بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College Of Graduate Studies

Performance Analysis for Kaplan Hydraulic Turbines in Jebel Aulia Dam

تحليل الأداء لتوربينات كابلن الهيدروليكية في خزان جبل أولياء

Thesis Submitted in Partial Fulfillment of Requirement for the Degree of
M.Sc in Mechanical Engineering (Power)

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قَالَ تَعَالَى:

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سورة العلق

الآيات (1 – 5)

DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this project.

I also dedicate this work to my father (God bless his soul) who taught me the confidence in myself.

ACKNOWLEDGEMENTS

Firstly, thanking all thanks to God Almighty, who without his help, this work has not been done.

I offer my sincerest gratitude to my supervisor, ***Dr. Mohyedin Ahmed Abdelghadir***, who has supported me in my thesis with his patience and knowledge.

I never forget my mother and my wife for their continued support for me to complete this work.

Thanks also to the engineers at Jebel Aulia Dam whose did not hesitate to give me any information I needed from them.

Abstract:

Kaplan Hydraulic Turbines defined as prime movers that transform the kinetic energy for the flow rate of water and head to mechanical energy and electrical energy by electric generator shaft. And knowing the efficiency of a hydraulic turbine has important operational and financial benefits to those who operate in power plant stations.

This research focused on the analysis of the effect of the head and the rate of discharge on the energy produced and compared with the other theoretical and design in different seasons of the year. These results show in the form of curves and tables. For the knowledge of the highest and lowest case of the turbine can work in it, this study was done on the turbines of the jebel aulai dam .and Microsoft excel program was used to complete the calculations and draw the curves.

المستخلص:

يمكن تعريف توربينات كابلان الهيدروليكية كمحركات رئيسية تعمل على تحويل الطاقة الحركية لتدفق المياه من ارتفاع معين الي طاقة ميكانيكية ثم الي طاقه كهربائيه عن طريق تدوير عمود المولد الكهربائي. ومعرفة كفاءة التوربين الهيدروليكي له فوائد تشغيلية ومالية مهمة للذين يعملون في محطات توليد الطاقه.

هذا البحث ركز علي تحليل تاثير السمت ومعدل التصريف علي الطاقه المنتجه ومقارنتها بالأخري النظرية والتصميمية وذلك في مختلف فصول السنة.وإظهار هذه النتائج في شكل منحنيات وجداول .ولمعرفة أعلي وأقل حاله يمكن للتوربين العمل فيها.تم إجراء هذه الدراسة علي توربينات سد جبل أولياء .كما تمت الاستعانه ببرنامج (Microsoft excel) في إكمال العمليات الحسابيه ورسم المنحنيات .

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1	RVR	Rotating Vortex Rope
2	CFD	Computational Fluid Dynamics
3	KVA	Kilo Volt Ampere
4	MVA	Mega Volt Ampere
5	RPM	Revolution Per Minute
6	DIS	Descriptions
7	GH	Gross Head
8	MD	Module Discharge
9	HL	Head Losses
10	NH	Net Head
11	TE	Turbine Efficiency
12	T MOP	Transformer Module out put
13	GE	Generator Efficiency
14	G MOP	Generator Module output
15	mcm/day	Million Cubic Meter per day
16	BS	British Standard
17	EN	European Standard
18	10025	number of the relevant
19	S	Standard Structural Steels
20	JR	the Impact Test was conducted to 27 joules minimum at room temperature
21	425C11	C 0.10 ,Si 1.0 ,Mn 1.0 ,P0.040 ,S 0.030 ,Cr 11.5/13.5 Mo0.60 ,Ni3.4/4.2
22	AB2- C	Aluminum Bronze- Cold Rolled

CHAPTER 1

INTRODUCTION

Introduction

1-1 Background:

Mainly the Kaplan turbine is used to create the power from the low head and large flow rate is required to Kaplan turbine. The main purpose passage in between the rotor and guide vane which the flow is in the radial direction. Initially the flow must be in radial direction but the radial direction is forced to move in the axial direction. That can observe Kaplan turbine to provide loading at large flow rates. The water flow in the Kaplan turbine is in the radial direction the flow is entered and exists axially. Inlets of the turbine guide vanes are fixed. The similarity in between the rotor and propeller of a ship. To the central shaft of the turbine rotor blades are attached. With the help of moveable joints blades are connected to the shaft. The blades are rotated according to the water flow rate and the water head available. Compare to the other axial flow turbines the blades of the Kaplan turbine are not planer. So they are designed with a twist along the total length so it allows rotation of the water flow at the inlet and leaves at the axial flow.

The performance of a Kaplan turbine in partial operation conditions is often limited by cavitation and stability, especially at the large flow rate operation conditions. Many problems such as vibration[1], efficiency dropping[2], cavitation[3], and blade cracks[4] caused by unstable flow in each of the flow passage components of the turbine seriously affect the safe operation of the unit, and because of these problems, many power plants are forced to undergo downtime for repairs or renovation

1-2 Importance of the research:

Usually produced water power plants station, especially the Kaplan, high efficiency turbines, but there must be constraints to reduce this efficiency.

The importance of this research appears in the presentation of these obstacles and their study and knowledge of the best points in which efficiency is at its highest values.

1-3 Problem statement:

In Kaplan's turbines at the jebel Aulia station find a difference in the ability produced by the turbines and the supposed capacity of the turbines due to several reasons including improper flow, inappropriate head, and shaft rotation velocity.

1-4 Objectives:

Determine the turbine performance characteristics of output power and efficiency of fixed blade kaplan turbine in station jebel aulia dam.

Compare between the numerical calculations (theoretical and designing) results of power output and power that already readable from the dam.

1-5 Research methods:

- Study for literature review
- An analytical approach will be used to collect information from the power plant station (head, flow rate, shaft speed, and power) and monitor it in the form of curves and compare it with the theoretical and designing values of the input data.

- The excel program will be used to schedule data and calculate the variable values by inserting equations that already previously prepared and draw the result as a curves .

1-6 Thesis structure:

- Introduction.
- Literature Review.
- Calculations.
- Results & Discussions.
- Conclusions & Recommendations.
- Appendix.

CHAPTER 2

LITERATURE REVIEW

2-1 Introduction:

Hydraulic turbines may be defined as prime movers that transform the kinetic energy of the falling water into mechanical energy of rotation and whose primary function is to drive an electric generator.

A cubic meter of water can give about 9800 Joules of mechanical energy for every meter it descends and a flow of a cubic meter per second in a fall of 1 meter can provide 9800 W of power Hydro-power is essentially a controlled method of water descent usefully utilized to generate power.

Hydroelectric plants utilize the energy of water falling through a head that may vary from a few meters to ~1500 or even 2000 m. To manage this wide range of heads, many different kinds of turbines are employed, which differ in their working components.

– The hydraulic system components that include the turbine, the associated conduits-like penstocks, tunnel and surge tank-and its control system

2-2 History of Hydraulic Turbines:

Firstly Water wheels – China and Egypt – thousands of years ago and then Reaction runner – J a Segnar – 1950,and Euler turbine theory – Leonard Euler – valid till today

Turbine is a designation that was introduced in 1824 in a dissertation of the French engineer Burden. Fourneyron designed a radial turbine and put to operation the first real turbine in 1827 – power 20-30kW and runner diameter of 500 mm. Henschel and Jonval in 1840 independently developed turbine with axial water flow through it. They were the first ones to apply draft tube and in that way to utilize the water head between runner outlet and tail water level.

Francis in 1849 developed the radial turbine, named Francis turbine. in 1870 professor Fink introduced an important improvement in Francis turbine by making the guide vanes turning on a pivot in order to regulate the flow discharge.

In 1890 American engineer Pelton developed impulse turbine, named Pelton turbine

In 1913 Kaplan designed a propeller turbine, named Kaplan turbine Subsequent developments were made on Francis, Pelton and Kaplan turbines.

2-3 Classification of Hydraulic Turbines:

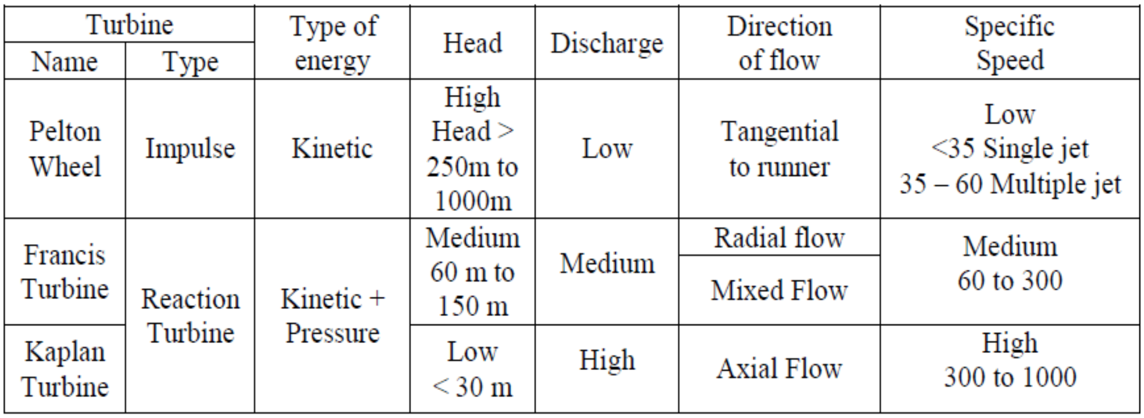
Hydraulic turbines are generally classified as:

- Impulse Turbine – (Pelton, Turgo turbine)
- Reaction Turbine – (Francis, Kaplan and Propeller turbine)

Based on flow direction, they are further classified as:

- Tangential Flow.
- Radial Flow.
- Axial Flow.
- Mixed Flow.

Table (2-1) Classification of Hydraulic Turbines



Turbine		Type of energy	Head	Discharge	Direction of flow	Specific Speed
Name	Type					
Pelton Wheel	Impulse	Kinetic	High Head > 250m to 1000m	Low	Tangential to runner	Low <35 Single jet 35 – 60 Multiple jet
Francis Turbine	Reaction Turbine	Kinetic + Pressure	Medium 60 m to 150 m	Medium	Radial flow Mixed Flow	Medium 60 to 300
Kaplan Turbine			Low < 30 m	High	Axial Flow	High 300 to 1000

The flow energy to the impulse turbines is completely converted to kinetic energy before transformation in the runner.

The impulse forces being transferred by the direction changes of the flow velocity vectors when passing the buckets create the energy converted to mechanical energy on the turbine shaft.

The flow enters the runner from jets spaced around the rim of the runners.

The jet hits momentarily only a part of the circumference of the runner.

In the reaction turbines two effects because the energy transfer from the flow to the mechanical energy on the turbine shaft:

Firstly, it follows from a drop in pressure from inlet to outlet of the runner. This is denoted as the *reaction part* of the energy conversion.

Secondly, the changes in the directions of the flow velocity vectors through the runner blade channels transfer impulse forces. This is denoted as the *impulse part* of the energy conversion.

The pressure from inlet to outlet of the runners is obtained because the runners are completely filled with water

2-4 Hydraulic Turbines:

2-4-1 Pelton Turbine:

Invented by Pelton in 1890.The Pelton turbine is a tangential flow impulse turbine. The Pelton wheel is most efficient in high head applications. Power plants with net heads ranging from 200 to1,500m.

The largest units can be up to 200 Megawatts.

Pelton turbines are best suited for high head and low flow sites, depending on water flow and design, Pelton wheels can operate with heads as small as 15 meters and as high as 1800 meters.

As the height of fall increases, less volume of water can generate same power.

2-4-1-1 Horizontal Arrangement of a Pelton Turbine:

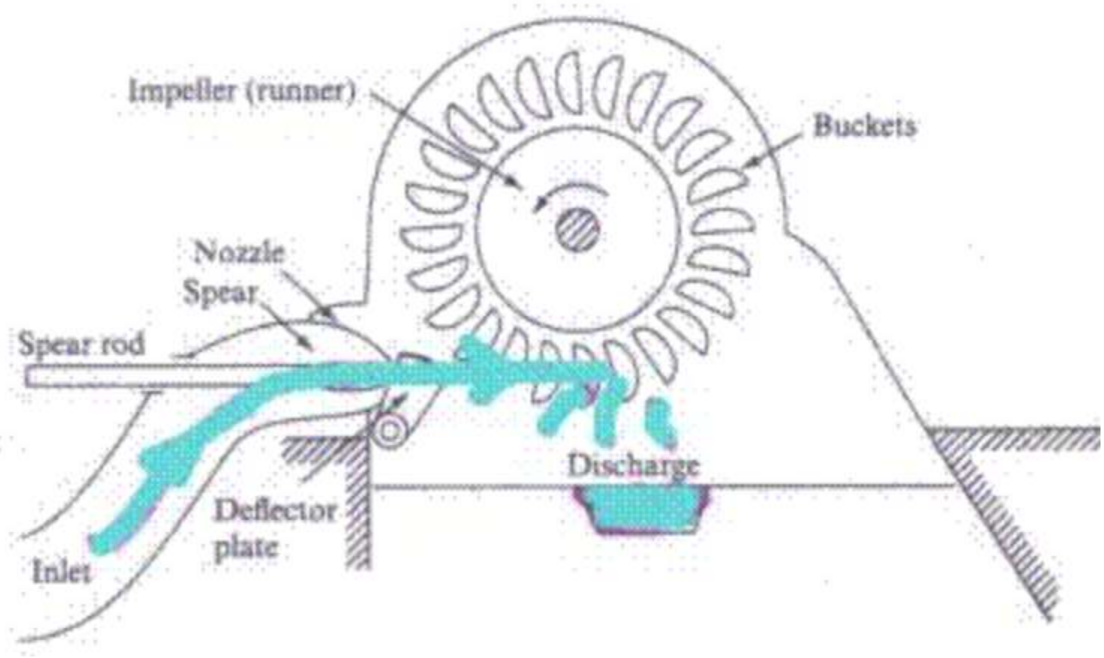


Figure (2-1) Horizontal Arrangement of a Pelton Turbine

Horizontal arrangement is found only in medium and small sized turbines with usually one or two jets. In some designs, up to four jets have been used.

The flow passes through the inlet bend to the nozzle outlet, where it flows out as a compact through atmospheric air on to the heel beckets from the outlet of jet through wheel buckets. Outlet the buckets the water falls through the pit down into the tail water canal.

2-4-1-2 Vertical Arrangement of a Pelton Turbine:

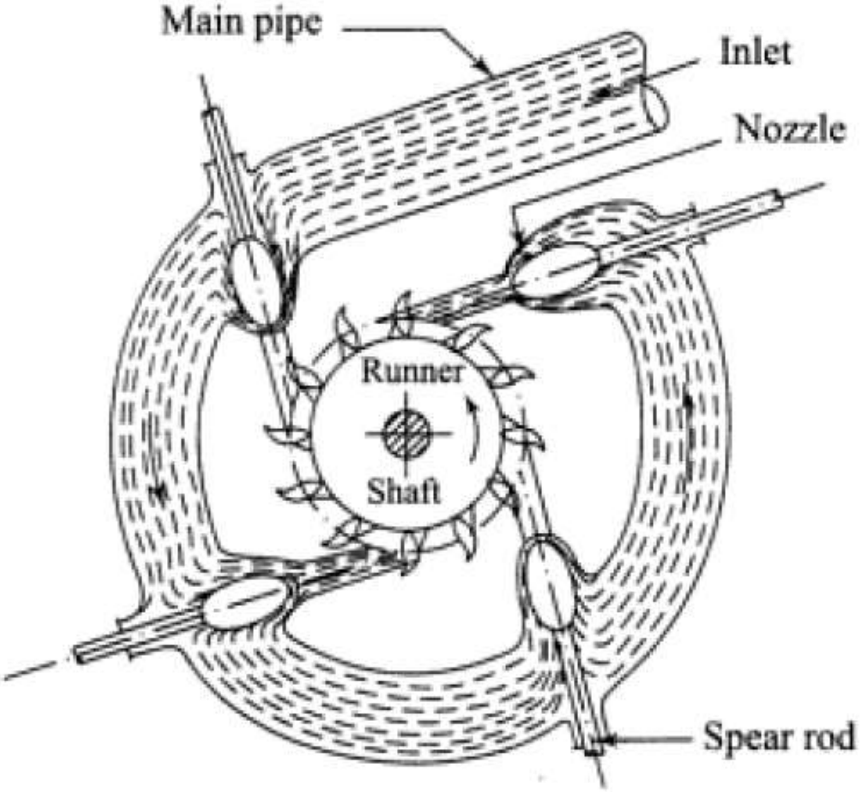


Figure (2-2) Vertical Arrangement of a Pelton Turbine

Large Pelton turbines with many jets are normally arranged with vertical shaft.The jets are symmetrically distributed around the runner to balance the jet forces.

The figure shows the vertical and horizontal sections of the arrangement of a six jet vertical Pelton turbine.

2-4-1-3 Parts of a Pelton Turbine:

The Pelton runners may be designed either for casting of the disc and buckets in one piece, i.e. monocast, or the disc and each of the buckets are casted in separate pieces.

The shape of the buckets is decisive for the efficiency of the turbines, limitations however that bucket shape always will be a compromise between a hydraulically ideal and a structural optimum design. The runner disc is fastened to the shaft by bolts and nuts.

The turbine shaft of vertical Pelton turbines is made of forged steel with an integral flange at both ends. A hole is drilled centrally through the whole length of the shaft. An oil reservoir is a rotating member bolted to the shaft flange.

