogen content}\\ &\quad+ \text{moisture content}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.10)\end{aligned}$$

$$\text{heat input to boiler (nett CV)} = \text{heat input to boiler (gross CV)} \times \frac{\text{nett CV}}{\text{gross CV}} \ldots\ldots...(3.11)$$

$$\text{net boiler efficiency} = \frac{\text{heat output from boiler}}{\text{net heat input to boiler}} \ldots\ldots\ldots...(3.12)$$

$$\text{heat in leakages} = \frac{\text{total leak}}{2} \times \text{water enthalpy} + \frac{\text{total leak}}{2} \times \text{steam enthalpy} \ldots\ldots.(3.13)$$

$$\begin{aligned}&\text{heat in makeup water to replace in leakages}\\ &\quad= \text{leak amount} \times \text{enthalpy of water from reserve tank} \ldots\ldots\ldots (3.14)\end{aligned}$$

$$\begin{aligned}&\text{net heat carried away in leakage}\\ &\quad= \text{heat loss in leakages}\\ &\quad- \text{heat in makeup water which replace leakage} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3.15)\end{aligned}$$

$$\text{steam used fro soot blowing} = \frac{\text{amount of soot blowing}}{\text{time for soot blowing}} \ldots\ldots\ldots\ldots\ldots\ldots..(3.16)$$

$$\text{heat for soot blowing} = \text{steam for sootblowing } (\text{enthalpy of steam for sootblowing} - \text{enthaply of makeup water}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.17)$$

$$\text{heat used for atomizing} = \text{amount of steam for atomizing } (\text{enthalpy of steam for atomizing} - \text{enthalpy of make up water}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.18)$$

$$\text{total heat lost in leakage section} = \text{net heat carried away in leakages} + \text{heat for soot blowing} + \text{heat used for atomizing} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.19)$$

$$\text{heat passed to steam pipe work} = \text{heat output from pipework} - \text{heat lost by leakage} \ldots (3.20)$$

$$\text{thermal efficiency at leakage section} = \frac{\text{heat passed to steam pipe work}}{\text{heat output from boiler}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.21)$$

$$\text{total heat lost by radiation} = \text{heat lost for main steam by radiation} + \text{heat lost for feed water by radiation} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.22)$$

$$\text{heat passed to turbine} = \text{heat passed into pipework} - \text{heat lost by radiation} \ldots (3.23)$$

$$\text{efficiency in radiation section} = \frac{\text{Heat passed to turbine}}{\text{heat passed into pipe work}} \ldots \ldots \ldots \ldots \ldots (3.24)$$

$$\text{design heat input} = \text{design output} \times \text{design turbine heat rate (at that load)} .. (3.25)$$

$$\text{design heat input} = \text{incremental heat} \times \text{load} + \text{fixed heat} \ldots \ldots \ldots (3.26)$$

$$\text{design heat input} = \text{m} \times \text{load} + \text{C} \ldots \ldots (3.27)$$

$$\text{output from turbine} = \frac{\text{heat passed to turbine} - \text{c}}{\text{m}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.28)$$

$$\text{heat rate} = \frac{\text{fixed heat}}{\text{out from turbine}} + \text{incremental heat} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.29)$$

$$\text{turbine efficiency} = \frac{3600}{\text{heat rate}} \ldots \ldots \ldots \ldots \ldots \ldots (3.30)$$

$$\text{output from generator} = 0.94 \times \text{output from turbine} \ldots \ldots (3.31)$$

$$\text{generator efficiency} = \frac{\text{output from generator}}{\text{output from turbine}} \ldots.(3.32)$$

$$\text{output from unit} = \text{out from generator } \times \text{transformer efficiency} \ldots \ldots.(3.33)$$

$$\begin{aligned}\text{unit efficiency} = {} & \text{boiler efficiency } \times \text{leakage efficiency } \times \text{raditiation efficiency} \\ & \times \text{turbine efficiency } \times \text{generator efficiency} \\ & \times \text{transformer efficiency} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.34)\end{aligned}$$

$$\eta_{\text{overall}} = \eta_{\text{boiler}} \times \eta_{\text{leakage}} \times \eta_{\text{radiation}} \times \eta_{\text{turbine}} \times \eta_{\text{work power}} \times \eta_{\text{transformer}} (3.35)$$

$$\text{CW temperature rise} = \text{CW2} - \text{CW1} \ldots..(3.36)$$

$$\text{average generated load} = \frac{\text{unit generated}}{\text{time}} \ldots \ldots..(3.37)$$

$$\text{average sent out load} = \frac{\text{unit sent out}}{\text{time}} \ldots \ldots...(3.38)$$

$$\text{thermal efficiency (gross CV)} = \frac{\text{output from transformer}}{\text{heat input to unit gross (CV)}} \ldots \ldots (3.39)$$

$$\text{heat rate (gross CV)} = \frac{3600}{\text{thermal efficiency (gross CV)}} \ldots.(3.40)$$

$$\text{thermal efficiency (gross CV)} = \frac{\text{output from transformer}}{\text{heat input to unit (gross CV)}} \ldots (3.41)$$

$$\text{heat rate (gross CV)} = \frac{3600}{\text{thermal efficiency (gross CV)}} \ldots (3.42)$$

$$\text{taarget heat rate} = \frac{\text{fixed heat}}{\text{sent out load}} + \text{inremental heat} \ldots \ldots.(3.43)$$

$$\text{target thermal efficiency} = \frac{3600}{\text{target heat rate}} \ldots.(3.44)$$

$$\begin{aligned}&\text{heat to condenser} \\ &\quad = \text{output kw} \left(\text{heat rate} - \frac{3600}{\eta_{\text{E}} \times \eta_{\text{M}}}\right) + 3600 \times \text{feed pump power} \times \eta_{\text{EFP}} (3.45)\end{aligned}$$

$$\text{actual coolig water flow} = \frac{\text{actual heat rejected}}{\text{temp rise } \times \text{specific heat (p = c)}} \ldots.(3.46)$$

$$m4 = \frac{heat19}{cw \times 4.187} \ldots\ldots (3.47)$$

$$actual\ mean\ temp = \frac{cw1 + cw2}{2} \ldots\ldots (3.48)$$

$$new\ LMTD = design\ LMTD \times \sqrt[4]{\frac{design\ mean\ temp}{actual\ mean\ temp}} \times \sqrt{\frac{design\ CW\ flow}{actual\ CW\ flow}}$$

$$\times \frac{actual\ heat\ rejected}{design\ heat\ rejected} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.49)$$

$$heat\ rate = \frac{fixed\ heat}{load} + incremental\ heat \ldots\ldots (3.50)$$

$$CW\ rise = \frac{design\ heat\ rejected}{flow \times specific\ heat} \ldots\ldots (3.51)$$

$$lmtd3 = \frac{cw3}{\log\frac{ts-cw1}{ts-cw4}} \ldots\ldots\ldots (3.52)$$

$$heat25 = \frac{sent1 \times 3600}{10^3 \times eff14} \ldots\ldots (3.53)$$

$$eff20 = \frac{sent1 \times 3600}{10^3 \times heat26} \ldots. (3.54)$$

$$eff23 = eff14 \times \left(1 - \frac{loss2}{100}\right) \ldots. (3.55)$$

$$eff24 = 60.28 \left(\frac{1}{cont2} - 0.0683\right) \ldots. (3.56)$$

$$eff25 = eff14 \times \frac{95 - eff24)}{95} \ldots.. (3.57)$$

$$eff26 = eff14 \times (\frac{95 - loss3)}{95} \ldots.. (3.58)$$

$$aux1 = gen1 \times 0.069 \ldots\ldots (3.59)$$

$$aux4 = aux1 + aux2 + aux3 \ldots. (3.60)$$

$$aux5 = gen1 - sent1 \ldots. (3.61)$$

$$difference\ in\ aux\ power = actual\ power - target\ power \ldots.. (3.62)$$

$$\text{aux6} = \text{aux5} - \text{aux4} \ldots \ldots (3.63)$$

$$\text{heat27} = \frac{\text{aux6} \times 3600}{1000 \times \text{eff14}} \ldots \ldots (3.64)$$

$$\text{eff27} = \frac{\text{eff14} \times \text{sent1} \times 3600 \times 100}{100 \times \text{sent1} \times 3600 + \text{eff14} \times \text{heat27} \times 1000} \ldots \ldots (3.65)$$

CHAPTER FOUR

Results

4-1 readings:

Table 4.1 Parameter Reading from plant

Name of value	1	2	3	4	5	6
ms (kg/sec)	37.219	33.89	34.17	40	33.61	32
h1 (kJ/kg)	3377	3423.1	3457	3200	3440	3300
h2 (kJ/kg)	856	653.79	653.79	844	653.79	874
leak1 (kg/sec)	0.2	0.4	0.5	0.6	0.8	0.7
h3 (KJ/kg)	600	700	700	650	500	900
h4 (KJ/kg)	1200	1100	1200	1300	1400	1300
m1 (kg)	7400	2000	5000	3000	9000	7000
Time1 (sec)	8*60*60	2*60*60	3*60*60	7*60	21*60	7*60
h7 kJ/kg	2780	2600	2700	2800	2900	2800
m3 kg/sec	0.2	0.3	0.4	0.5	0.6	0.7
m kJ/kw hr	9875	9875	9875	9875	9875	9875
c GJ/hr.	$30.03*10^6$	$30.03*10^6$	$30.03*10^6$	$30.03*10^6$	$30.03*10^6$	$30.03*10^6$
Vacuum						
Name	1	2	3	4	5	6
CW1 ^{0}C	29.4	30	31	29	31	28
CW2 ^{0}C	35.5	39	40	34	40	36
Vac1 mbar	111	180	170	100	180	120
C	52.912×10^3	52414	51470	25929	23206	-50686
M	11213	11000	11000	16000	16000	11000
Vac2 mbar	102	165	177.3	102	177.3	123
Vac3 mbar	60.5	56.3	56.3	62	56.3	65.2
Part load	**Operation**					
Out9 MW	30	20	19	25	19	28
Vac6	127	165	177.3	102	177.3	123
Vac7	67	56.3	56.3	62	56.3	65.2
Off load	**And**	**startup**				
Heat21 GJs	70	80	90	80	60	50
Heat22 GJs	140	150	170	150	100	90
Heat23 GJs	230	200	250	300	300	180
Main	**Steam**	**Temp**				
T6 ^{o}C	469.1	500	490	485	498	490
Feed	**Heater**					
Loss1	0.012	0.012	0.012	0.012	0.012	0.012
Time6 hrs.	18	1	12	10	0	27
flue gas						
Cont1	2.4	2.4	2	1.9	1.5	3
T8 ^{o}C	162	155	155	160	154	157
T9 ^{o}C	41	36	38	35	34	31
Aux	**power**					
Aux2 MWhrs	17	20	25	30	15	25
aux3 MWhrs	17	10	20	15	15	10

4-2 Results Figures:

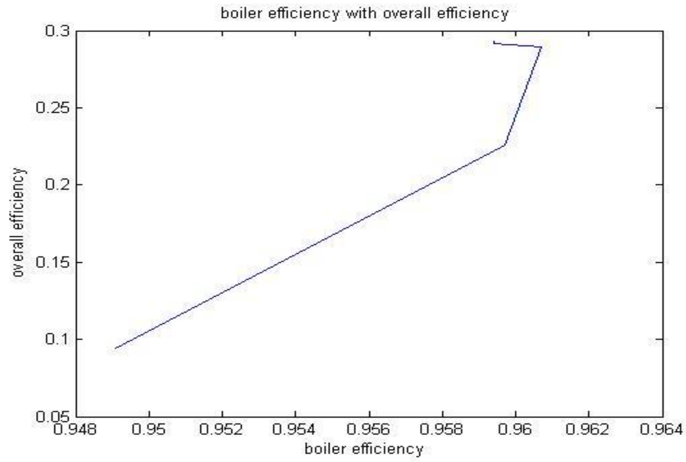


Figure 4.1: the relation between boiler efficiency and overall efficiency

When the boiler efficiency in increasing in overall efficiency increasing include in main steam and feed water enthalpy

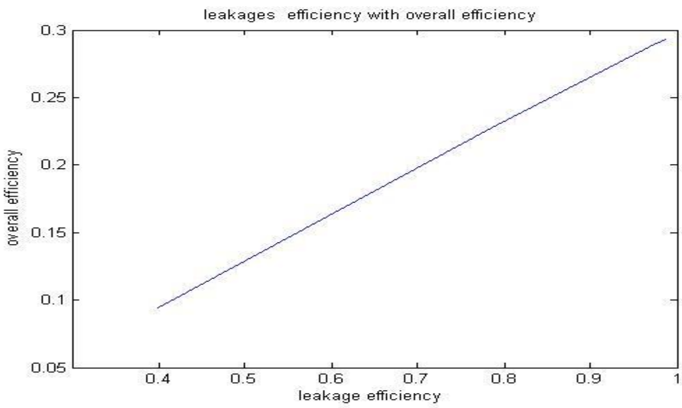


Figure 4.2:the relation between leakage efficiency and overall efficiency

When the leakage efficiency in increasing in overall efficiency include decreasing on all leakages of steam and feed water