Journal and thrust bearings are provided with circulating oil to carry the heat dissipated by the shaft and bearings. The distributor pipe is designed to provide an acceleration of the water flow through the bifurcation towards each of the main injectors. This design is advantageous, because it by contributes in keeping a uniform velocity profile of the flow, the injector is operated hydraulically by servo motors.

2-4-1-4 Material of Pelton Turbine:

Case : fabricated carbon steel to BS EN 10025:1993 S275JR.

Runner : cast Stainless BS 3100 Grade 425 C11.

Shaft seal: cast gunmetal labyrinth type seal.

Bearings: rolling element or sleeve type.

Spear : stainless steel internal components housed in a carbon
Needle valve steel fabricated or cast branch pipe.

Deflector: stainless steel plate.

The material of the runner and buckets are chosen according to the head, stresses, content of sand in the water and other strain factors. For the large turbines the main strain factors are cavitation, sand erosion and cycle fatigue.

2-4-2 Turgo Impulse Turbine:

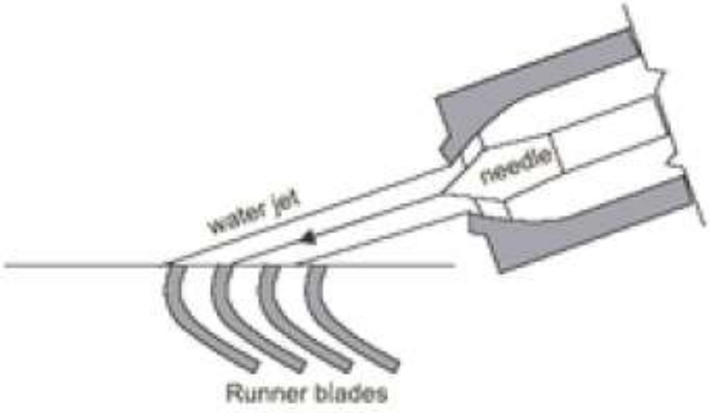


Figure (2-3)Turgo turbine

Turgo impulse turbine design was developed by Gilkes in 1919 to provide a simple impulse type machine with considerably higher specific speed than a single jet Pelton. The design allows larger jet of water to be directed at an angle onto the runner face.

The Turgo turbine is an impulse water turbine designed for medium head applications.

Turgo runners may have an efficiency of over 90%.and runner looks like a Pelton runner split in half. For the same power, the runner is one half the diameters of the Pelton runner and so twice the specific speed.

The Turgo can handle a greater water flow than the Pelton because exiting water does not interfere with adjacent buckets.

2-4-2-1 Parts of Turgo Impulse Turbine:

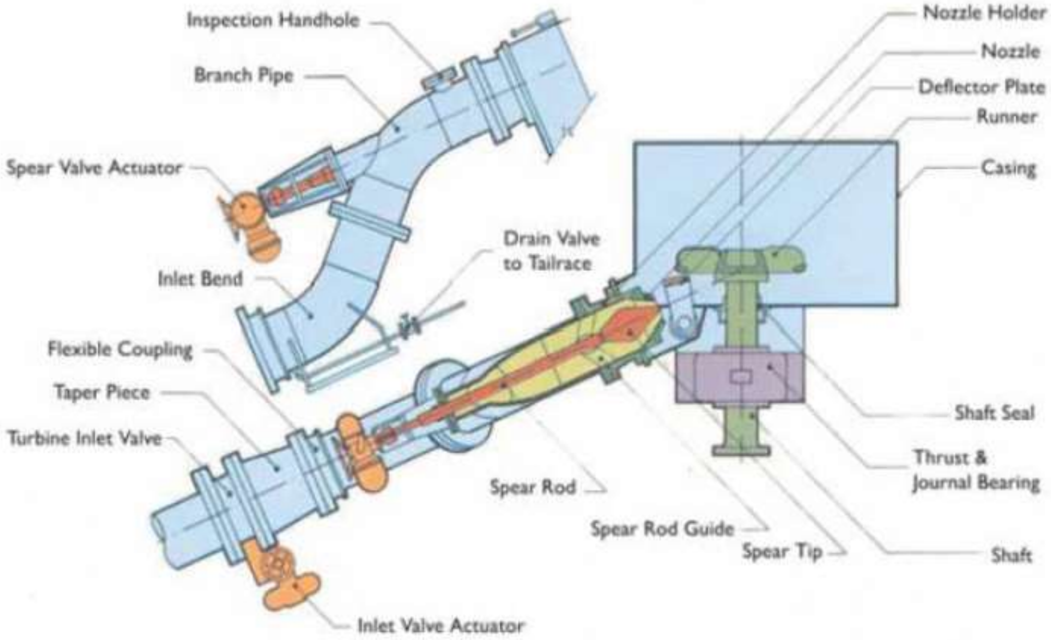


Figure (2-4) Parts of Turgo Impulse Turbine

2-4-2-2 Material of Turgo Impulse Turbine

Case : fabricated carbon steel to BS EN 10025:1993 S275JR

Runner : cast Stainless BS3100 Grade 425 C11 or Aluminum bronze Gr. AB2 C (20).

Shaft seal: cast gunmetal labyrinth type seal.

Bearings : rolling element or sleeve type.

Spear : stainless steel internal components housed in a carbon needle valve steel fabricated or cast branch pipe .

Deflector: stainless steel plate.

2-4-3 Francis Turbine:

The Francis turbine is a reaction turbine, which means that the working fluid changes pressure as it moves through the turbine, giving up its energy.

The inlet is spiral shaped. The guide vanes direct the water tangentially to the runner causing the runner to spin.

The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions. Power plants with net heads ranging from 20 to750m.

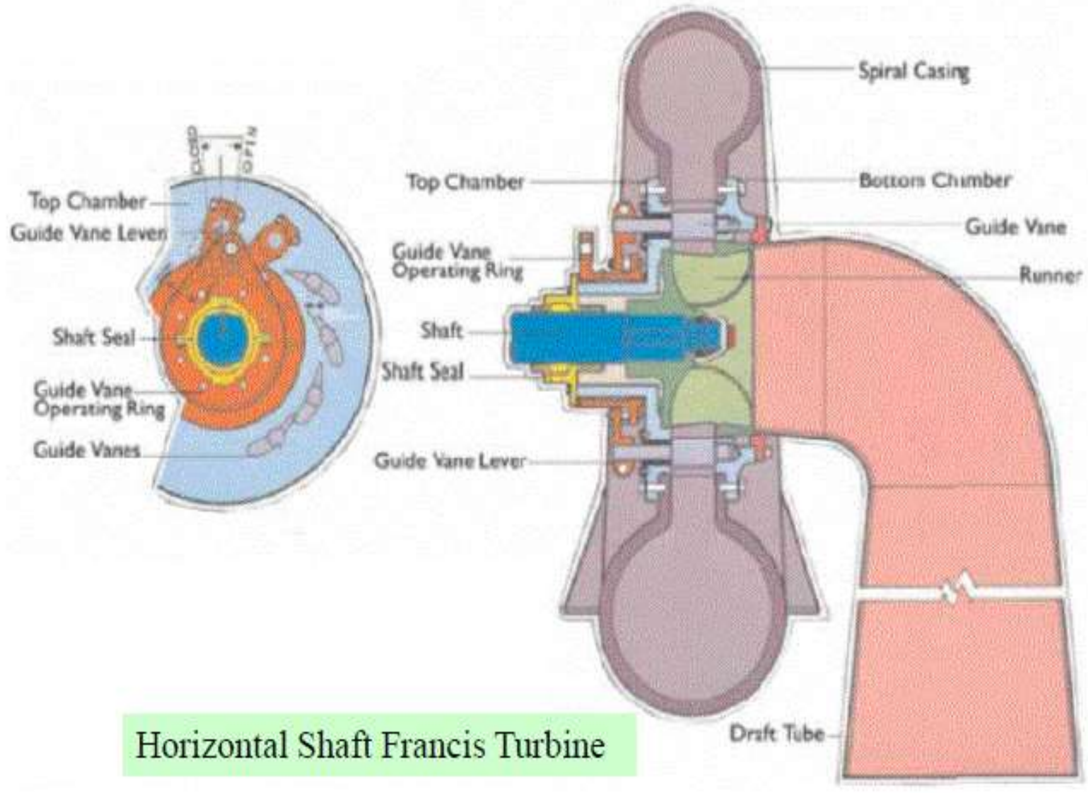


Figure (2-5) Horizontal shaft Francis turbine

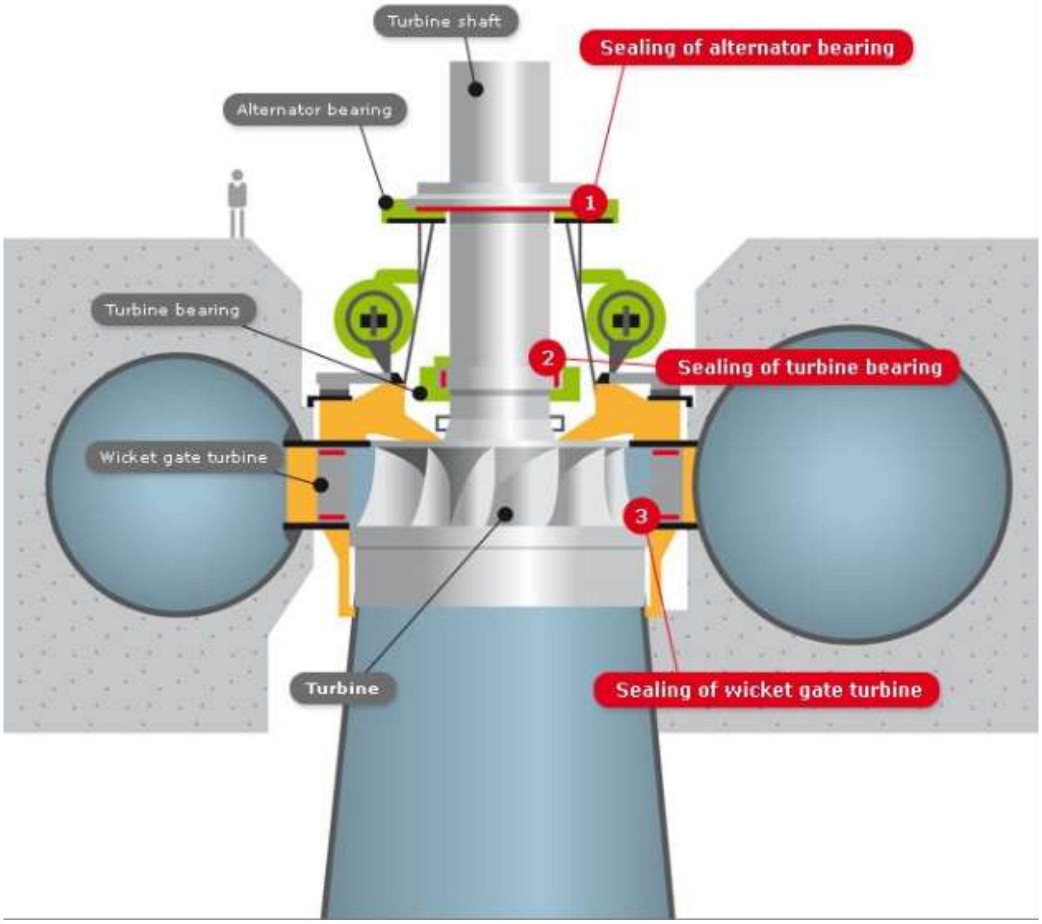


Figure (2-6) Vertical Shaft Francis Turbine

The water from the penstock is conducted through the scroll casing and distributed around the stay ring and the complete circumference of the guide vane cascade. The scroll casings are normally welded steel plate constructions for turbines at low, medium as well as high heads.

The openings of the guide vanes are adjustable by the regulating ring, the links and levers. The vanes are shaped according to hydraulic design specifications and given a smooth surface finish. The bearings of the guide vane shafts are lubricated with oil or grease.

Casing covers are bolted to the stay ring of the scroll casing. They are designed for high stiffness to keep the deformations caused by the water pressure at a minimum. This is of great importance for achieving a minimal clearance gap between the guide vane ends and the facing plates of the covers. Between the runner and the covers the clearance is also made as small as possible.

The turbine shaft is steel forged and has forged flanges at both ends; the turbine and generator shafts are connected by a flanged joint. This joint may be a bolted reamed or friction coupling where the torque is transferred by means of shear or friction.

2-4-3-1 Regulating Mechanism for Francis Turbine:

The guide vane mechanism along with the governors provides the regulation of the turbine output.

The turbine governor controls the servomotor which transfers its force through a rod to the regulating ring. This ring transfers the movement to the guide vanes through a rod, lever and link construction.

The guide vane exit area in flow direction is varied by an equal rotation of each of the guide vane.

2-4-3-2 Material of Francis Turbine:

Case: Fabricated carbon steel to BS EN 10025:1993 S275JR
Runner: Cast Stainless BS3100 Grade 425 C11 or Aluminum Bronze BS 1400Gr.AB2C.
Draft tube: Fabricated carbon steel.
Bearings: Rolling element or sleeve type.
Guide vanes: Stainless steel or Aluminum Bronze.
Operating ring: Fabricated steel BS 10025:1993 S275 JR.
Deflector: Stainless steel plate.

2-4-4 Propeller Turbine

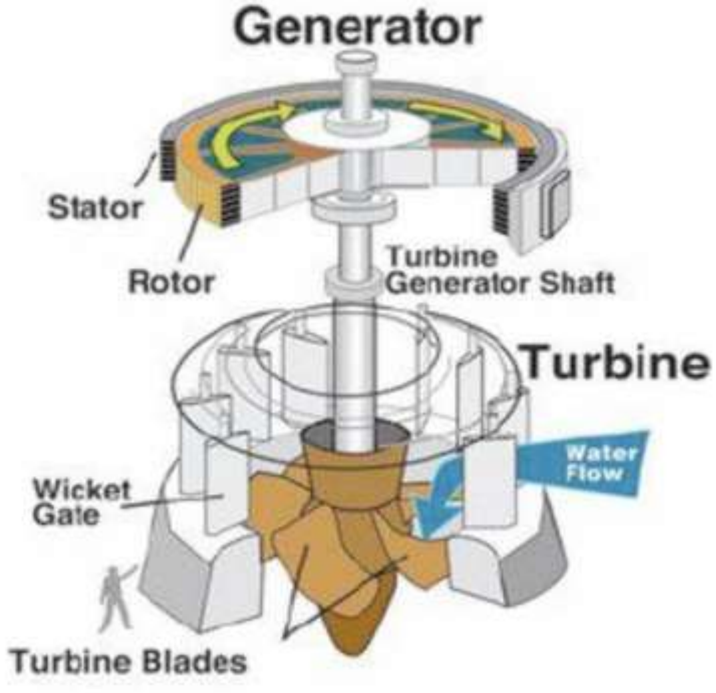


Figure (2-7) propeller turbine

The propeller turbines have the following favorable characteristics: relatively small dimensions combined with high rotational speed a favorable efficiency curve large overloading capacity

The runner has only a few blades radially oriented on the hub and without an outer rim. The water flows axially through the runner, the runner blades have a slight curvature and cause relatively low flow losses. This allows for higher flow velocities without great loss of efficiency.

Accordingly, the runner diameter becomes relatively smaller and the rotational speed more than twice than that for a Francis turbine of the corresponding head and discharge.

The comparatively high efficiencies at partial loads and the ability of overloading is obtained by a coordinated regulation of the guide vanes and the runner blades to obtain optimal efficiency for all operations

2-4-5 Kaplan Turbine:

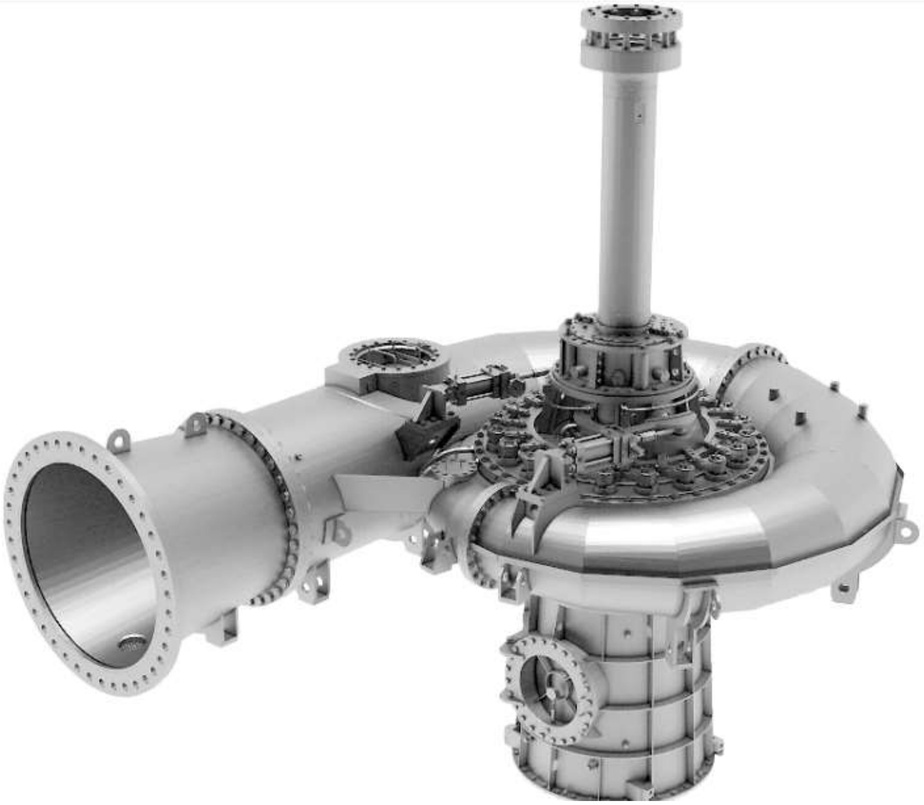


Figure (2-8) Kaplan turbine

The Kaplan turbine is a propeller-type water turbine that has adjustable blades. It was developed in 1913 by the Austrian professor, Viktor Kaplan.