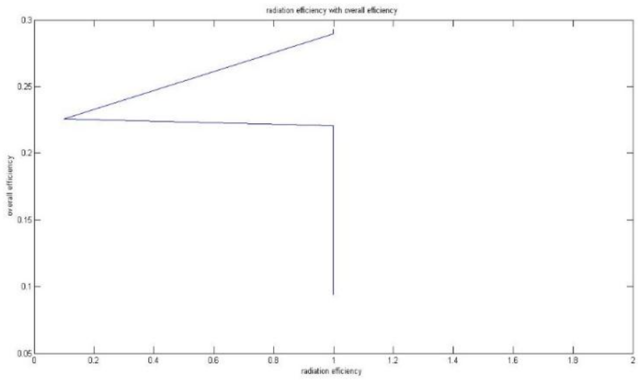


Figure 4.3: Radiation efficiency with overall efficiency

When radiation efficiency increased the overall efficiency increased by minimizing the radiation loss in feed water and steam

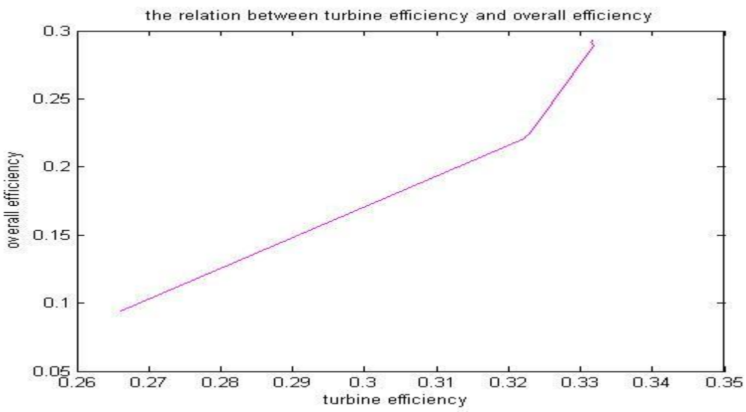


Figure 4.4: the relation between turbine efficiency and overall efficiency

When turbine efficiency increased it make increasing in overall efficiency by got high benefits in expanding of steam in turbine

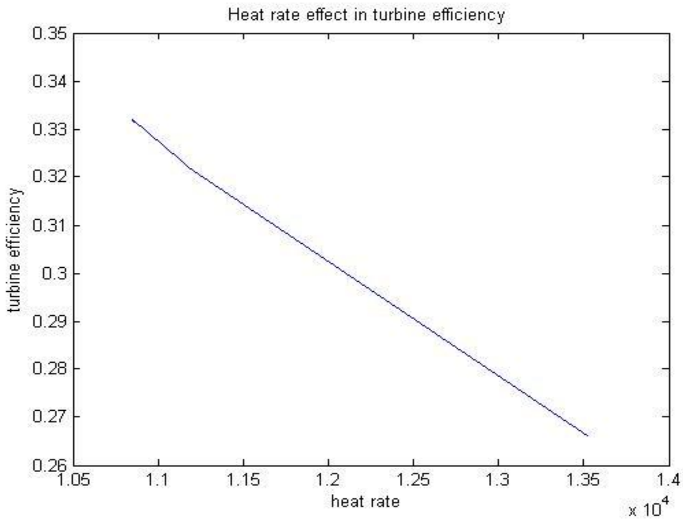


Figure 4.5: turbine efficiency

It must decrease the heat rate to increase turbine efficiency

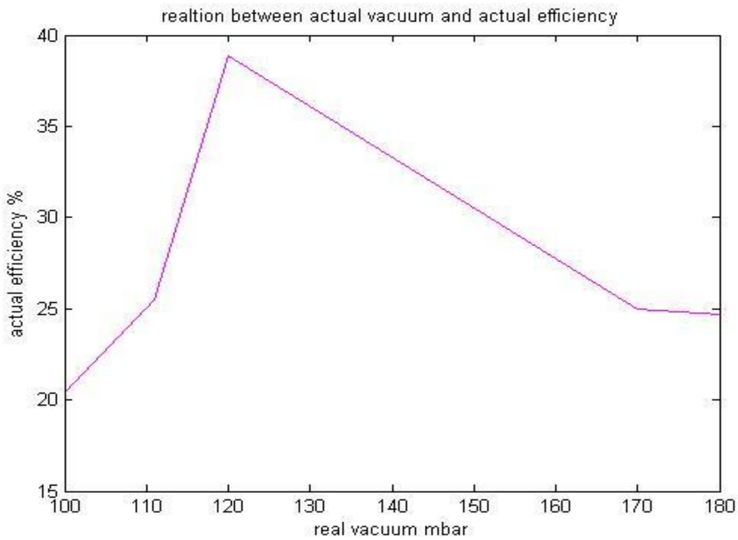


Figure 4.6: the relation between thermal efficiency with real vacuum

The vacuum it decreases the efficiency is the major reason to loss efficiency it raised in this figure due to approximate reading or high value for target efficiency

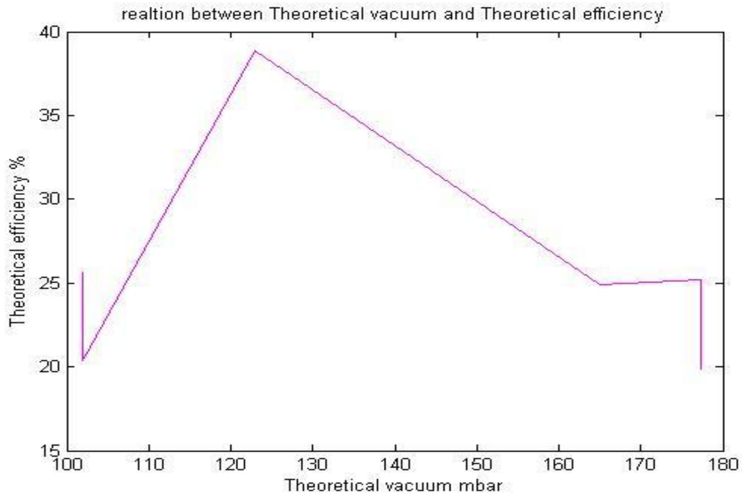


Figure 4.7: the relation between theoretical vacuum and theoretical efficiency

The vacuum it decreases the efficiency is the major reason to loss efficiency it raised in this figure due to approximate reading or high value for target efficiency is same as real vacuum