The Kaplan turbine was an evolution of the Francis turbine. Its invention allowed efficient power production in low head applications that was not possible with Francis turbines.

Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. Power plants with net heads ranging from 10 to 70m.

Kaplan turbines have an adjustable runner blade, that offers significant advantage to give high efficiency even in the range of partial load, and there is little drop in efficiency due to head variation or load.

The runner blade operating mechanism consists of a pressure oil head, a runner servomotor and the blade operating rod inside the shaft, etc.

The runner blades are operated to smoothly adjust their blade angles by a link mechanism installed inside the runner hub.

2-4-5-1 Parts of a Kaplan Turbine

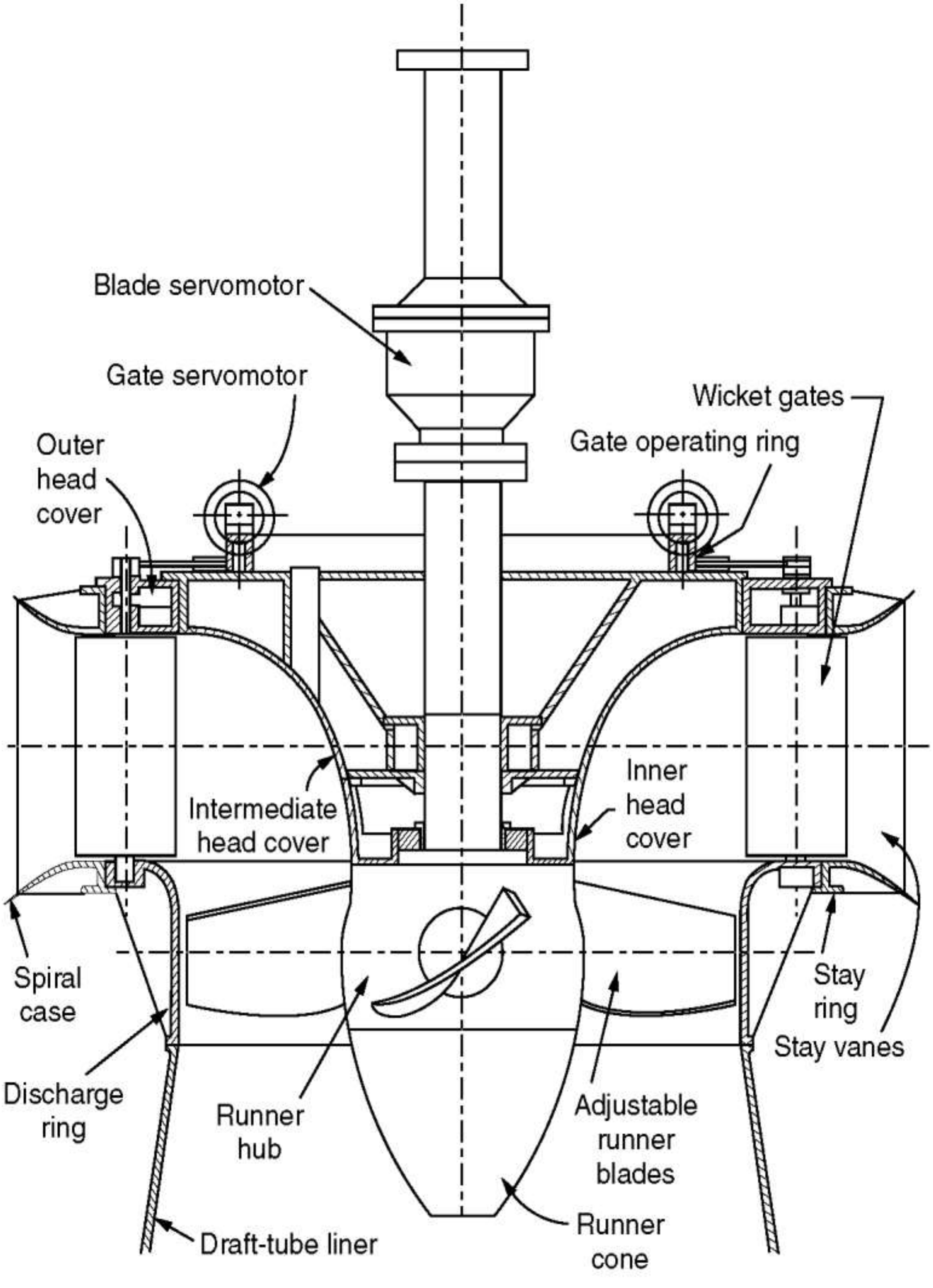


Figure (2-9) Parts of a Kaplan Turbine

a- Spiral Case:

The function of the spiral case (or scroll case) is to supply water from the intake to the stay vanes, directly to the upstream portion of the turbine, and through a unique shape of continual cross sectional area reduction to the downstream portion of the turbine; maintaining a near uniform velocity of water around the stay vanes and wicket gates.

b-Stay Ring/Vanes:

The function of the stay vanes (and stay ring) is to align the flow of water from the spiral casing to the wicket gates. They also function as support columns in vertical units for supporting the static weight of the unit's stationary components and hydraulic thrust during turbine operation.

c-Wicket Gates:

The function of the wicket gates is primarily to control the quantity of water entering the turbine runner, thereby controlling power output. Secondarily, the gates control the angle of the high tangential velocity water striking the runner blades. The optimum angle of attack will be at peak efficiency. In an adjustable-blade unit, the tilt of the blades and opening of the gates are synchronized to maximize efficiency over as much of the operating range as possible. The wicket gates also function as a closure valve to minimize leakage through the turbine while it is shut down.

d-Runner:

The function of the runner is to convert the potential energy of pressure (head) and flow of water into mechanical energy or rotational horsepower. The Kaplan runner is comprised of a hub, nosecone, blades, and an internal blade tilting mechanism - typically a hydraulically-driven piston with linkage and seals. Oil pressure is provided by the governor hydraulic system.

e-Draft Tube:

The function of the draft tube, which is initially conically shaped and attached to the turbine discharge, is to gradually slow down the high discharge velocity water, capturing kinetic energy from the water, which is usually below atmospheric pressure. In most cases, it has an elbow in order to minimize excavation for the unit. The head recovery from the draft tube is the difference between the velocity head at the runner discharge and draft tube discharge, overall increasing the head across the turbine. The larger the head differential is across the turbine, the higher the turbine power output. The throat ring of the draft tube should be steel lined from the discharge ring to the point where the water velocity reduces to about 20 ft /s, which is considered below concrete scouring velocity

Non-performance but reliability related components of a Propeller/Kaplan turbine include the wicket gate mechanism/servomotors, head cover, bottom ring, turbine shaft, guide bearing, mechanical seals/packing and discharge/throat ring.

f-Wicket Gate Mechanism/Servomotors:

The function of the wicket gate mechanism and servomotors is to control the opening and closing of the wicket gate assembly. The mechanism includes arms, linkages, pins, shear pins, turnbuckles or eccentric pins for closure adjustment, operating ring (or shift ring, and bearing pads), and bushings either greased bronze or greaseless type. Servomotors are usually hydraulically actuated using high pressure oil from the unit governor. In some limited cases a very small unit may have electro-mechanical servomotors.

g-Turbine Shaft:

The function of the turbine shaft is to transfer the torque from the turbine runner to the generator shaft and generator rotor. The shaft typically has a bearing journal for oil lubricated hydrodynamic guide bearings on the turbine runner end or wearing sleeve for water lubricated guide bearings. Shafts are usually manufactured from forged steel, but some of the largest shafts can be fabricated.

h-Guide Bearing:

The function of the turbine guide bearing is to resist the mechanical imbalance and hydraulic side loads from the turbine runner thereby maintaining the turbine runner in its centered position in the runner seals. It is typically mounted as close as practical to the turbine runner and supported by the head cover. Turbine guide bearings are usually either oil lubricated hydrodynamic (babbitted) bearings or water lubricated (plastic, wood, or composite) bearings.

i-Mechanical Seals / Packing:

Water retaining sealing components in the turbine includes the seal for the turbine shaft and the wicket gate stem seals. Shaft seals are typically either packing boxes with square braided packing or for high speed units a mechanical seal is required. Wicket gate stem packing is usually either a square braided compression packing, a V type or Chevron packing, or some type of hydraulic elastomer seal. Although in the truest sense any sealing components on a turbine could be a performance issue, since any leakage that by-passes the turbine runner is a loss of energy, the leakage into the wheel pit is considered insignificant to the overall flow through the turbine.

Oil filled Kaplan hubs have seals around the blade trunnions to prevent oil leakage and to prevent water leakage into the oil. These trunnions seals are usually either double opposing or chevron packing type.

j-Head Cover / Bottom Ring:

The head cover is a pressurized structural member covering the turbine runner chamber that functions as a water barrier to seal the turbine. It also serves as a carrier for the upper wicket gate bushings, upper seal surface for the wicket gate vanes, support for the gate operating ring, carrier for the runner stationary seal rings, and support for the turbine guide bearing. The bottom ring serves as a carrier for the bottom wicket gate bushings, bottom seal surface for the wicket gate vanes, and a carrier for the bottom runner stationary seal ring.

k-Discharge / Throat Ring:

The discharge ring serves as the steel housing of the runner which is the transitional piece to the expanding draft tube.

2-4-5-2 Material of Kaplan Turbine:

ASTM A487 / A743 CA6NM stainless steel to manufacture Propeller/Kaplan turbine runners, wicket gates, and water lubricated bearing shaft sleeves to maximize resistance to erosion, abrasive wear, and cavitation.

2-4-6 Diagonal Flow Turbine:

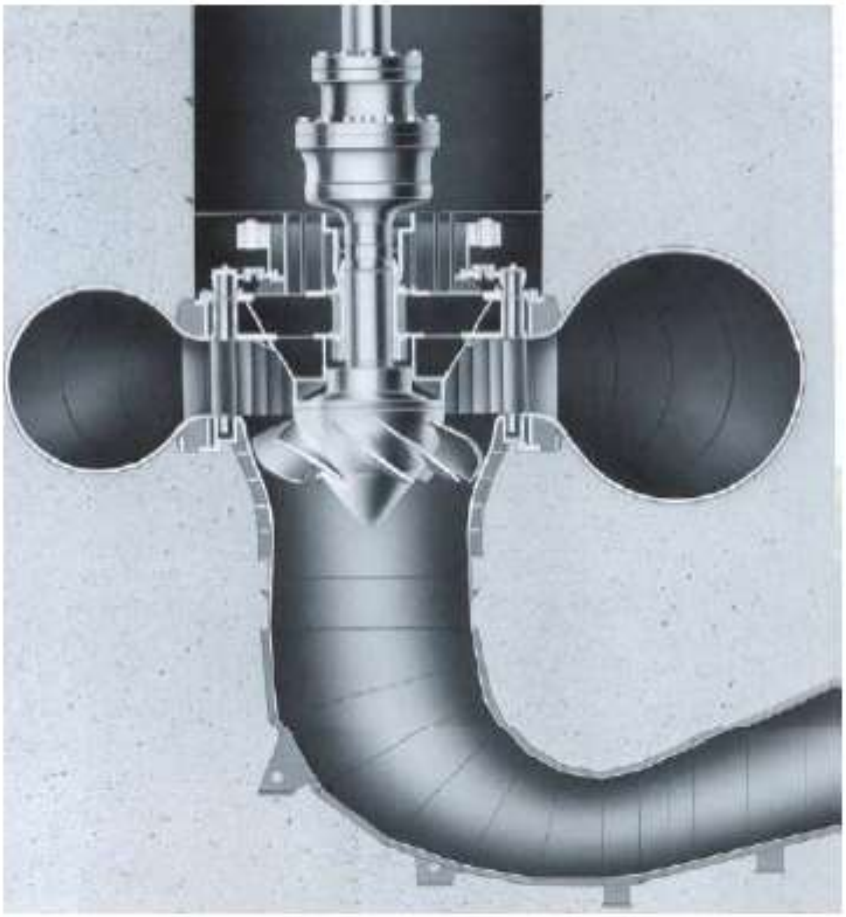


Figure (2-10) Diagonal Flow Turbine

The Diagonal flow turbine is an improvement of Kaplan turbine with better performance for high head, as a result of using adjustable runner blades, has high efficiency over a wide range of head and load. Thus, it is suitable for a power station with wide variation of head or large variation of discharge.

The Diagonal flow turbine has runner blade-stems constructed at a certain diagonal angle to the vertical center line of the machine

2-4-7 Tubular or Bulb Turbine:

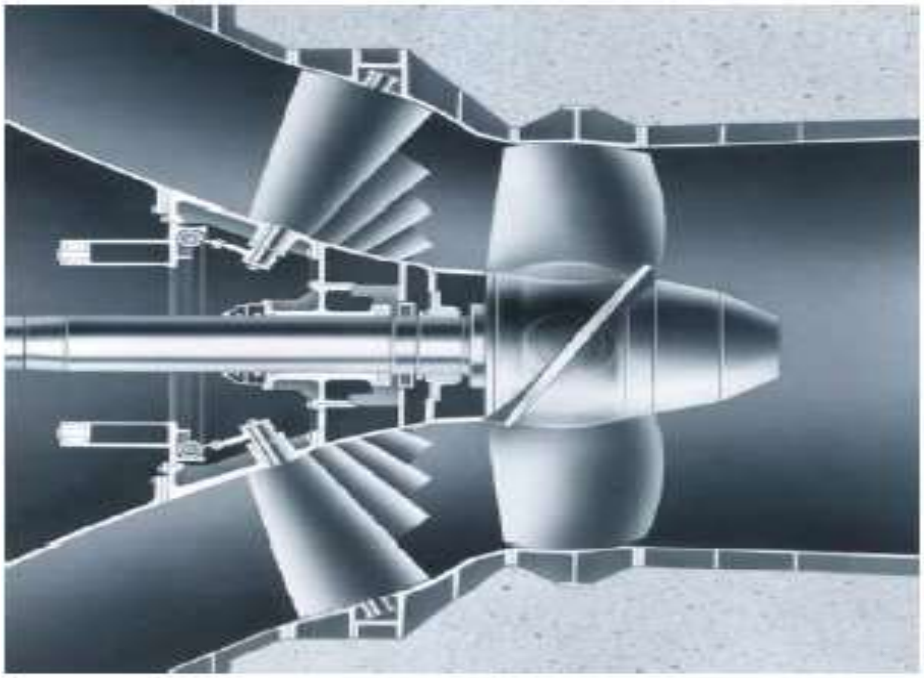


Figure (2-11) Tubular or Bulb Turbine

In a Bulb turbine, the water flows with a mixed axial-radial direction into the tubular turbine is a reaction turbine of Kaplan type which is used for the lowest head .guide vane cascade and not through a scroll casing. The guide vane spindles are inclined (normally 60^{o}) in relation to the turbine shaft. contrary to other turbine types, this results in a conical guide vane cascade, The Bulb turbine runner is of the same design as the Kaplan turbine runner.

The tubular turbine is equipped with adjustable wicket gates and adjustable runner blades.

This arrangement provides the greatest possible flexibility in adapting to changing net head and changing demands for power output, because the gates and blades can be adjusted to their optimum openings.

2-4-7-1 Parts of a Bulb Turbine:

1. Bulb nose.
2. Access arm to upstream compartment.
3. Removable cover for generator dismantling.
4. Oil distribution head.
5. Generator.
6. Upper stay vane for access to downstream compartment.
7. Upstream thrust and counter thrust bearing.
8. Lower stay vane.
9. Downstream bearing.
10. Adjustable distributor.
11. Blade.
12. Turbine pit.

2-5 Literature review:

Several studies have been done in the Kaplan hydraulic turbines. these studies discussed different aspects of the turbine from the improvement of efficiency and different studies on the characteristics and features of Kaplan's turbine on other water turbines ,and the work of miniature models, and studies on them for the calculation efficiency ,and output and knowing the factors affecting in the efficiency , Also some research going in direction to calculate the proper dimensions of the basic parts (by using CFD or Other methods), like rotor shaft ,vanes, gates ,hub,…etc.

2-5-1experimental analysis:

Bodkhe[1]the experimental analysis to get the actual performance characteristics curves. The experimentation is carried out in the fluid power laboratory .head and gate opening are maintain constant .speed is varied by allowing available quantity of water to flow through the inlet openings. The brake power is then measured mechanically by means of eddy current dynamometer. the curves between Qn and Nu for a Kaplan turbine are rising curves, the discharge increases with the increase in speed. The overall efficiency occurs at different gate opening.

2-5-2 Enhance the Efficiency:

According to Bhoumika[2] :

1-The Kaplan's blades are adjustable for pitch and will handle a great variation of flow very efficiently. They are 90% or better in efficiency and are used in place some of the old (but great) Francis types in a good many of installations. Hence failure of a Kaplan turbine operation result efficiency loss of production supply

2-operating life of a Kaplan turbine can be drastically curtailed by improper start up and shut down practices. So properly planed executed maintenance schedule is in dispensable for very power plant having hydraulic turbine on their main equipment in their process plant.

2-5-3 Effects of scaling:

The new directions are opened concerning the scale effect at Kaplan turbines .The original relationships are developed for the calculation of coefficients and V in the whole domain of operating of Kaplan turbines. Their use needs only the hill diagram of the turbine. Applying a new method there were obtained new relations, for the coefficients corresponding to the optimum operating regime of a Kaplan turbine [3].

2-5-4 Effect of blade profile:

The optimization technique carried out on a complex geometry of blade profile through static and dynamic computational analysis. It is used through change of the blade profile geometry at five different angles in the 3D (Three Dimensional) CAD model. Blade complex geometry and design have been developed by using the coordinate's point system on the blade in PRO-E /CREO software. Five different blade models are developed for analysis purpose. Based on the flow rate and heads, blade profiles are analyzed using ANSYS software to check and compare the output results for optimization of the blades for improved results which show that by changing blade profile angle and its geometry, different blade sizes and geometry can be optimized using the computational techniques with changes in CAD models[4].

2-5-5 Effects of load variation in runner:

The purpose of this study is to investigate the effect of transient operations on the pressure fluctuations on the runner and mechanism of the RVR formation/mitigation [5]. Draft tube and runner blades of the Porjus U9 model, a Kaplan turbine, were equipped with pressure sensors.

The model was run in off-cam mode during different load variation conditions to check the runner performance under unsteady condition. The results showed that the transients between the best efficiency point and the high load happens in a smooth way while transitions to/from the part load, where rotating vortex rope (RVR) forms in the draft tube induces high level of fluctuations with two frequencies on the runner; plunging and rotating mode of the RVR.

2-5-6 Runner Blade and cavitation:

a- [6] the flow behavior for two types of geometry of Kaplan runner blade anti cavitation lip. The first lip had the original dimensions from the hydropower plant. The second lip had a modified cross section and smooth edges at the extremities. Tip vortex, cavitation caverns and pressure coefficient diagrams were generated.

b- Cavitation characteristics [8]

Numerical simulation of cavitation characteristic in pure water and solid-liquid two-phase flow in Kaplan turbine was performed. The solid-liquid two-fluid model were adopted in the numerical simulation, and the pressure, velocity and particle concentration distributive regularity on turbine blade surface under different diameter and concentration was revealed. Particle trajectory model was used to investigate the region and degree of runner blade abrasion in different conditions.

c- Types of cavitation

Types of cavitation [11] occurring in hydraulic turbines. Focused on the most important ones which is the leading edge cavitation due to its erosive power, the bubble cavitation because it affects the machine performance and the draft tube swirl that limits the operation stability.

Cavitation detection is based on the previous understanding of the cavity dynamics and its location inside the machine. This knowledge has been gained from flow visualizations and measurements in laboratory devices such as a high-speed cavitation tunnel and a reduced scale turbine test rig. The main techniques are the study of the high frequency spectral content of the signals and of their amplitude demodulation for a given frequency band. Moreover, low frequency spectral content can also be used in certain cases

2-5-7 CFD simulations:

In three computation examples; each of them concentrates on different aspects of computational fluid dynamics (CFD) utilization.

The numerical tests of various turbulent models for Kaplan turbine CFD applications, numerical determination of the cam curve characteristic and numerical analysis of operating parameters of the semi-Kaplan machine have been presented [7].

2-5-8 Effect of Solidity on Flow Pattern in Kaplan Turbine Runner:

The presence of stationary and rotating blades in axial flow reaction turbine i.e. Kaplan turbine makes the flow complex in the turbine space. The overall performance of turbine depends on loss and flow characteristics of different components. The conventional method to predict the turbine performance is physical testing of turbine model which is time consuming and costly. The runner is the heart of turbine and its design has vital effects on overall performance of turbine. The design of runner includes derivation of runner blade profile and solidity. The solidity greatly affects the loss and flow characteristics of runner. In present paper, Kaplan turbine characteristics are derived for different solidities from numerical simulation results. The computed efficiencies at best operating regime are also compared with experimental values for validation and found to bear close comparison [9].

2-5-9 Design of Runner Wheel:

This work aims to study the design of a Kaplan turbine runner wheel [10]. First, a theoretical design was performed for determining the main characteristics where it showed an efficiency of 94%. Usually, theoretical equations are generalized and simplified and also they assumed constants of experienced data and hence a theoretical design will only be an approximate. This was confirmed as the same theoretical design showed only 59.98% of efficiency with a computational fluids dynamics (CFD) evaluation. Then, the theoretically proposed design was further analyzed where pressure distribution and inlet/outlet tangential velocities of the blades were analyzed and corrected with CFD to improve the efficiency of power generation. The original design could be improved to achieve an efficiency of 93.01%. In general, the blades’ inlet/outlet angles showed a significant influence on the turbine’s power output. Finally, a comparison of the optimized and theoretical design is presented.

2-5-10 Jebel Aulia Dam:

a- The Dam descriptions:

Total long is 5km, Building 1.7km,highest elevation 22m,total approximately square 1million m^3,elvation storage 337.2m,storage altitude 300km and the total storage water is 300 million m^3.

It is located at Jebel Aulia 40 km south of Khartoum, the capital of Sudan on the White Nile River [12].

b- General plant descriptions:

- This project uses the hydro matrix technology to produce 30.4MW.
- Using 80 units, each unit is combined of turbine and generator Called (TG) unit.
- All units are divided in 8 groups called Lots, each lot contains 10 (TG).
- The lot is divided in pairs, each pair contains (2TG) units called Module.
- There are “8” transformers 690/33 KV, 5MVA.
- The project uses “2” transformers 33 KV /415 V by capacity of 250 KVA for supplying the station.
- Also there is a Substation with 4 entrances and 4 exits.
- The project uses a crane 40 T.

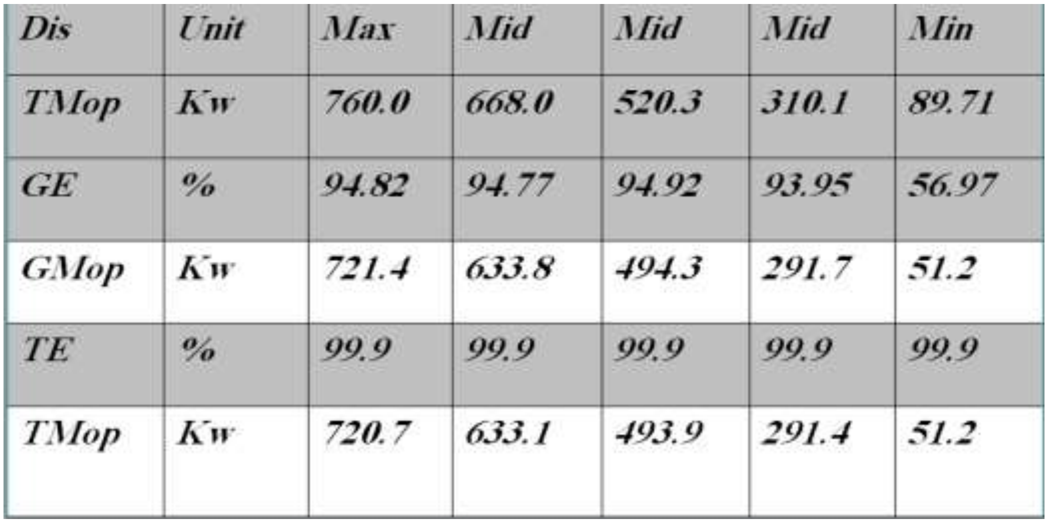
Figure (2-12) plan chart

c-General Technical Description

- Type of turbine is Hydro Matrix.
- Turbine arrangement is horizontal shaft.
- Distributor arrangement is fixed wicket gates.
- Runner arrangement is fixed runner blades ,diameter is 1.12m, 3 Runner blades.
- Turbine/Generator speed in range 375 to 380 rpm and the max runway speed is 920 rpm.

Technical data of the plant:

Table (2-2) Technical data of the plant



Dis	*Unit*	*Max*	*Mid*	*Mid*	*Mid*	*Min*
TMop	*Kw*	*760.0*	*668.0*	*520.3*	*310.1*	*89.71*
GE	*%*	*94.82*	*94.77*	*94.92*	*93.95*	*56.97*
GMop	*Kw*	*721.4*	*633.8*	*494.3*	*291.7*	*51.2*
TE	*%*	*99.9*	*99.9*	*99.9*	*99.9*	*99.9*
TMop	*Kw*	*720.7*	*633.1*	*493.9*	*291.4*	*51.2*

Dis	Unit	Max	Mid	Mid	Mid	Min
GH	m	5.43	4.87	4.00	2.9	1.88
MD	m^3/s	17.30	16.96	16.39	15.53	14.58
HL	m	0.22	0.21	0.20	0.18	0.16
NH	m	5.21	4.66	3.80	2.72	1.72
TE	%	86.39	86.57	85.45	75.17	36.54

CHAPTER 3

CALCULATIONS

3-1 Collecting Data:

The first phase of this research was based on collection of information about the dam (head, flow rate, produced power…) for different periods according to the seasons of the year. The study was focused on the selection of a month of each season (January is the winter months, April is the summer months, and October is autumn months).

- January data:

Table (3-1) January data

no	**H**$_{(m)}$	**Lot1**	**lot2**	**Lot3**	**lot4**	**lot5**	**lot6**	**lot7**	**lot8**	**Q**$_{(mcm/day)}$	**P**$_{(MW/day)}$
1	4.64	0.000	2.907	5.814	2.907	7.267	5.814	0.000	0.000	24.71	221
2	4.61	0.000	2.904	5.807	2.904	7.259	5.807	0.000	0.000	24.68	212
3	4.48	0.000	2.046	5.778	3.431	7.223	5.778	0.000	0.000	24.26	217
4	4.39	0.000	2.279	5.757	4.318	7.197	5.757	0.000	0.000	25.31	214
5	4.43	0.000	2.883	5.767	4.325	7.208	5.767	0.000	0.000	25.95	224
6	4.55	0.000	2.897	5.794	4.345	7.242	5.794	0.000	0.000	26.07	231
7	4.58	0.000	2.900	5.800	4.350	7.250	5.800	0.000	0.000	26.10	231
8	4.53	0.000	2.895	5.789	4.342	7.237	5.789	0.000	0.000	26.05	229
9	4.50	0.000	2.891	5.783	4.337	7.228	5.783	0.000	0.000	26.02	218
10	4.63	0.000	2.179	4.237	3.148	5.206	4.237	0.000	0.000	19.01	167
11	4.62	0.000	3.510	5.809	4.357	7.262	5.809	0.000	0.000	26.75	239
12	4.70	0.000	4.370	5.827	4.370	7.283	5.827	0.000	0.000	27.68	249
13	4.70	0.000	4.370	5.827	4.370	7.283	5.827	0.000	0.000	27.68	247
14	4.80	0.000	3.350	4.386	3.350	5.483	4.508	0.000	0.000	21.08	192
15	4.76	0.000	4.380	5.840	4.380	7.299	5.840	0.000	0.000	27.74	251
16	4.70	0.000	4.370	5.827	4.370	7.283	5.827	0.000	0.000	27.68	254
17	4.67	0.000	4.365	5.820	4.365	7.275	5.820	0.000	0.000	27.65	257
18	4.54	0.000	4.344	5.791	4.344	7.239	5.791	0.000	0.000	27.51	235

19	4.53	0.000	4.342	5.789	4.342	7.237	5.789	0.000	0.000	27.50	244
20	4.54	0.000	4.344	5.791	4.344	7.239	5.791	0.000	0.000	27.51	245
21	4.55	0.000	3.983	5.311	3.983	6.639	5.311	0.000	0.000	25.23	226
22	4.46	0.000	4.210	5.773	4.330	7.097	5.773	0.000	0.000	27.18	229
23	4.45	0.000	4.328	4.569	4.328	7.214	5.771	0.000	0.000	26.21	227
24	4.46	0.000	4.330	4.330	4.330	7.217	5.773	0.000	0.000	25.98	220
25	4.51	0.000	4.218	4.218	4.218	7.110	5.664	0.000	0.000	25.43	226
26	4.51	0.000	4.339	4.339	4.339	7.231	4.821	0.000	0.000	25.07	222
27	4.33	0.000	4.308	4.308	4.308	7.179	5.744	0.000	0.000	25.85	211
28	4.27	0.000	4.297	4.297	4.297	7.162	5.730	0.000	0.000	25.78	212
29	4.26	0.000	4.295	4.295	3.579	7.159	5.727	0.000	0.000	25.06	206
30	4.34	0.000	1.975	1.975	1.377	3.292	2.634	0.000	0.000	11.25	94
31	4.32	0.000	2.392	2.871	2.871	3.828	3.648	0.000	0.000	15.61	138

H=Head (m), Q=Flow rate mcm/day , P=Power output (MW/day)

- April Data:

Table (3-2) April data

no	H(m)	Lot1	lot2	Lot3	lot4	lot5	lot6	lot7	lot8	Q(mcm/day)	P(MW/day)
1	3.49	2.766	2.766	4.149	4.149	5.532	5.532	0.000	0.000	24.90	163
2	3.35	2.746	2.746	4.119	4.119	5.493	5.493	0.000	0.000	24.72	150
3	3.25	2.733	2.733	3.758	4.100	5.466	5.466	0.000	0.000	24.26	145
4	3.24	2.675	2.732	4.097	4.097	5.463	5.463	0.000	0.000	24.53	144
5	3.24	2.447	2.732	4.097	4.097	5.463	5.463	0.000	0.000	24.30	142
6	3.19	1.646	2.725	4.087	4.087	5.449	5.449	0.000	0.000	23.44	136
7	3.06	2.255	2.706	4.059	4.059	5.412	5.412	0.000	0.000	23.90	128
8	3.00	2.360	2.697	4.046	4.046	5.394	5.394	0.000	0.000	23.94	123
9	3.06	1.297	2.706	4.059	4.059	5.412	5.412	0.000	0.000	22.94	123
10	3.13	1.245	2.716	4.074	4.074	5.432	5.432	0.000	0.000	22.97	130
11	3.17	1.077	1.644	2.892	2.892	3.459	2.835	0.000	0.000	14.80	83

12	3.21	1.364	2.727	4.091	4.091	5.455	4.262	0.000	0.000	21.99	130
13	3.08	2.709	2.709	4.063	4.063	5.418	5.418	0.000	0.000	24.38	135
14	2.88	2.679	2.679	3.238	4.019	5.359	5.359	0.000	0.000	23.33	111
15	2.89	2.681	2.681	2.178	4.021	5.362	5.362	0.000	0.000	22.29	83
16	2.50	2.621	2.621	2.621	3.932	5.243	5.243	0.000	0.000	22.28	81
17	2.49	2.620	2.620	2.620	3.930	5.239	4.857	0.000	0.000	21.89	79
18	2.45	2.613	2.613	2.613	3.920	5.227	5.227	0.000	0.000	22.21	77
19	2.47	2.344	2.508	2.508	3.925	5.233	5.015	0.000	0.000	21.53	75
20	2.47	2.071	2.071	2.180	3.271	4.361	4.361	0.000	0.000	18.32	64
21	2.43	2.610	2.610	2.610	3.915	5.220	4.677	0.000	0.000	21.64	74
22	2.39	2.604	2.604	2.387	3.906	5.208	3.906	0.000	0.000	20.61	73
23	2.32	2.485	2.593	2.593	3.889	5.185	4.645	0.000	0.000	21.39	57
24	2.10	0.959	1.065	1.172	1.917	2.983	3.409	0.000	0.000	11.50	23
25	2.02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0
26	2.06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0
27	2.01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0
28	1.89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0
29	1.87	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0
30	1.89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0

- October Data:

Table (3-3) October data

no	**H$_{(m)}$**	**Lot1**	**lot2**	**Lot3**	**lot4**	**lot5**	**lot6**	**lot7**	**lot8**	**Q$_{(mcm/day)}$**	**P$_{(MW/day)}$**
1	3.34	2.059	0.000	0.000	3.146	2.746	1.544	0.000	0.000	9.50	60
2	3.37	3.609	0.000	0.000	4.869	4.125	3.323	0.000	0.000	15.93	90
3	3.29	4.108	0.000	0.000	5.477	4.108	4.108	0.000	0.000	17.80	106

4	3.29	4.108	0.000	0.000	4.564	4.108	3.937	0.000	0.000	16.72	98
5	3.07	4.061	0.000	0.564	5.189	4.061	4.794	0.000	0.000	18.67	98
6	2.85	2.731	0.000	1.170	4.848	3.567	4.570	0.000	0.000	16.89	78
7	2.82	2.559	0.000	1.224	5.118	3.839	5.118	0.000	0.000	17.86	83
8	2.81	2.335	0.000	1.335	3.447	3.058	4.059	0.000	0.000	14.23	68
9	2.79	3.499	0.000	3.444	5.332	3.999	5.332	0.000	0.000	21.61	93
10	3.08	3.217	0.000	4.063	5.418	4.063	5.418	0.000	0.000	22.18	115
11	3.16	4.080	0.453	4.080	5.441	4.080	5.441	0.000	0.000	23.58	129
12	3.43	4.137	1.379	3.390	5.516	4.137	5.516	0.000	0.000	24.07	152
13	3.63	4.177	0.696	2.785	5.570	4.177	4.351	0.000	0.000	21.76	154
14	3.70	4.191	0.000	2.794	5.588	4.191	4.016	0.000	0.000	20.78	146
15	3.56	4.163	0.752	2.776	5.551	4.163	4.452	0.000	0.000	21.86	143
16	3.53	4.157	2.772	2.772	5.543	4.157	5.543	0.000	0.000	24.94	161
17	3.37	4.125	3.494	2.692	5.499	4.125	5.499	0.000	0.000	25.44	154
18	3.44	1.667	1.380	1.035	2.184	1.552	2.069	0.000	0.000	9.89	77
19	3.59	4.169	3.880	2.780	5.559	4.169	5.559	0.000	0.000	26.12	179
20	3.58	4.167	4.167	2.778	5.556	4.167	5.556	0.000	0.000	26.39	176
21	3.56	4.163	4.163	2.776	5.551	4.163	5.551	0.000	0.000	26.37	174
22	3.52	3.001	1.962	2.424	4.848	3.463	4.617	0.000	0.000	20.31	161
23	3.47	4.145	4.145	2.763	5.527	4.145	5.527	0.000	0.000	26.25	163
24	3.36	4.123	4.123	2.748	5.497	4.123	5.497	0.000	0.000	26.11	159
25	3.03	4.052	3.151	2.701	5.403	4.052	5.403	0.000	0.000	24.76	149
26	3.26	3.988	2.677	2.620	5.298	3.931	5.184	0.000	0.399	24.10	144
27	3.41	4.133	4.133	2.755	5.510	4.133	5.510	0.000	1.378	27.55	173
28	3.53	4.157	4.100	2.772	5.543	4.157	5.543	0.000	1.386	27.66	178
29	3.53	4.157	3.869	2.772	5.543	4.157	5.543	0.000	2.021	28.06	187
30	3.62	4.117	4.175	2.784	5.567	4.175	5.567	0.000	2.784	29.17	200
31	3.70	4.366	4.249	2.910	5.821	4.366	5.821	0.000	2.910	30.44	212

3-2 Classification and Arranging Data:

The actual produced power from the dam is taken periodically every hour and collected at the end of the day to give the average energy produced per day for the plant (Mw/day).