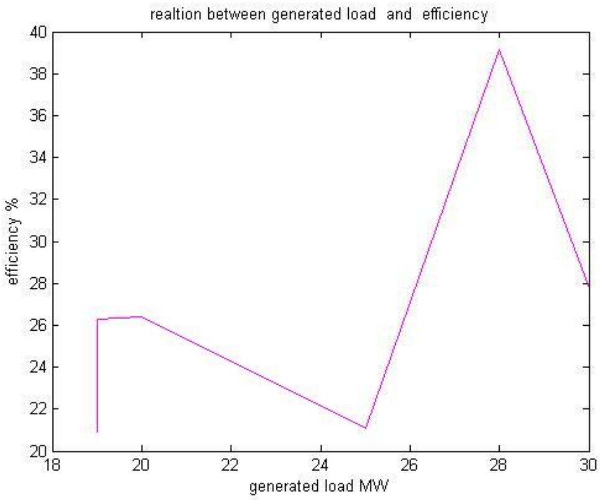


Figure 4.8: the relation between efficiency and load

The optimum load is 28 MW to get high efficiency load increase the efficiency but in this approximate value change different or may be target efficiency

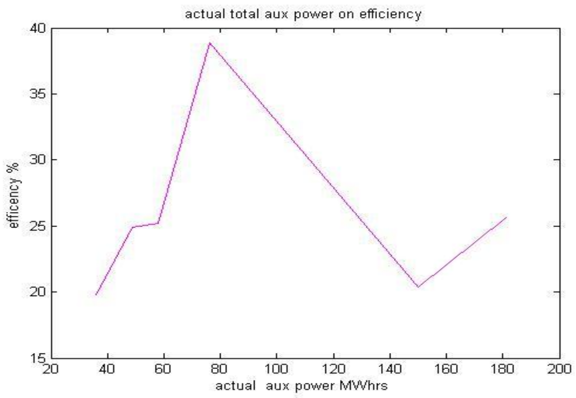


Figure 4.9: the relation between actual auxiliary power and efficiency

The auxiliary power decreases the efficiency because take from generated load from unit output it must minimize that value

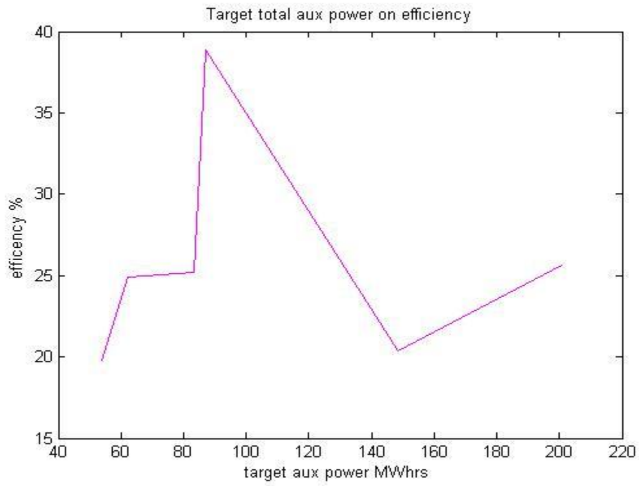


Figure 4.10 : the relation between target auxiliary power and efficiency

The target auxiliary power is same as real auxiliary power it increases in figure because approximate reading or target efficiency

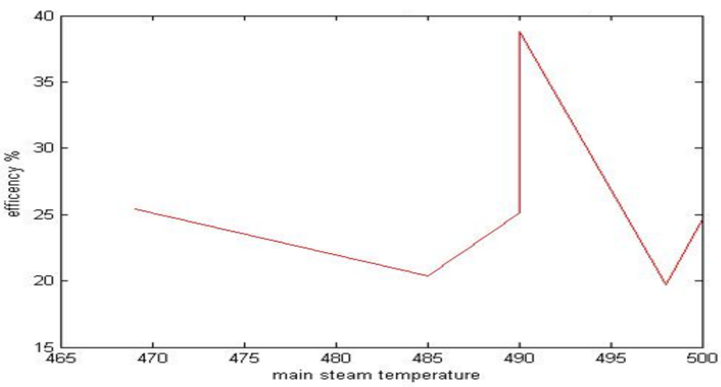


Figure 4.11: the relation between main steam temperature and efficiency

The optimum value of main steam 490 to get high efficiency

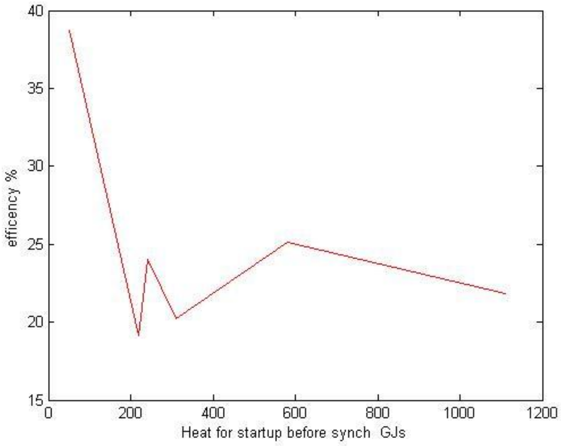


Figure 4.12: the relation between heat for startup and efficiency

Heat used for startup affect in fuel consumption and aux consumption it also decrease the efficiency

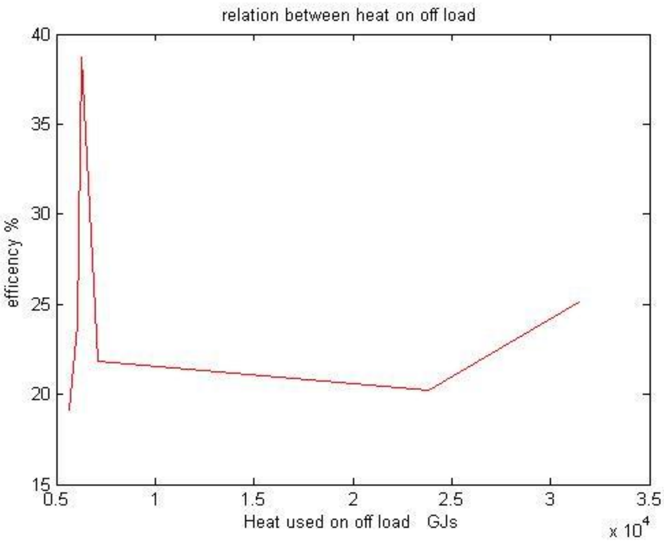


Figure 4.13 the relation between heat used on off load and efficiency

this heat also decreases the efficiency it has no different with heat for start up