Different readings of the flow rate are taken every six hours (four times a day) and an average is calculated to give one flow rate per day (mcm/day).

The head readings are taken every hour and an average is done to give one reading (m/day)

`3-3 The Calculations:

- Calculation consider for one module.
- The basic equation to calculate the power output is:

$$P = \rho\ g\ Q\ H \qquad (3\text{-}1)$$

P= power output (W)

ρ= density of water (1000 Kg/m^3)

g = earth gravity (9.81 m/s^2)

Q= flow rate or discharge of the dam

H= head (m)

3-3-1The Actual Status:

Actual Power Output:

Previously the actual power taken for one day for all dam turbines, and to found the power for one module per hour:

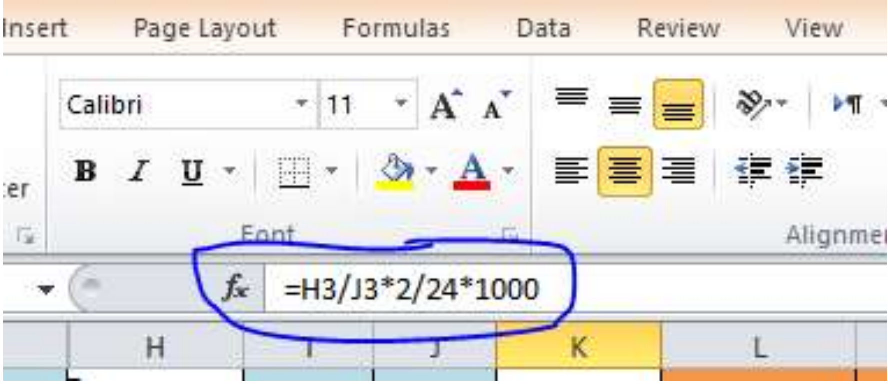
$$P_{act/mod} = (P_{act}*1000*2)/\ (n*24) \qquad (3\text{-}2)$$

$P_{act/mod}$ = actual power for one module (kW).

$P_{ac\ t}$= actual power output for all turbines (MW/day)

n = number of turbines.

In excel program:



=H3/J3*2/24*1000

Figure (3-1) Actual power output in excel

Actual Flow Rate:

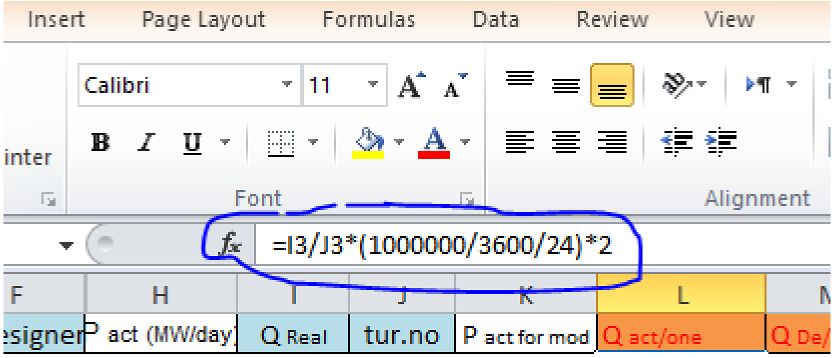
$$Q_{act/mod} = (Q_{act}*10^6*2)/(n*3600*24) \qquad (3\text{-}3)$$

$Q_{act/mod}$ = actual flow rate for one module (m3/s)

$Q_{ac\ t}$= actual flow rate for all turbines (mcm/day)

n = number of turbines.

In excel program:



=I3/J3*(1000000/3600/24)*2

esigner	P act (MW/day)	Q Real	tur.no	P act for mod	Q act/one	Q De/

Figure (3-2) Actual Flow rate in excel

3-3-1 The Designer Status

The design status is calculated according to the ideal values of the designer, which does not take some of the losses and external influences and negligence of emergency cases.

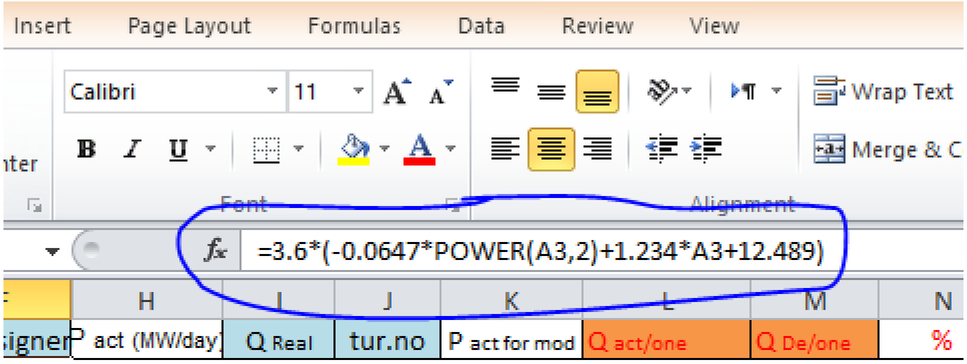
Designer flow Rate:

There is relation between head and flow rate in designer case show in equation:

$$Q_{De}= 3.6\ (-0.0647H^2+1.234H+12.489) \qquad (3\text{-}4)$$

Q_{De}= designer flow rate for all dam turbines (mcm/day).

In excel program:



=3.6*(-0.0647*POWER(A3,2)+1.234*A3+12.489)

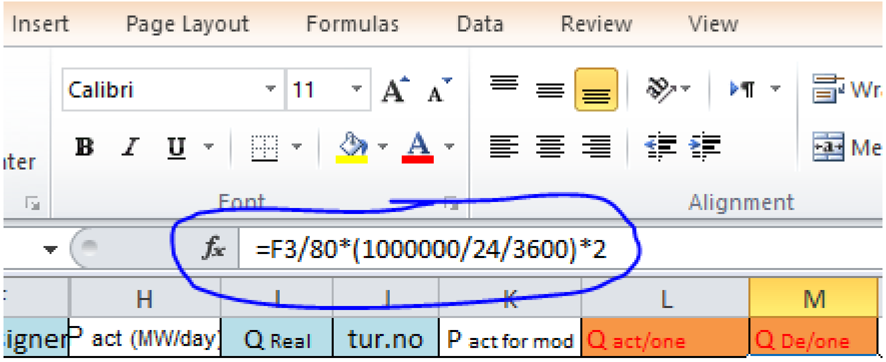
	H	I	J	K	L	M	N
igner	P act (MW/day)	Q Real	tur.no	P act for mod	Q act/one	Q De/one	%

Figure (3-3) Designer flow rate in excel

To calculated the flow rate for each module:

$$Q_{De/mod} = (Q_{De}*10^6*2) / (80*3600*24) \qquad (3\text{-}5)$$

In excel program:



=F3/80*(1000000/24/3600)*2

igner | P act (MW/day) | Q Real | tur.no | P act for mod | Q act/one | Q De/one

Figure (3-4) designer flow rate for each module in excel

Designer Power Output :

By main equation for each module:

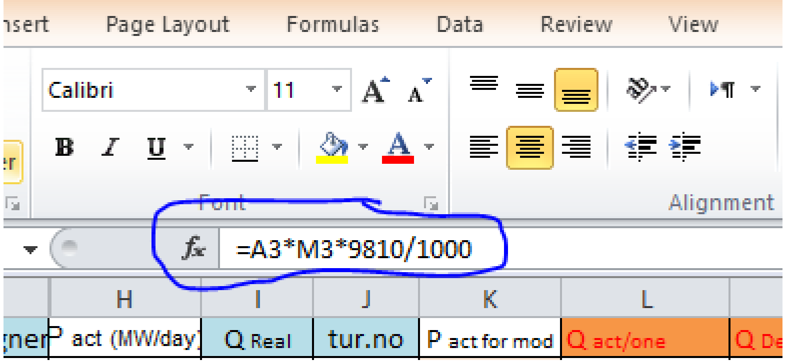
$$P_{De/mod} = \rho g\, Q_{De/mod} H_{De} \tag{3-6}$$

$P_{De/mod}$ = designer power output for each module (W)

$Q_{De/mod}$ = designer flow rate for each module (m^3/s)

H_{De} = designer head for each module (m)

In excel program:



=A3*M3*9810/1000

ner | P act (MW/day) | Q Real | tur.no | P act for mod | Q act/one | Q De

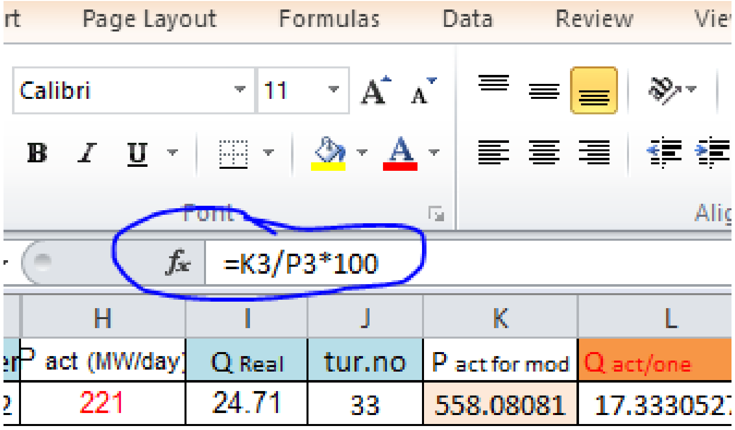
Figure (3-5) Designer power output in excel

Designer Efficiency ζ_{De}:

For one module the designer efficiency equal:

$$\zeta_{De} = (P_{act/mod} / P_{De/mod})\ x100 \qquad (3\text{-}7)$$

In excel program:



=K3/P3*100

H	I	J	K	L
P act (MW/day	Q Real	tur.no	P act for mod	Q act/one
221	24.71	33	558.08081	17.333052

Figure (3-6) Designer Efficiency in excel

3-3-2 Theoretical Status:

The Theoretical status is calculated according to the theoretical values of the dam parameters, which does not take any losses.

Theoretical Flow rate:

There is ratio between theoretical and designer states shown in Figure (3-7).

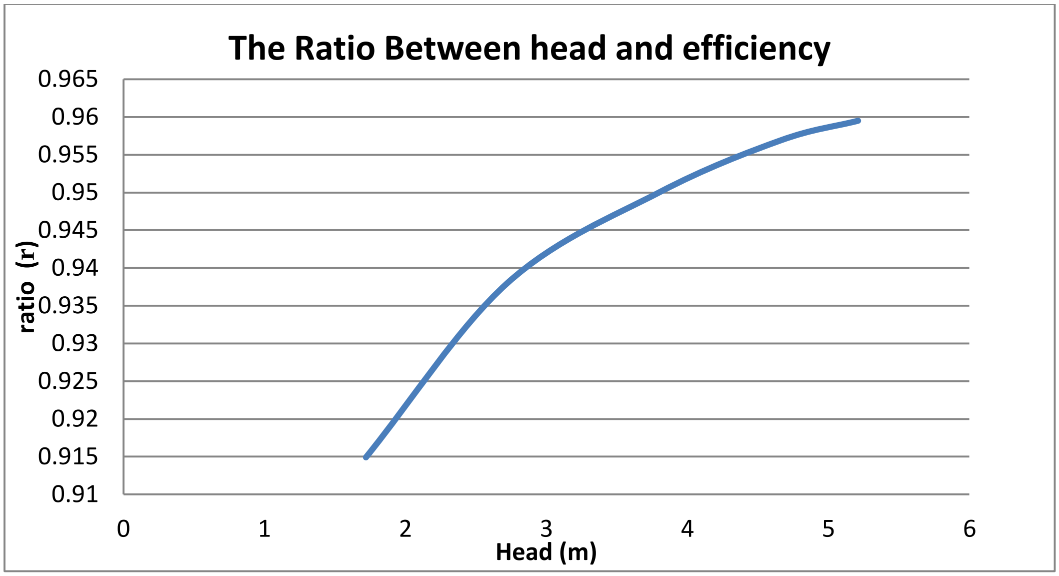
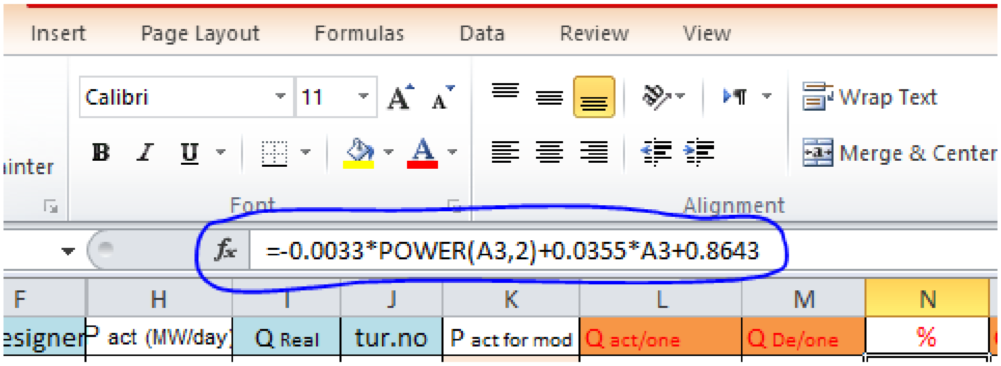


Figure (3-7) relation between theoretical and designer states

This relation can be written as equation against the head as a main factor like:

$$r = -0.003H^2+0.0355H+0.8643 \tag{3-8}$$

Show in excel program as a picture:



=-0.0033*POWER(A3,2)+0.0355*A3+0.8643

Figure (3-8) relation between theoretical and designer in excel

To calculate the theoretical flow rate for all turbines:

$$Q_{th} = Q_{De} / r \tag{3-9}$$

Q_{Th} = theoretical flow rate for all dam turbines (mcm/day).

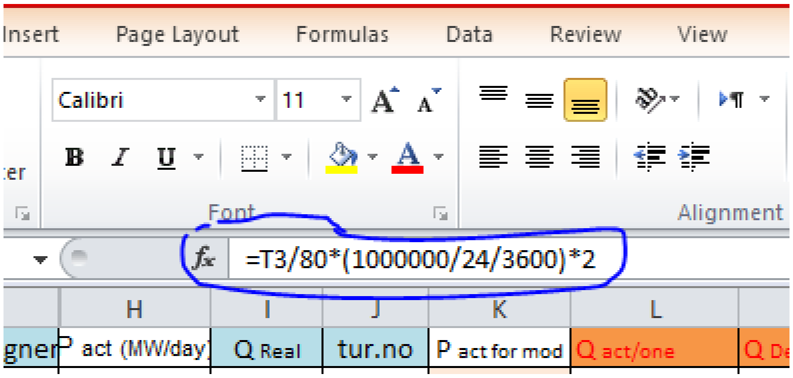
r = ratio between theoretical and designer states.

To calculated the theoretical flow rate for each module:

$$Q_{Th/mod} = (Q_{Th}*10^6*2)/\ (80*3600*24) \qquad (3\text{-}10)$$

$Q_{Th/mod}$ = theoretical flow rate for one module (m^3/s).