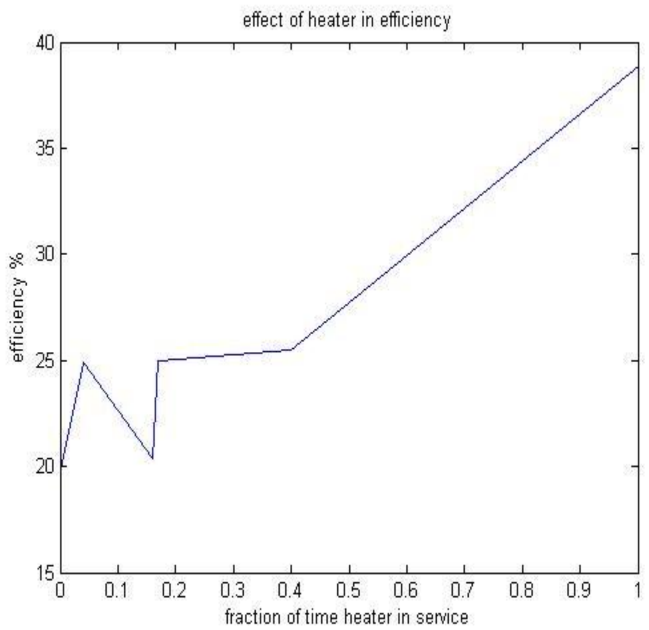


Figure 4.14: the relation between fraction of time for heater in service and efficiency

The heater decreases the fuel consumption it is the major cause to loss efficiency

CHAPTER FIVE
Conclusions, Recommendations

CHAPTER FIVE

Conclusions, Recommendations

5-1 Conclusion:

In this research some reading is estimated because no data or some parameter is constant at that duration it happens some result not acceptable or desired**.**

The overall efficiency increased with boiler efficiency, turbine efficiency decrease loss and leakages and The amount of heat lost by radiation it named leakage efficiency radiation efficiency and Take advantage of all the energy enter turbine and improve turbine efficiency to increase overall efficiency the value of heat rate Inversely proportional to turbine efficiency. The increase of heat loss by leakage in water and steam decrease leakage efficiency and heat loss by radiation decrease radiation efficiency

I saw the value of real vacuum decrease the unit thermal efficiency this reading took from local gauge I saw in value 100 m bar the efficiency 20.4%this is lowest value. there are more factors effect on this value may be effort in reading in gauge or other. in 120 m bar the efficiency 38.95% this return to change load 28 MW may consider this value is optimum for operation variables and consider Best operating conditions. in theoretical value was calculated from steam tables I saw Reverse relationshipbetween theoretical vacuum and efficiency except in 123 m bar I considered optimum status.

The load was the most influential factors on efficiency when the load increase the efficiency increase I saw in high efficiency at load 28MW

When the increase load it happened increase on real power consumption this would to decrease efficiency when the load is constant the relationship became Reverse when the power consumption increases the efficiency decrease this like target auxiliary power consumption .In main steam pressure in value 490^{o}C this is optimum degree to get high efficiency with load 28MW .In heat for startup in general when increases it decreases the efficiency in status 50 GJs it is optimum and the heat with no of start when decreases it increase the efficiency but in status the last one it is odd because the efficiency is high. The feed water heaters it minimizes the fuel consumption, improve boiler efficiency and overall efficiency I found when feed heater in service increase efficiency the change in this value because change in target thermal efficiency and change and calculation the times and hours get high difference.

5-2 Recommendation:

- It must to get high benefit from heat energy exit from boiler until converted to electrical energy to get optimum efficiency. Improve combustion efficiency and Reduce Fuel exchange and reduce steam and water losses from cycle and losses from radiation by make Good Installationfor lagging and cladding to reduce losses by radiation. Detraction the heat rate to raise the turbine efficiency and overall efficiency.
- In real vacuum I found the best choice value for real vacuum Must work on stability of this value of vacuum and best choice operation Factors like cooling water temperature inlet, ejector work high performance by make setup it is temperature, tapproagge system to clean condenser tubefrom time to time and make cooling tower clean to get optimum value of vacuum.
- In theoretical vacuum it must to reduce exhaust temperature because this value meets theoretical value of vacuum from steam table by of the impact of steam expansion in turbine and complete vanes

- Make best choice of load to get high efficiency in this is 28 MW

In actual auxiliary power it Must be exploited auxiliary power Optimize Exploit like Not running equipment is not required in this time or runs too much or by high current and high power Without benefiting from it like equipment that variable speed (boiler feed water pump, forced draught fan) and chiller and power consumption for services and others

- In main steam temperature in this research the decrease of this values increase efficiency (this value is different because the target value is different from reading to reading but always the increase the temp increase efficiency.
- In the heat used before starting and heat in the in the unit in off load must decrees this value Take care to subscribe to the machines as soon as possible.
- In feed water heater must prepared heaters and put it service as long as possible.