In excel program:



=T3/80*(1000000/24/3600)*2

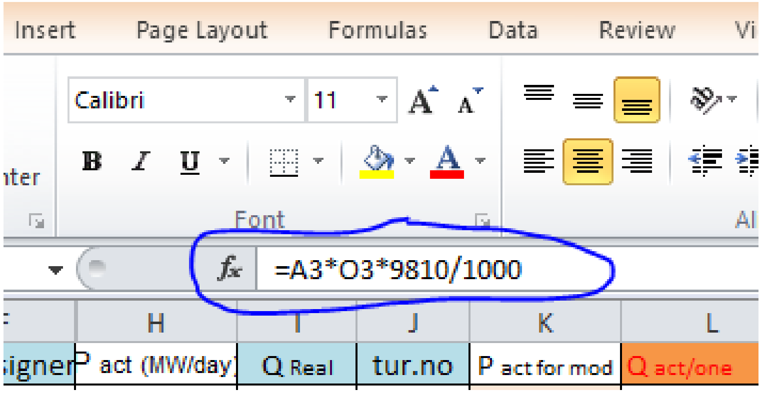
Figure (3-9) theoretical flow rate for each module in excel

Theoretical Power Output:

By using equation:

$$P_{Th/mod} = \rho g\ Q_{Th/mod} H_{De} \qquad (3\text{-}11)$$

In excel program:



=A3*O3*9810/1000

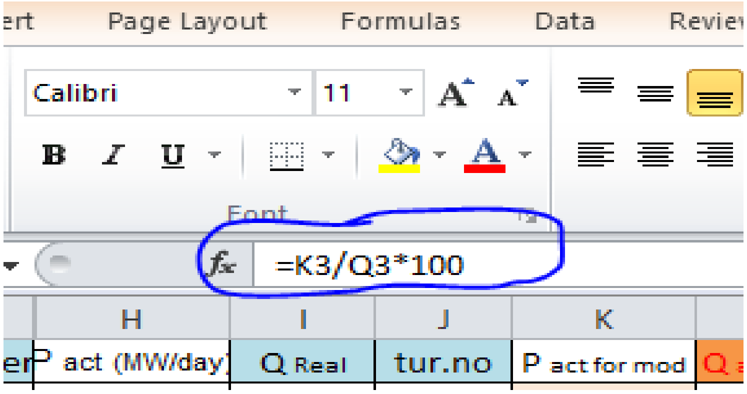
Figure (3-10) Theoretical power output in excel

Theoretical Efficiency ζTh:

For one module the Theoretical efficiency equal:

$$\zeta_{Th} = (P_{act/mod} / P_{Th/mod})\ x100 \qquad (3\text{-}12)$$

In excel program:



=K3/Q3*100

Figure (3-11) Theoretical Efficiency in excel

CHAPTER 4

RESULTS & DISCUSSIONS

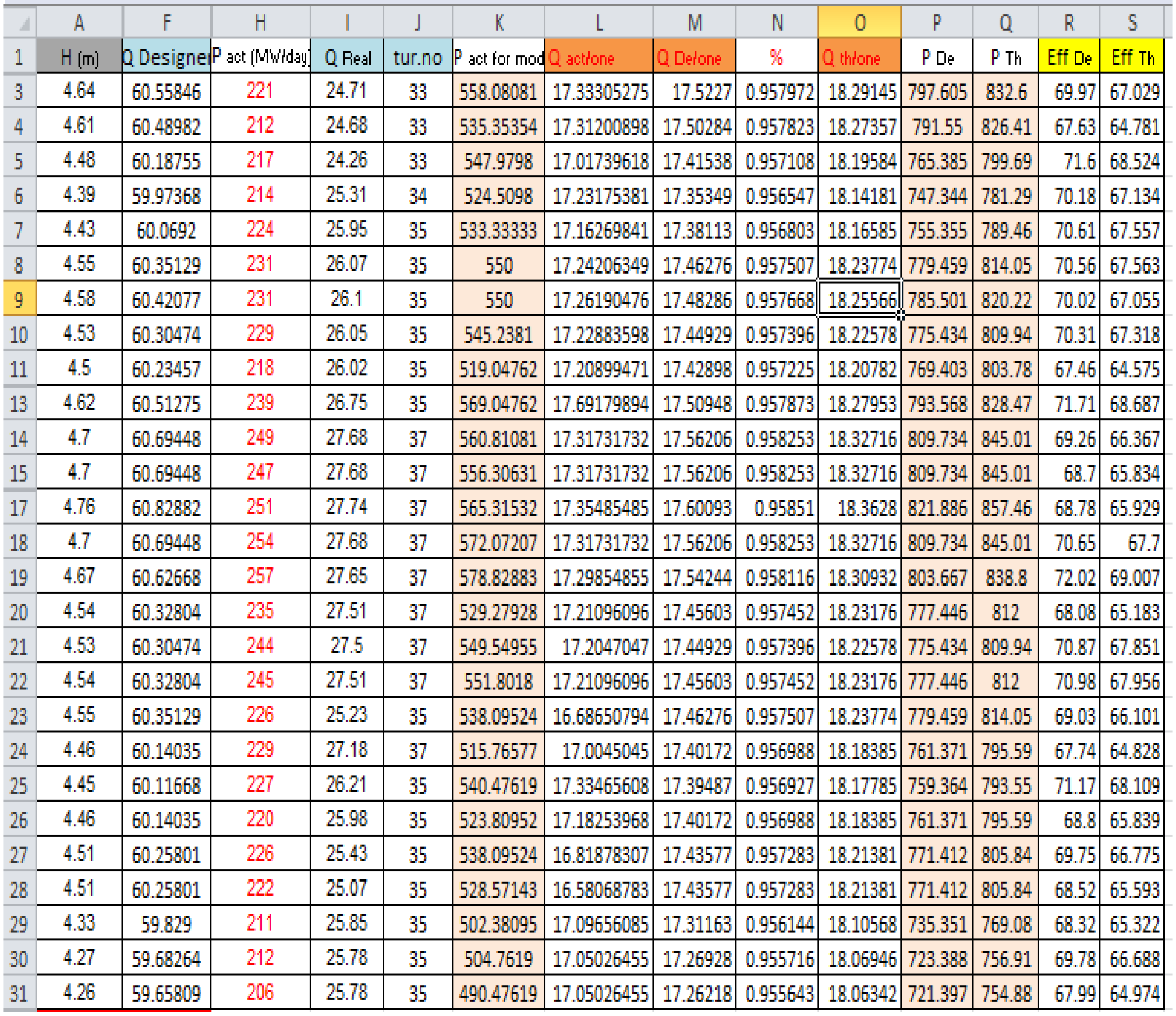
Results and Discussions

The main factor in power output and efficiency even the discharge in theoretical and designing status the head .There three curves shown the compare between actual and designing and theoretical status for each month.

4-1 January Results:

Table (4-1) show all data {head,discharge (actual, theoitcal and designing) ,power (actual ,theoretiacl and designing) ,efficiency (theoretical and designeing)} in january month

Table (4-1) January information



	A	F	H	I	J	K	L	M	N	O	P	Q	R	S
1	H (m)	Q Designe	P act (MW/day)	Q Real	tur.no	P act for mod	Q act/one	Q De/one	%	Q th/one	P De	P Th	Eff De	Eff Th
3	4.64	60.55846	221	24.71	33	558.08081	17.33305275	17.5227	0.957972	18.29145	797.605	832.6	69.97	67.029
4	4.61	60.48982	212	24.68	33	535.35354	17.31200898	17.50284	0.957823	18.27357	791.55	826.41	67.63	64.781
5	4.48	60.18755	217	24.26	33	547.9798	17.01739618	17.41538	0.957108	18.19584	765.385	799.69	71.6	68.524
6	4.39	59.97368	214	25.31	34	524.5098	17.23175381	17.35349	0.956547	18.14181	747.344	781.29	70.18	67.134
7	4.43	60.0692	224	25.95	35	533.33333	17.16269841	17.38113	0.956803	18.16585	755.355	789.46	70.61	67.557
8	4.55	60.35129	231	26.07	35	550	17.24206349	17.46276	0.957507	18.23774	779.459	814.05	70.56	67.563
9	4.58	60.42077	231	26.1	35	550	17.26190476	17.48286	0.957668	18.25566	785.501	820.22	70.02	67.055
10	4.53	60.30474	229	26.05	35	545.2381	17.22883598	17.44929	0.957396	18.22578	775.434	809.94	70.31	67.318
11	4.5	60.23457	218	26.02	35	519.04762	17.20899471	17.42898	0.957225	18.20782	769.403	803.78	67.46	64.575
13	4.62	60.51275	239	26.75	35	569.04762	17.69179894	17.50948	0.957873	18.27953	793.568	828.47	71.71	68.687
14	4.7	60.69448	249	27.68	37	560.81081	17.31731732	17.56206	0.958253	18.32716	809.734	845.01	69.26	66.367
15	4.7	60.69448	247	27.68	37	556.30631	17.31731732	17.56206	0.958253	18.32716	809.734	845.01	68.7	65.834
17	4.76	60.82882	251	27.74	37	565.31532	17.35485485	17.60093	0.95851	18.3628	821.886	857.46	68.78	65.929
18	4.7	60.69448	254	27.68	37	572.07207	17.31731732	17.56206	0.958253	18.32716	809.734	845.01	70.65	67.7
19	4.67	60.62668	257	27.65	37	578.82883	17.29854855	17.54244	0.958116	18.30932	803.667	838.8	72.02	69.007
20	4.54	60.32804	235	27.51	37	529.27928	17.21096096	17.45603	0.957452	18.23176	777.446	812	68.08	65.183
21	4.53	60.30474	244	27.5	37	549.54955	17.2047047	17.44929	0.957396	18.22578	775.434	809.94	70.87	67.851
22	4.54	60.32804	245	27.51	37	551.8018	17.21096096	17.45603	0.957452	18.23176	777.446	812	70.98	67.956
23	4.55	60.35129	226	25.23	35	538.09524	16.68650794	17.46276	0.957507	18.23774	779.459	814.05	69.03	66.101
24	4.46	60.14035	229	27.18	37	515.76577	17.0045045	17.40172	0.956988	18.18385	761.371	795.59	67.74	64.828
25	4.45	60.11668	227	26.21	35	540.47619	17.33465608	17.39487	0.956927	18.17785	759.364	793.55	71.17	68.109
26	4.46	60.14035	220	25.98	35	523.80952	17.18253968	17.40172	0.956988	18.18385	761.371	795.59	68.8	65.839
27	4.51	60.25801	226	25.43	35	538.09524	16.81878307	17.43577	0.957283	18.21381	771.412	805.84	69.75	66.775
28	4.51	60.25801	222	25.07	35	528.57143	16.58068783	17.43577	0.957283	18.21381	771.412	805.84	68.52	65.593
29	4.33	59.829	211	25.85	35	502.38095	17.09656085	17.31163	0.956144	18.10568	735.351	769.08	68.32	65.322
30	4.27	59.68264	212	25.78	35	504.7619	17.05026455	17.26928	0.955716	18.06946	723.388	756.91	69.78	66.688
31	4.26	59.65809	206	25.78	35	490.47619	17.05026455	17.26218	0.955643	18.06342	721.397	754.88	67.99	64.974

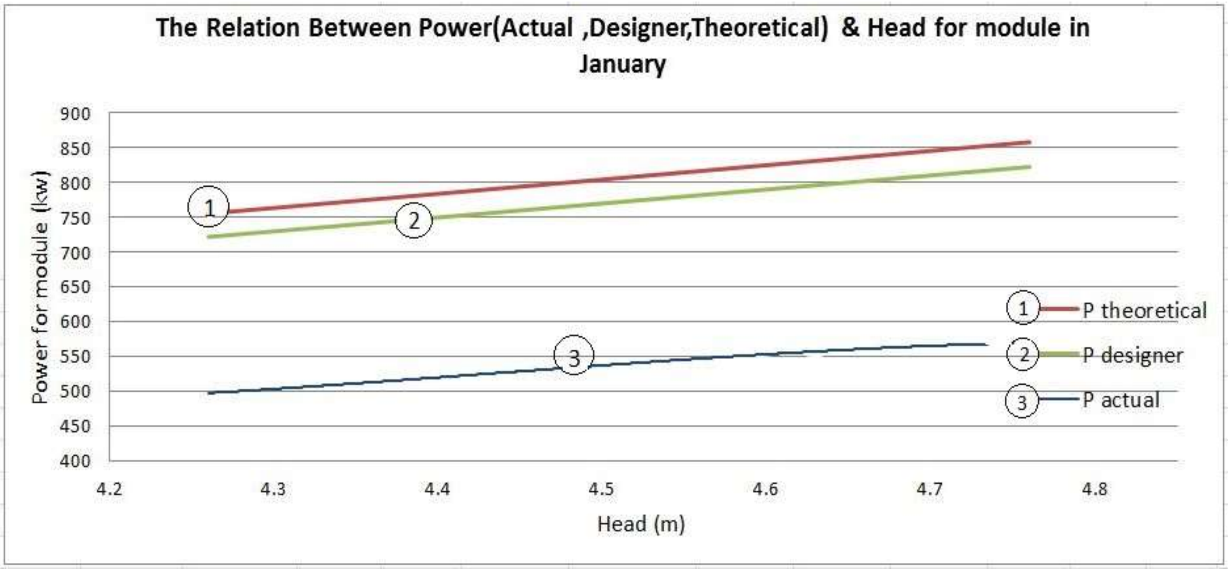


Figure (4-1) relation between powers vs. head in January

In figure (4-1) the high head values are clearly observed with stability in these values (change does not exceed 0.5m). Which due to an increase in theoretical and design power, which mainly depends on head.

The actual power in the highest level compared with the another months.

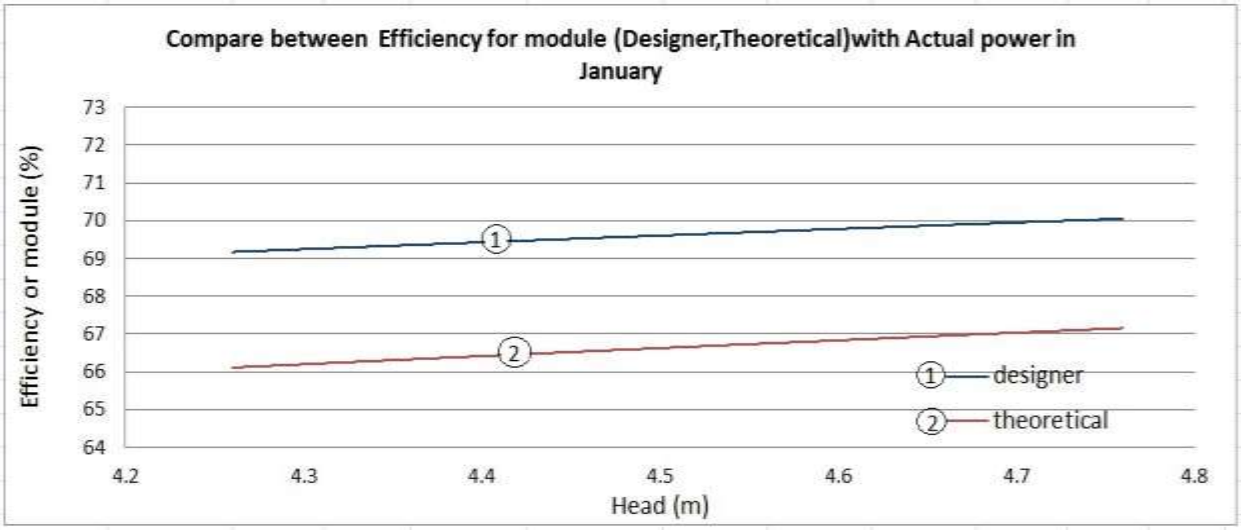


Figure (4-2) compare between efficiency for module and head in January

The theoretical and design efficiency in this month is high, and increasing with head but by little change. The difference between lowest and highest efficiency does not exceed 4%.