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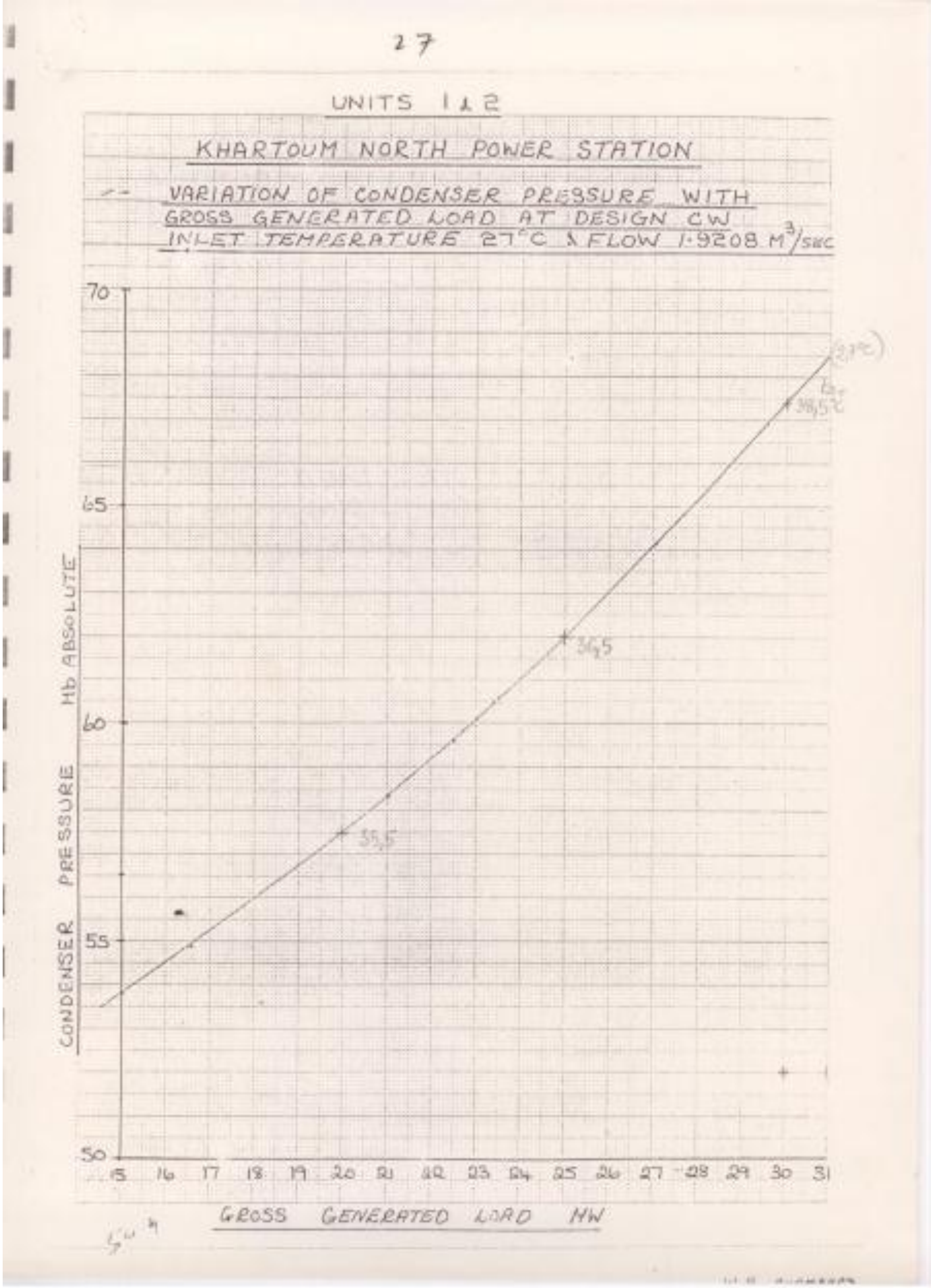
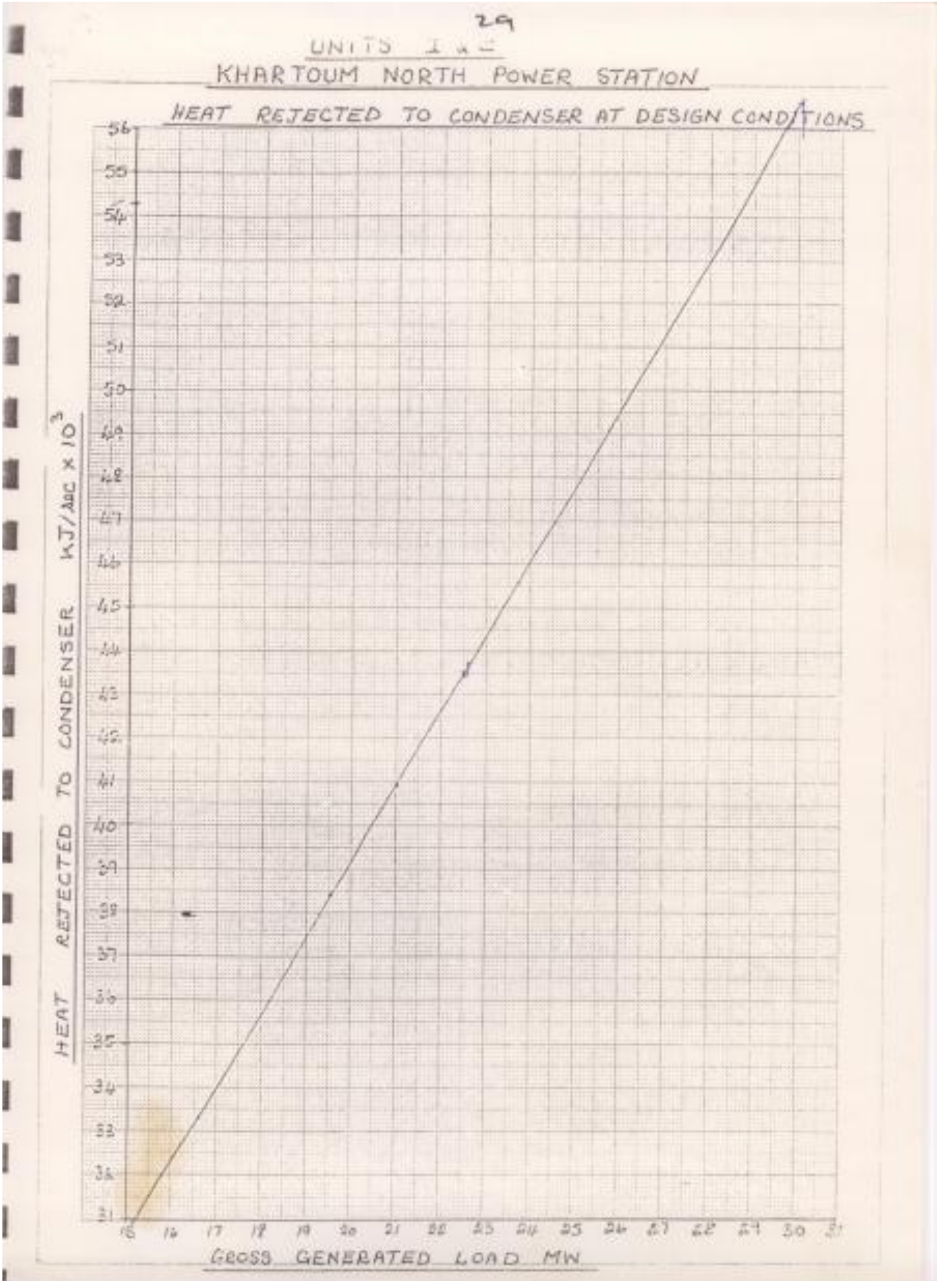
Appendences



A: Condenser pressure with gross generated load



B: Heat rejected to condenser at design condition

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MACHINE Nos. 4385-6

THE DEMOCRATIC REPUBLIC OF THE SUDAN

KHARTOUM NORTH POWER STATION

2 - 32 M.W. TURBO-GENERATORS

HEAT RATE CORRECTION FACTORS BASED UPON CONSTANT OUTPUT.

(NOZZLE GOVERNED MACHINE)

VARIABLE	LOAD M.W.	DATUM	VARIATION	HEAT RATE CORRECTION FACTOR
STOP VALVE PRESSURE	30	63·1 BAR ABS.	± 2 BAR	SEE P.D. 20641
	22·5			
	15			± 0·06 %
	9			± 0·07 %
STOP VALVE TEMP.	30	482°C	± 15 °C	± 0·81 %
	22·5			± 0·78 %
	15	456°C		± 0·75 %
	9	434°C		± 0·80 %
BOILER FEED PUMP ENTHALPY RIS.	30	12·6 KJ/KG	± 4·65 KJ/KG	± 0·11 %
	22·5	13·6 KJ/KG		± 0·10 %
	15	15·9 KJ/KG		± 0·09 %
	9	20·4 KJ/KG		± 0·09 %
FEED WATER THROUGH H.P. HEATERS ONLY	30	—	+ 4500 KG/HR	− 0·24 %
	22·5			− 0·30 %
	15			− 0·36 %
	9			− 0·48 %
CONDENSATE THROUGH L.P. HEATERS ONLY	30		± 4500 KG/HR	± 0·08 %
	22·5			± 0·10 %
	15			± 0·12 %
	9			± 0·14 %

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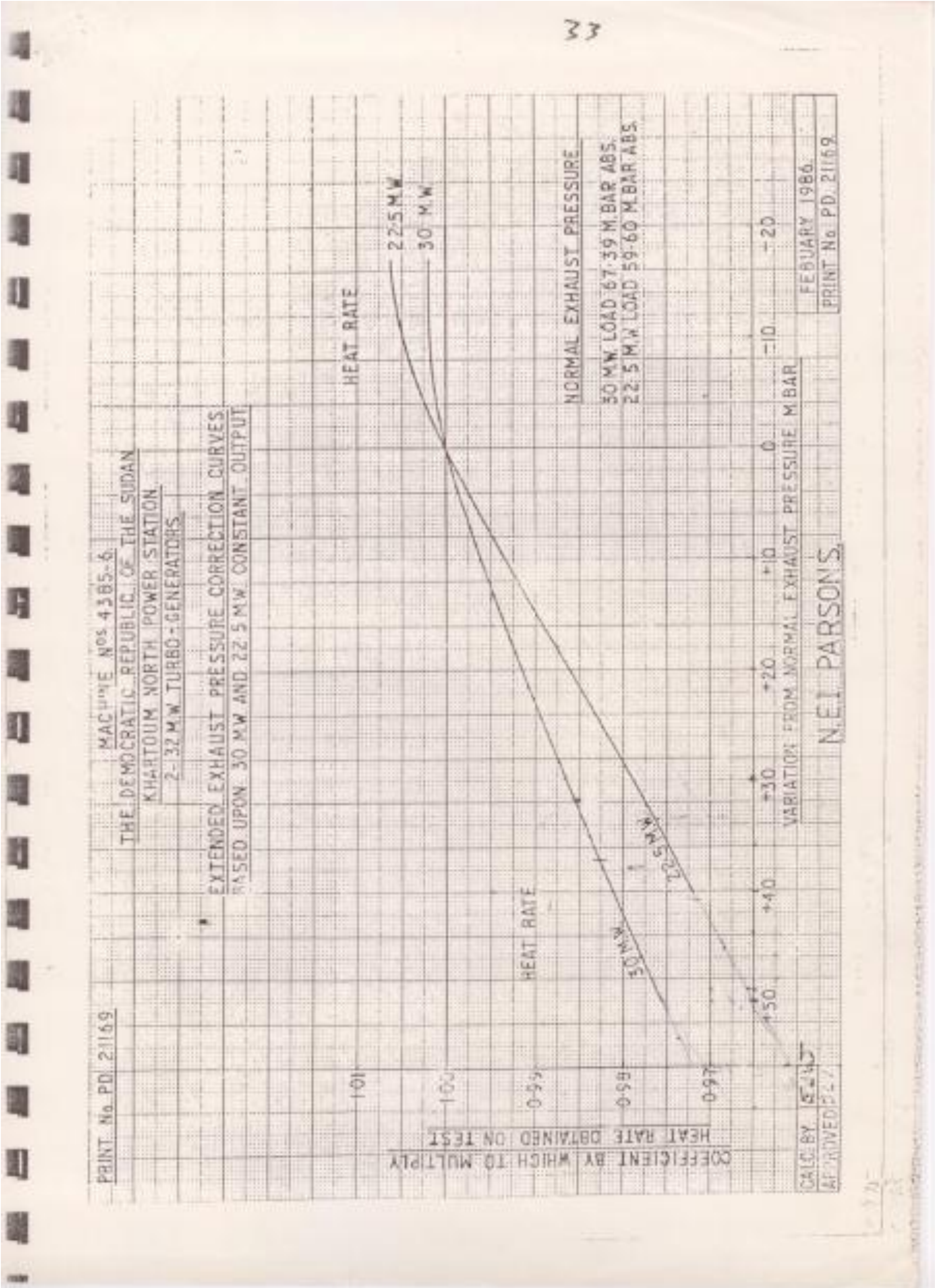
C :Heat rate correction factors based on constant output



D: Exhaust pressure correction curves based on 30 MW and 22.5 MW constant output

Table of Factors for Calculation of Heat Rejected to the Condenser

Gross Generated Load MW	Generator Efficiency		Turbine Mech Efficiency %	$\frac{10^4}{\eta_e \times \eta_M}$		Feed Pump Power kW	Motor Efficiency η_{ME} %	Heat Added kJ/sec (kW)
	PF 1·0 %	PF 0·8 lag %		1·0 PF	0·8 PF			
30·00	97·74	97·34	99·20	1·0314	1·0356	576	90	518
22·50	97·30	96·99	98·93	1·0389	1·0422	506	89	450
15·00	96·28	96·06	98·40	1·0556	1·0579	443	87	385
9·00	94·20	94·04	95·20	1·1151	1·1170	398.	86	342

E: Table of factors for calculation of heat rejected to the condenser

Table Showing Calculated Heat Rejected to Condenser for Various Generated Outputs at 0·8 lag & 1·0 Power Factors

Gross Generated Output kW	Nett Generated Output kW	Power Factor 0·8 lag		Power Factor 1·0		
		Turbine Heat Rate kJ/kWhr	Heat Rejected to Condenser kW	PF Correction (Division)	Turbine Heat Rate kJ/kWhr	Heat Rejected to Condenser kW
30,000	28 289	10 876	56 686	1·0032	10 841	56 530
22 500	20 933	11 153	43 485	1·0028	11 122	43 374
15 000	13 554	11 877	30 763	1·0022	11 851	30 696
9,000	7,623	13 971	21 411	1·0015	13 930	21,381