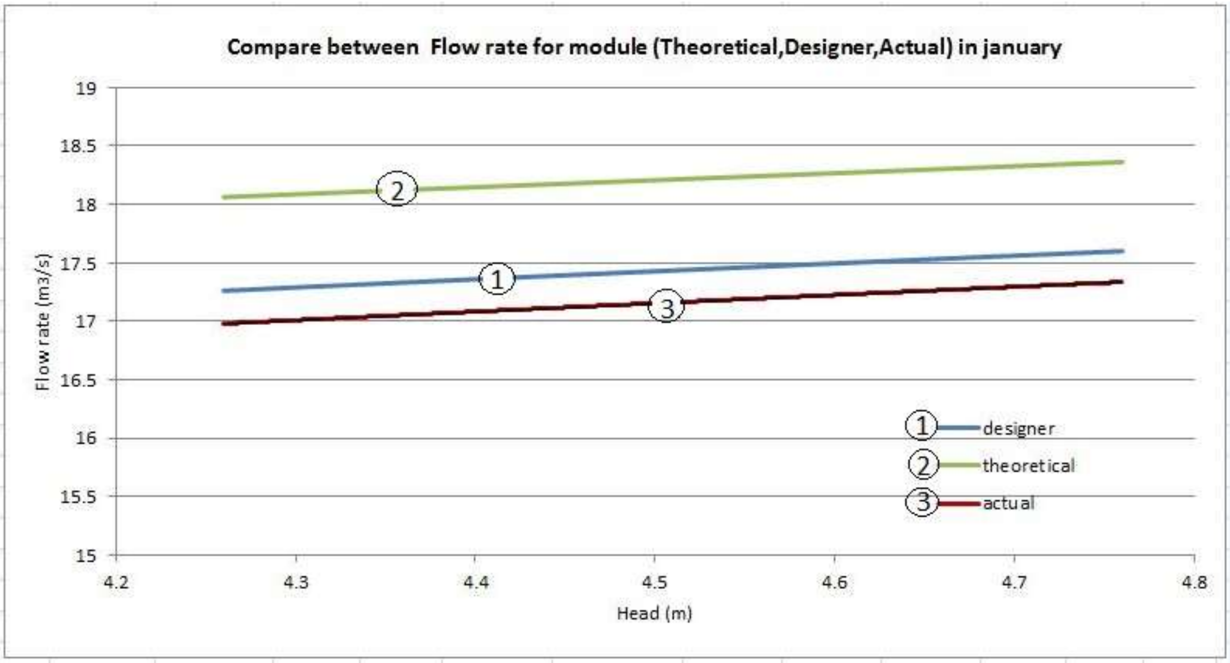
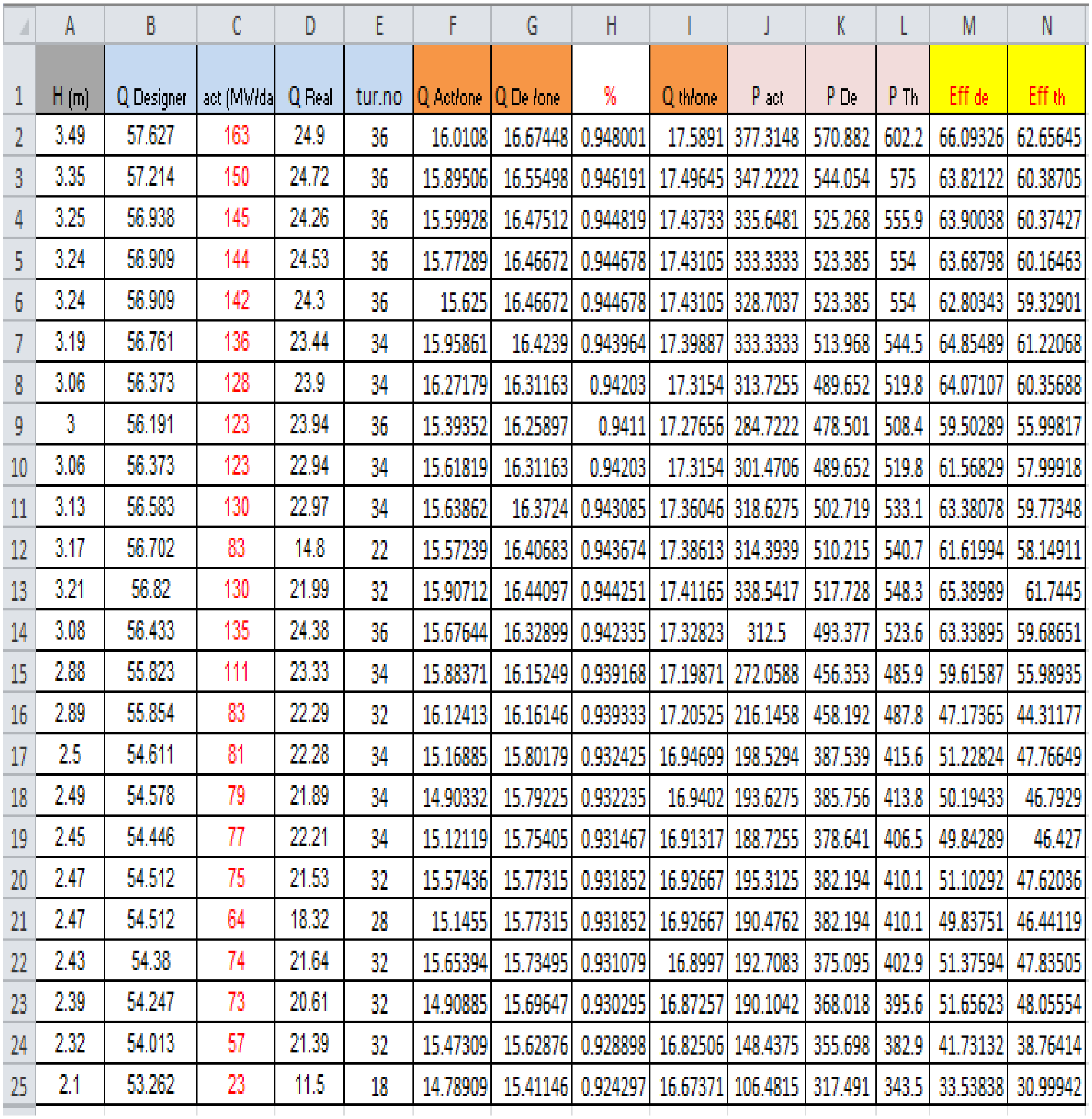


Figure (4-3) compare between flow rate for module and head in January

The increase in head does not significantly effect on water flow rate because the small change happened in head during this month.

4-2 April Results:

Table (4-2) April information



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	H (m)	Q Designer	act (MW/da	Q Real	tur.no	Q Act/one	Q De /one	%	Q th/one	P act	P De	P Th	Eff de	Eff th
2	3.49	57.627	163	24.9	36	16.0108	16.67448	0.948001	17.5891	377.3148	570.882	602.2	66.09326	62.65645
3	3.35	57.214	150	24.72	36	15.89506	16.55498	0.946191	17.49645	347.2222	544.054	575	63.82122	60.38705
4	3.25	56.938	145	24.26	36	15.59928	16.47512	0.944819	17.43733	335.6481	525.268	555.9	63.90038	60.37427
5	3.24	56.909	144	24.53	36	15.77289	16.46672	0.944678	17.43105	333.3333	523.385	554	63.68798	60.16463
6	3.24	56.909	142	24.3	36	15.625	16.46672	0.944678	17.43105	328.7037	523.385	554	62.80343	59.32901
7	3.19	56.761	136	23.44	34	15.95861	16.4239	0.943964	17.39887	333.3333	513.968	544.5	64.85489	61.22068
8	3.06	56.373	128	23.9	34	16.27179	16.31163	0.94203	17.3154	313.7255	489.652	519.8	64.07107	60.35688
9	3	56.191	123	23.94	36	15.39352	16.25897	0.9411	17.27656	284.7222	478.501	508.4	59.50289	55.99817
10	3.06	56.373	123	22.94	34	15.61819	16.31163	0.94203	17.3154	301.4706	489.652	519.8	61.56829	57.99918
11	3.13	56.583	130	22.97	34	15.63862	16.3724	0.943085	17.36046	318.6275	502.719	533.1	63.38078	59.77348
12	3.17	56.702	83	14.8	22	15.57239	16.40683	0.943674	17.38613	314.3939	510.215	540.7	61.61994	58.14911
13	3.21	56.82	130	21.99	32	15.90712	16.44097	0.944251	17.41165	338.5417	517.728	548.3	65.38989	61.7445
14	3.08	56.433	135	24.38	36	15.67644	16.32899	0.942335	17.32823	312.5	493.377	523.6	63.33895	59.68651
15	2.88	55.823	111	23.33	34	15.88371	16.15249	0.939168	17.19871	272.0588	456.353	485.9	59.61587	55.98935
16	2.89	55.854	83	22.29	32	16.12413	16.16146	0.939333	17.20525	216.1458	458.192	487.8	47.17365	44.31177
17	2.5	54.611	81	22.28	34	15.16885	15.80179	0.932425	16.94699	198.5294	387.539	415.6	51.22824	47.76649
18	2.49	54.578	79	21.89	34	14.90332	15.79225	0.932235	16.9402	193.6275	385.756	413.8	50.19433	46.7929
19	2.45	54.446	77	22.21	34	15.12119	15.75405	0.931467	16.91317	188.7255	378.641	406.5	49.84289	46.427
20	2.47	54.512	75	21.53	32	15.57436	15.77315	0.931852	16.92667	195.3125	382.194	410.1	51.10292	47.62036
21	2.47	54.512	64	18.32	28	15.1455	15.77315	0.931852	16.92667	190.4762	382.194	410.1	49.83751	46.44119
22	2.43	54.38	74	21.64	32	15.65394	15.73495	0.931079	16.8997	192.7083	375.095	402.9	51.37594	47.83505
23	2.39	54.247	73	20.61	32	14.90885	15.69647	0.930295	16.87257	190.1042	368.018	395.6	51.65623	48.05554
24	2.32	54.013	57	21.39	32	15.47309	15.62876	0.928898	16.82506	148.4375	355.698	382.9	41.73132	38.76414
25	2.1	53.262	23	11.5	18	14.78909	15.41146	0.924297	16.67371	106.4815	317.491	343.5	33.53838	30.99942

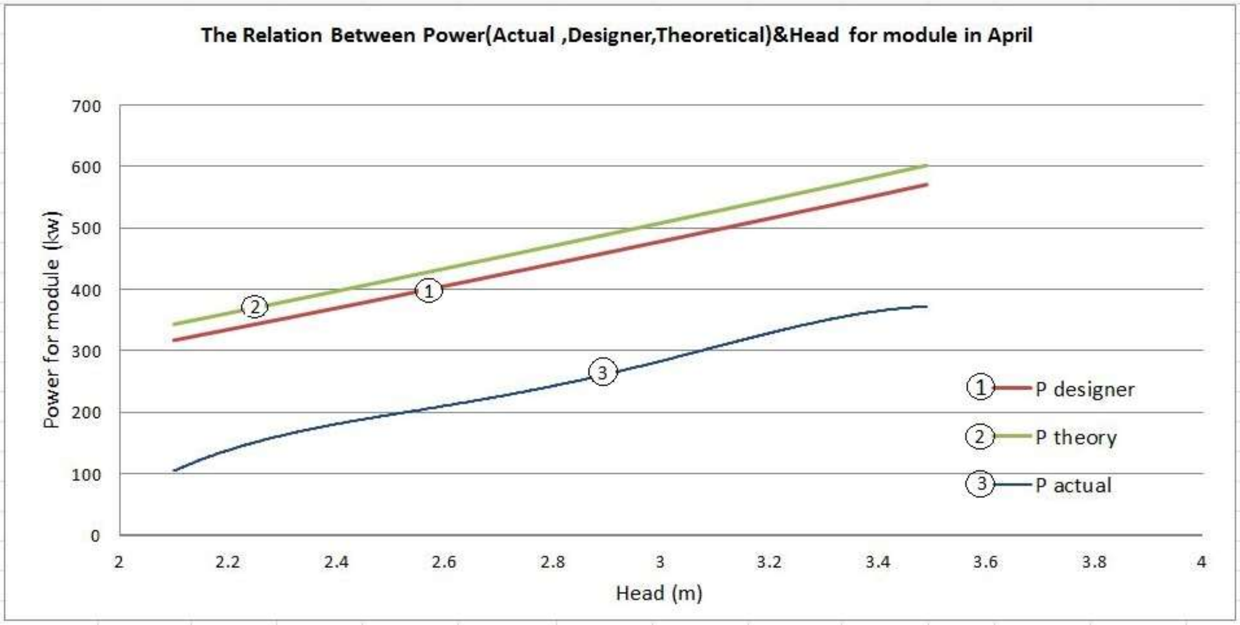


Figure (4-4) relation between powers vs. head in April

At April month the power produced is few, figure (4-4), theoretical and design power is changing drastically (300-600) kW, the head begins at 2.1m until exceed 3.5m.

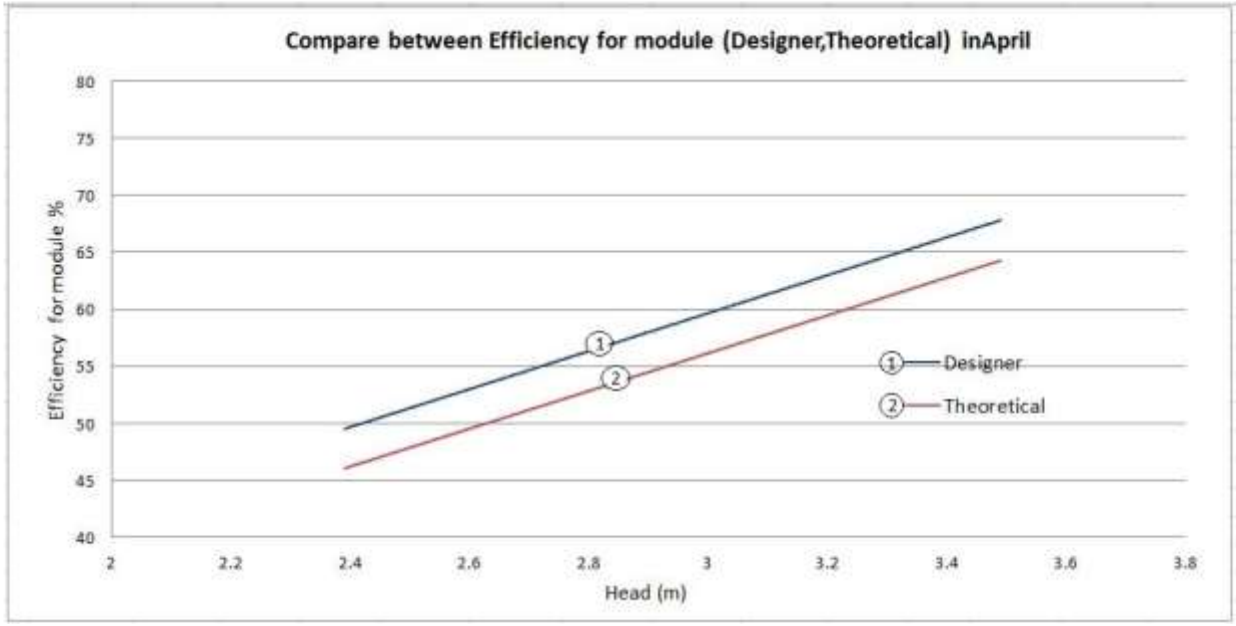


Figure (4-5) compare between efficiency for module and head in April

The lower in head values effect negatively in the efficiency theoretical and design, sometimes the efficiency lower than 50%.

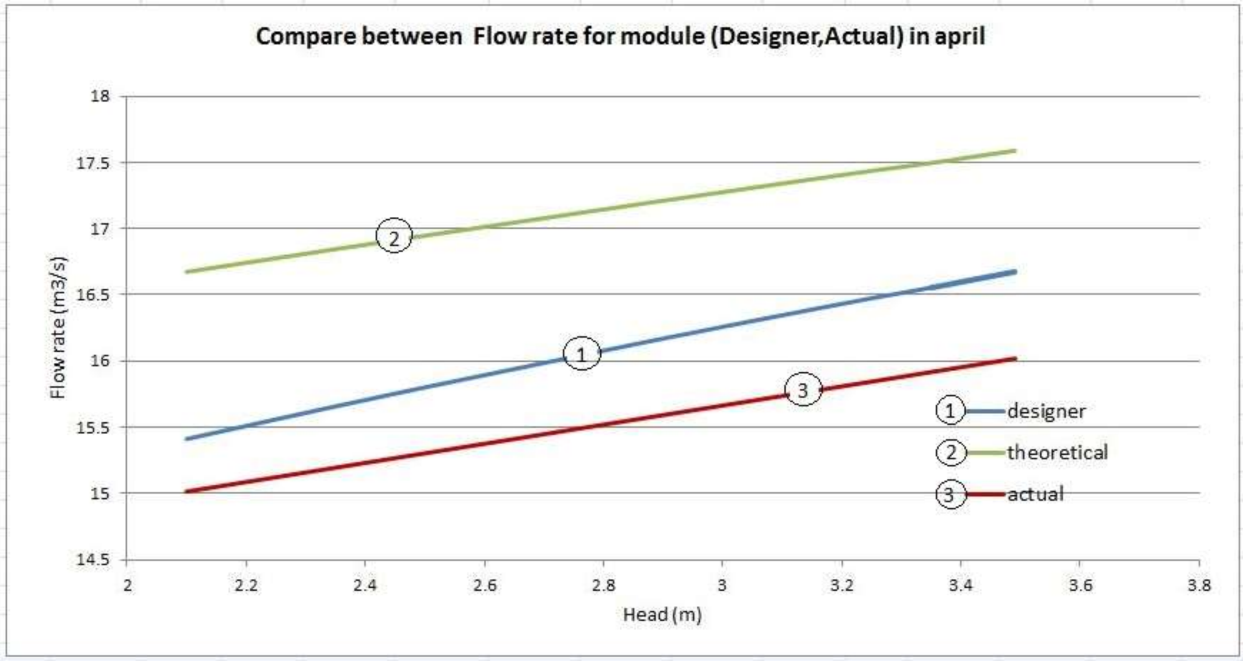
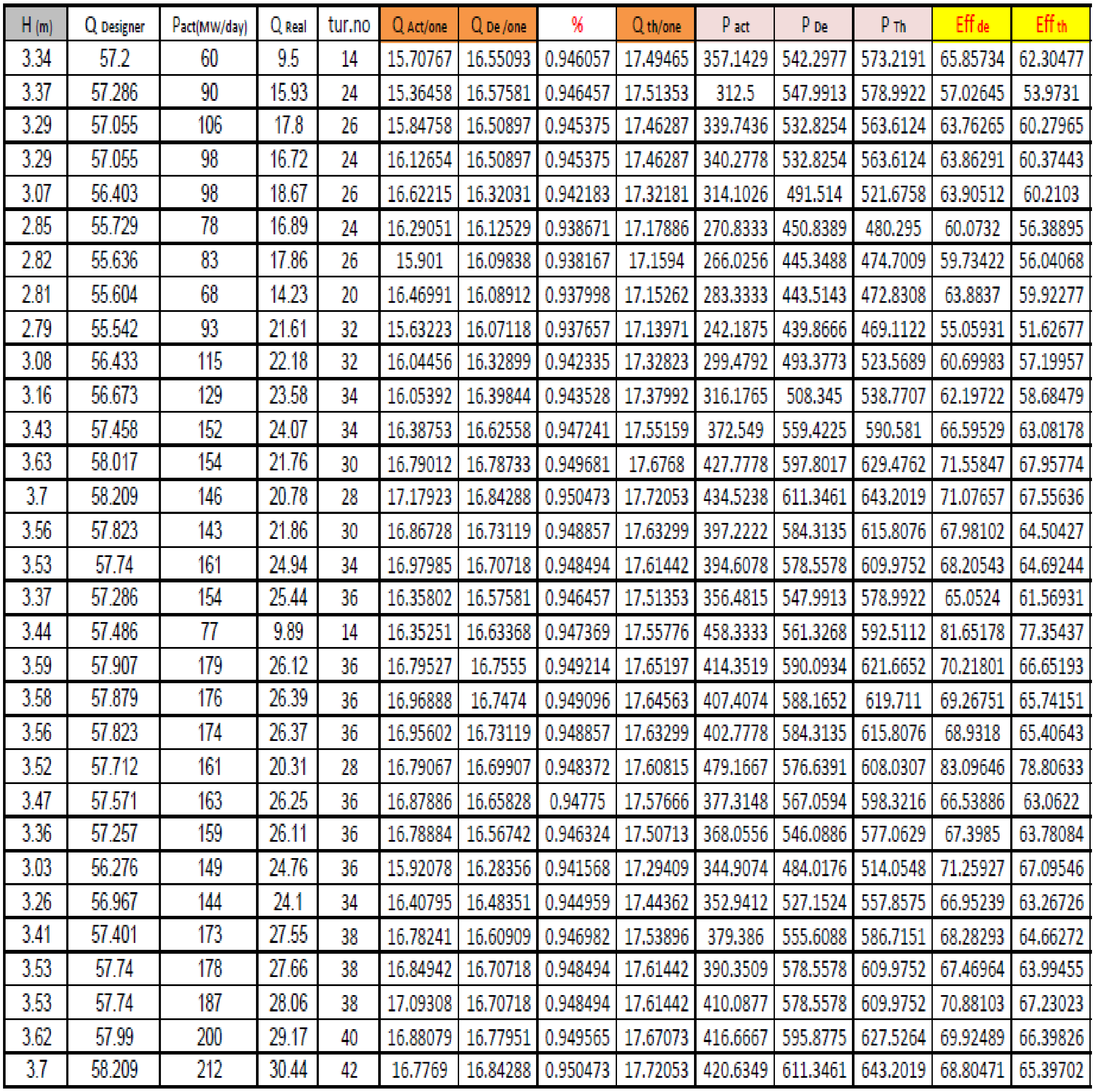


Figure (4-6) compare between flow rate for module and head in April

4-3 October Results:

Table (4-3) October information



H (m)	Q Designer	Pact(MW/day)	Q Real	tur.no	Q Act/one	Q De /one	%	Q th/one	P act	P De	P Th	Eff de	Eff th
3.34	57.2	60	9.5	14	15.70767	16.55093	0.946057	17.49465	357.1429	542.2977	573.2191	65.85734	62.30477
3.37	57.286	90	15.93	24	15.36458	16.57581	0.946457	17.51353	312.5	547.9913	578.9922	57.02645	53.9731
3.29	57.055	106	17.8	26	15.84758	16.50897	0.945375	17.46287	339.7436	532.8254	563.6124	63.76265	60.27965
3.29	57.055	98	16.72	24	16.12654	16.50897	0.945375	17.46287	340.2778	532.8254	563.6124	63.86291	60.37443
3.07	56.403	98	18.67	26	16.62215	16.32031	0.942183	17.32181	314.1026	491.514	521.6758	63.90512	60.2103
2.85	55.729	78	16.89	24	16.29051	16.12529	0.938671	17.17886	270.8333	450.8389	480.295	60.0732	56.38895
2.82	55.636	83	17.86	26	15.901	16.09838	0.938167	17.1594	266.0256	445.3488	474.7009	59.73422	56.04068
2.81	55.604	68	14.23	20	16.46991	16.08912	0.937998	17.15262	283.3333	443.5143	472.8308	63.8837	59.92277
2.79	55.542	93	21.61	32	15.63223	16.07118	0.937657	17.13971	242.1875	439.8666	469.1122	55.05931	51.62677
3.08	56.433	115	22.18	32	16.04456	16.32899	0.942335	17.32823	299.4792	493.3773	523.5689	60.69983	57.19957
3.16	56.673	129	23.58	34	16.05392	16.39844	0.943528	17.37992	316.1765	508.345	538.7707	62.19722	58.68479
3.43	57.458	152	24.07	34	16.38753	16.62558	0.947241	17.55159	372.549	559.4225	590.581	66.59529	63.08178
3.63	58.017	154	21.76	30	16.79012	16.78733	0.949681	17.6768	427.7778	597.8017	629.4762	71.55847	67.95774
3.7	58.209	146	20.78	28	17.17923	16.84288	0.950473	17.72053	434.5238	611.3461	643.2019	71.07657	67.55636
3.56	57.823	143	21.86	30	16.86728	16.73119	0.948857	17.63299	397.2222	584.3135	615.8076	67.98102	64.50427
3.53	57.74	161	24.94	34	16.97985	16.70718	0.948494	17.61442	394.6078	578.5578	609.9752	68.20543	64.69244
3.37	57.286	154	25.44	36	16.35802	16.57581	0.946457	17.51353	356.4815	547.9913	578.9922	65.0524	61.56931
3.44	57.486	77	9.89	14	16.35251	16.63368	0.947369	17.55776	458.3333	561.3268	592.5112	81.65178	77.35437
3.59	57.907	179	26.12	36	16.79527	16.7555	0.949214	17.65197	414.3519	590.0934	621.6652	70.21801	66.65193
3.58	57.879	176	26.39	36	16.96888	16.7474	0.949096	17.64563	407.4074	588.1652	619.711	69.26751	65.74151
3.56	57.823	174	26.37	36	16.95602	16.73119	0.948857	17.63299	402.7778	584.3135	615.8076	68.9318	65.40643
3.52	57.712	161	20.31	28	16.79067	16.69907	0.948372	17.60815	479.1667	576.6391	608.0307	83.09646	78.80633
3.47	57.571	163	26.25	36	16.87886	16.65828	0.94775	17.57666	377.3148	567.0594	598.3216	66.53886	63.0622
3.36	57.257	159	26.11	36	16.78884	16.56742	0.946324	17.50713	368.0556	546.0886	577.0629	67.3985	63.78084
3.03	56.276	149	24.76	36	15.92078	16.28356	0.941568	17.29409	344.9074	484.0176	514.0548	71.25927	67.09546
3.26	56.967	144	24.1	34	16.40795	16.48351	0.944959	17.44362	352.9412	527.1524	557.8575	66.95239	63.26726
3.41	57.401	173	27.55	38	16.78241	16.60909	0.946982	17.53896	379.386	555.6088	586.7151	68.28293	64.66272
3.53	57.74	178	27.66	38	16.84942	16.70718	0.948494	17.61442	390.3509	578.5578	609.9752	67.46964	63.99455
3.53	57.74	187	28.06	38	17.09308	16.70718	0.948494	17.61442	410.0877	578.5578	609.9752	70.88103	67.23023
3.62	57.99	200	29.17	40	16.88079	16.77951	0.949565	17.67073	416.6667	595.8775	627.5264	69.92489	66.39826
3.7	58.209	212	30.44	42	16.7769	16.84288	0.950473	17.72053	420.6349	611.3461	643.2019	68.80471	65.39702

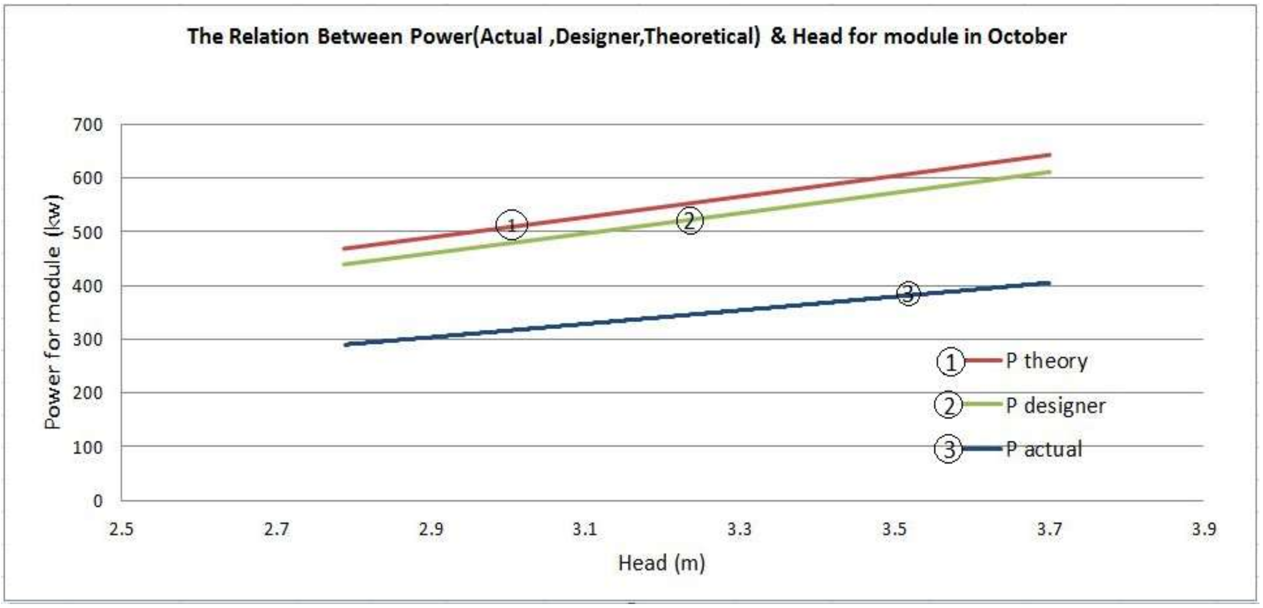


Figure (4-7) relation between powers vs. head in October

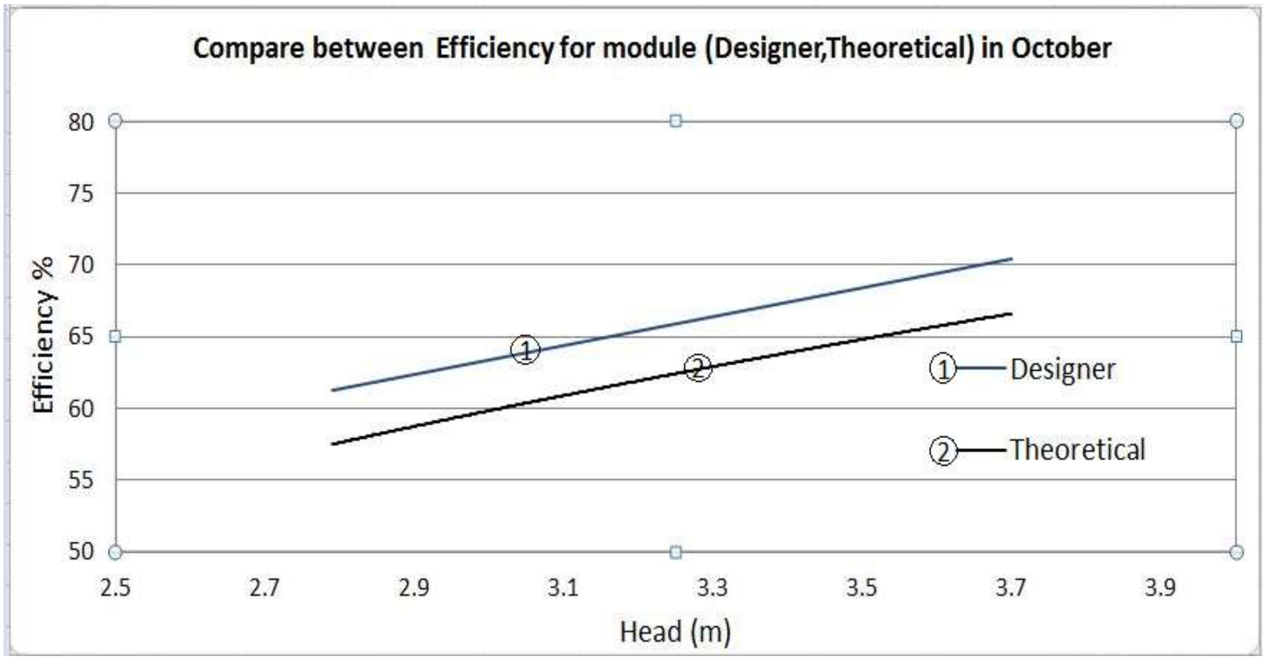


Figure (4-8) compare between efficiency for module and head in October

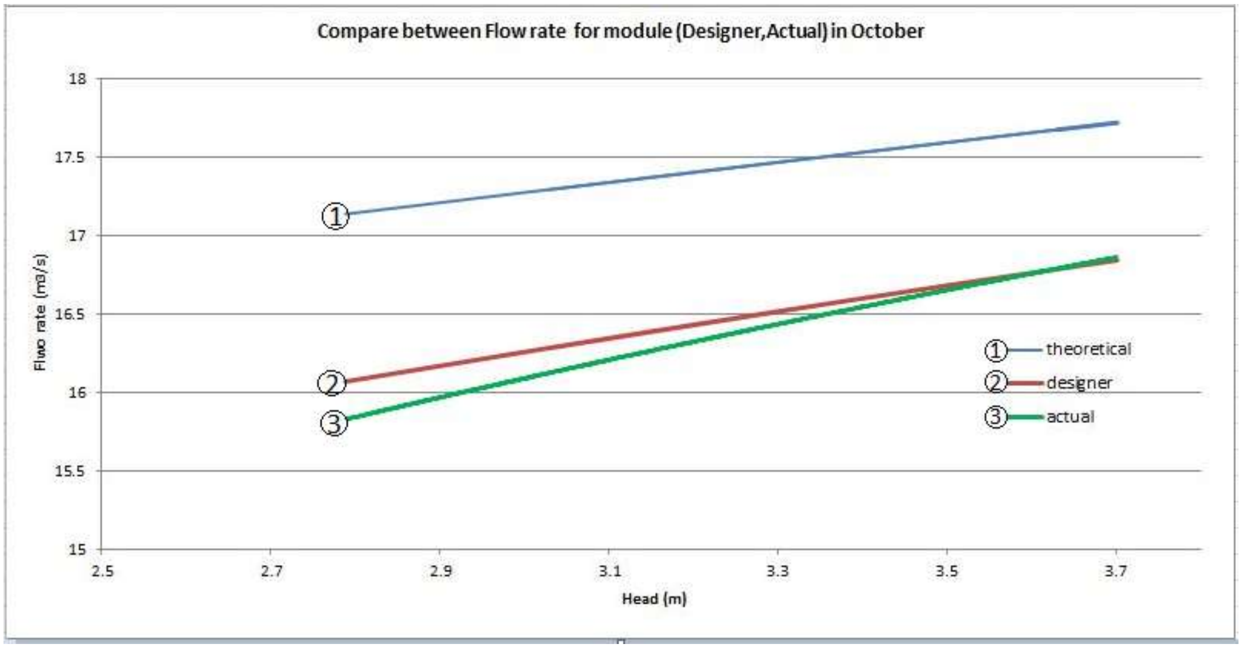


Figure (4-9) compare between flow rate for module and head in October

Head change between (2.7-3.7m), power produced in these month is small but stable does not exceed (400kw) for module. Figure (4-7).

Amount of water flowing helps to fill the resulting decrease of head, turbine efficiency about (63-70%) figure (4-8), The water level is increasing, but facing it from the other side of the dam (downstream). figure (4-9).

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

Conclusions & Recommendations

5-1 Conclusion:

In this study the theoretical and designing efficiencies are basically depends on the head but in actual state we found the flow rate affecting also. Changes in the seasons can be summed up in:

a-In winter, high rise in level of a head, where the ranges of head between (4.26-4.76m) as it is close to the extreme head (5.21 m) and also notes the stability of the water level with cool water and clean. The flow rate of water is high and stable also ranging from (24.2-27.7) mcm/day.

And the capacity is high in the day of (200-250) megawatts with high turbine efficiency and stable about (70%).

b-In summer, there is a very low level of water, sometimes near the minimum allowable state of the operation of turbines (1.72-2m) and increase to 3.5 m. The rate of water flow is relatively low up to (16 m^3/s). In this period there are a lot of operational problems so usually the periodic maintenance work in this period of the months of the year urges the graduation of the station from the service throughout the summer months. This is because of the low energy rate produced by the plant, Exceeding (200 MW/day) maximum. Turbine efficiency (50-65%).

c- In autumn, water level is increasing, but facing it from the other side of the dam (downstream), the water flow from the Blue Nile is very strong, which impairs the flow of the White Nile, until it reaches the critical stages in the operating conditions. Head (3.1-3.6m) with water filled with silt that obstructs the movement of feathers in the turbine.

The power produced in these months is small but stable does not exceed (200 MW/day).

(The amount of water flowing helps to fill the resulting decrease of head). .

Turbine efficiency about (63-70%).

5-2 Recommendations:

It was recommended that studies be directed to study in losses and examine ways to reduce them.

The downstream side is a very important aspect because it represents a net loss in the head.

Therefore, it is recommended that studies be directed at reducing the downstream level from the upstream side.

Appendix

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