F: Table showing calculated heat rejected to condenser for various generated output at 0.8 and 1.0 power factor

```
ms=input ('input main steam flow = ')
h1=input ('input main steam enthalpy =  ')
t2=input ('input feed water inlet temperature =  ')
h2=input ('input feed water enthalpy =  ')
heat1=ms*(h1-h2)
eff1=input('input boiler thermal efficiency');
heat2=heat1/eff1
CV1=input('please insert gross CV of oil')
mf=heat2/CV1
moist=input('please insert the content of moist in fuel instead of percentage from oil analysis =')
H2=input('please insert the content of H2 in fuel instead of percentage from oil analysis =')
n=input('please insert number of mole of H2')
CV2=CV1-(mf*1000)*(n*H2+moist)
heat3=heat2*CV2/CV1
eff2=heat1/heat3
leak1=input('the miscillaneous leakages and valve spindle,drains and steam traps estmated = ')
h3=input('enthalpy of the leak of water= ')
h4=input('enthalpy of the leak of steam = ')
heat4=leak1/2*h3+leak1/2*h4
h5=input('enthalpy of makeup from reserve feed tank = ')
heat5=leak1*h5
heat6=heat4-heat5
m1=input('estimte the amount of steam for sootblowing in g =  ')
time1=input('the time of sootblowing in sec = ')
m2=m1/time1
t3=input('insert air heater gas outlet temperature = ')
p1=input('insert partial pressure or furnace pressure  = ')
h7=input('insert enthalpy of steam for sootblowing = ')
h8=input('insert enthalpy of makeup water = ')
heat7=m2*(h7-h8)
m3=input('insert the amount of steam to atomizing= ' )
heat8=m3*(h7-h8)
heat9=heat6+heat7+heat8
heat10=heat1-heat9
eff3=heat10/heat1
heat11=input('input heat lost from  main steam by radiation  = ')
heat12=input('input heat lost from  feed system by radiation  = ')
heat13=heat11+heat12
heat14=heat10-heat13
eff4=heat14/heat10
out1=input('design out put =  ')
hr1=input('design heat rate at design power = ')
out2=input('design out put at 50 % MCR =  ')
hr2=input('design heat rate at 50 % MCR  = ')
a=[out1 1;out2 1]
b=[out1*hr1;out2*hr2]
x=a\b
m=input('input incremental heat =  ')
c=input('input fixed heat =   ')
out3=(heat14*60*60-c)/m
hr=(c/out3)+m
eff5=3600/hr
out4=0.94*out3
eff6=out4/out3
eff7=0.993
out5=out4*eff7
eff8=eff2*eff3*eff4*eff5*eff6*eff7
```

G1: MATLAB code programme no (1)

```
gen1=input(' input unit generated during period =  ')
sent1=input('input sent out during period =  ')
time2=input('input time generating =  ')
cw1=input('input CW inlet temperture =  ')
cw2=input('input CW outlet temperture =  ')
cw=cw2-cw1
vac1=input('input the cndenser vaccum pressure from local gauge =  ')
gen2=gen1/time2
sent2=sent1/time2
heat15=input('heat input to unit gross CV at high load =  ')
out6=input('the output from generator transformer at high load  =   '
)
eff8=out6/heat15
hr3=3600/eff8
heat16=input('heat input to unit gross CV at 15% load at MCR =  ')
out7=input('the output from generator transformer at 15% MCR load =')
eff9=out7/heat16
hr4=3600/eff9
a=[out6 1;out7 1]
b=[out6*hr3;out7*hr4]
x=a\b
c=input('input fixed heat in mega =  ')
m=input('input incremental heat in mega =   ')
hr5=c/sent2+m
eff10=3600/hr5
out8=input('input nett generated output')
hr6=input('turbine heat rate = ')
eff11=input('generator efficicy at 0.8 P.F =  ')
eff12=input('input turbine mechanical efficiency =   ')
power1=input('feed pump power =  ')
eff13=input('input motor efficiency =   ')
heat17=out8*(hr6-(3600/(eff11*eff12)))+3600*power1*eff13
heat18=heat17/3600
heat19=input('input atual heat rejected to condenser at gen load =
')
m4=heat19/(cw*4.187);
m5=1921;
mean1=(cw1+cw2)/2;
mean2=30.53;
lmtd1=16.63;
lmtd2=lmtd1*(mean2/mean1)^(1/4)*(m5/m4)^(1/2)*(heat19/heat18)
y=exp(cw/lmtd2)
t3=(y*cw2-cw1)/(y-1)
vac2=input('insert condenser vacuum coreesponding to ts t3 from steam
table =  ')
vac3=input('vacuum from graph at gen load ')
vac4=vac2-vac3
vr1=input('vacuum correction from manufactures = ')
eff14=eff10*vr1
vac5=vac1-vac3
vr2=input('vacuum correction from manufactures = ')
eff15=eff10*vr2
eff16=eff14-eff15
out9=input('input initial load in MW =    ')
hr7=c/out9+m
eff17=3600/hr7
cw3=heat18/(m4*4.187)
heat20=input('input heat rate at load out9 now load =   ')
lmtd3=lmtd1*(mean2/(cw1+cw3/2))^(1/4)*(m5/m4)^(1/2)*(heat20/heat18)
cw4=cw1+cw3
```

```
y2=exp(cw3/lmtd3)
t4=(y2*cw4-cw1)/(y2-1)
vac6=input('input vacuum at ts=t4 =    ')
vac7=input('input condenser vacuum from graph ')
vac8=vac6-vac7
vr3=input('input correction value ')
eff18=eff17*vr3
eff19=eff18-eff14
heat21=input('heat for start of hot type')
heat22=input('heat for start of warm type')
heat23=input('heat for start of cold type')
time3=input('time used for hot tupe')
time4=input('time used for warm tupe')
time5=input('time used for cold tupe')
heat24=time3*heat21+time4*heat22+time5*heat23
heat25=(sent1*3600)/(1000*eff14)
heat26=heat24+heat25
eff20=(sent1*3600)/(1000*heat26)
eff21=eff14-eff20
t5=482.6
t6=input('input actual steam temp')
t7=t6-t5
vr4=input('correction factor of steam temp')
eff22=eff14*(1-vr4)
loss1=0.012
time6=input('the time when heater out of service')
time7=time6/time2
loss2=time7*loss1
eff23=eff14*(1-loss2)
cont1=input('input % O2 at air heater gas outlet')
t8=input('air heater gas outlet temperature =')
t9=input('air heater gas air inlet temperature = ')
cont2=(21-cont1)/21*16.1
eff24=60.28*(1/cont2-0.0683)
eff25=eff14*(95-eff24)/95
loss3=0.0374*((t8-t9)-110)
eff26=eff14*(95-loss3)/95
aux1=gen1*0.069
aux2=input('input general services aux power  =')
aux3=input('off load auxpower consumption')
aux4=aux1+aux2+aux3
aux5=gen1-sent1
aux6=aux5-aux4
heat27=(aux6*3600)/(1000*eff14)
eff27=(eff14*sent1*3600*100)/(100*sent1*3600+eff14*heat27*1000)
eff28=eff27-eff14
```

G2: MATLAB code programme no (1)