Design and Establishment of a Small Hydroelectric Plant on the Barrage of Fallujah

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ABSTRACT.

The world is moving now to the energy of water to generate electric power and too much on several considerations, most important is that this energy is a clean and renewable energies as well as reasonably available. So we are going to create a small hydro power stations with limited power can be linked via the national grid or the completion of feeding limited areas to ease the load on the national network in addition to low cost of establishment and the costs of power processed. And now that we need t this specification at this stage and the availability of waterways and weirs in the governorate of AL-anbar has been building this research. We have in this search by selecting the barrage of Fallujah for the establishment of a hydroelectric plant it was a survey of geographical and engineering on the site of this barrage was recorded the water levels over the full year and found that the height of the water in which at least 3.5 meters, so the choice of equipment needed to build a hydroelectric plant with capacity of (140) KW aided with catalogues of well known international companies and accredited globally.

Keywords: Barrage of Fallujah, Small Hydroelectric Plant, 140 KW, Design, Site survey.

1. INTRODUCTION.

A hydropower is an important and vital renewable energy resource, which converts energy in flowing water into electricity. Hydroelectric power plants convert the potential energy in water pooled at a higher elevation into electricity by passing the water through a turbine and discharging it at a lower elevation. (The production of power through use of the gravitational force of falling or flowing water). The water moving downhill turns the turbine to generate electricity. The elevation difference between the upper and lower reservoirs is called the head. Worldwide, hydroelectricity supplied an estimated 715,000 MW in 2005. This was approximately 19% of the world's electricity (up from 16% in 2003), and accounted for over63% of electricity from renewable sources.[1][2]. Although large hydroelectric installations generate most of the world's hydroelectricity, some situations require small hydro plants. These are defined as plants producing up to 10 megawatts, or projects up to 30 megawatts. A small hydro plant may be connected to a distribution grid or may provide power only to an isolated community or a single home. Small hydro projects generally do not require the protracted economic, engineering and environmental studies associated with large projects, and often can be completed much more quickly. A small hydro development may be installed along with a project for flood control, irrigation or other purposes, providing extra revenue for project costs. In areas that formerly used waterwheels for milling and other purposes, often the site can be redeveloped for electric power production, possibly eliminating the new environmental impact of any demolition operation. Small hydro can be further divided into mini-hydro, units around 1 MW in size, and micro hydro with units as large as 100 kW down to a couple of kW rating. Small hydro units in the range 1 MW to about 30 MW are often available from multiple manufacturers using standardized "water to wire" packages; a single contractor can provide all the major mechanical and electrical equipment (turbine, generator, controls, switchgear),selecting from several standard designs to fit the site conditions. Micro hydro projects use a diverse range of equipment; in the smaller sizes industrial centrifugal pumps can be used as turbines, with comparatively low purchase cost compared to purpose-built turbines. Hydropower provides about 96 percent of the renewable energy in the United States. Other renewable resources include geothermal, wave power, tidal power, wind power, and solar power.[3][4].Small hydro schemes are particularly popular in China, which has over 50% of world small hydro capacity. Some jurisdictions do not consider large hydro projects to be a sustainable energy source, due to the human, economic and environmental impacts of dam construction and maintenance. A great advantage of hydro-electricity is that it is a renewable form of energy. The water is not used up but is returned to the rivers and the sea as part of the water cycle. It then evaporates and falls again as rain. [2][3].

2.REQUIREMENTS OF HYDROELECTRIC POWER STATIONS.

A sufficient quantity of falling water must be available the power available at any instant is the product of what is called head.

2.1. Determining of head.

Head is the vertical distance those waterfalls. It's usually measured in feet or meters. Most small hydropower sites are categorized as low or high head. The higher the head the better because you'll need less water to produce a given amount of power, and you can use smaller, less expensive equipment. Low head refers to a change in elevation of less than 10 feet (3 meters). A vertical drop of less than 2 feet (0.6 meters) will probably make a small scale hydroelectric system unfeasible.[5][6].

2.2. Determining of flow.

The quantity of water falling is called flow. It's measured in cubic feet per second or cubic meters per second. The flow potentially available for hydropower is that left after all other priorities are satisfied the daily flow rate should be recorded over12 months to determine the 'Flow Distribution Curve' and the 'mean annual flow' (m^3/s) for the proposed site[7].
Flow of water in m^3/sec is

$$Q = C \times A \times \sqrt{2gH} \qquad (1)$$

Q: water flow inm^3/sec, C: constant = 0.61, A: cross section area of penstock in m^2
H: head of water in meter, g: gravity = 10 m/sec^2.[7].

3. STEPS IN BUILDING A SMALL SCALE HYDROELECTRIC PLANT HEP.

3.1. Identify Sites with Potentially Good Water Resources.

A sufficient quantity of falling water must be available. Determine the amount of power that you can obtain from the flowing water on your site. The power available at any instant is the product of what is called flow volume and what is called head. The best sites have a reliable water supply year-round and large vertical drop in short distance. [5]
Theoretical power (P) = Flow rate (Q) x Head (H) x Gravity (g)
When Q is in cubic meters per second, H in meters and g = 10 m/s^2 then,[8]

$$P = 9.8 \times Q \times H \times \rho \quad (W) \qquad (2)$$

P: Power (W), Q: Water Flow (m^3/s), H: Net Head (m),ρ: density of water = 1000 Kg/m^3.

3.2. Environmental Impact.

Adequate screening has to be provided to stop fish entering the turbine however a well-designed hydro scheme will mitigate any environment damage caused during construction and over time will generate 'clean' energy for many years. [7]

3.3. Determine Proximity to Electricity Grid.

The electricity generated by this plant may be used at the point of generation, in place of electricity supplied by the national grid. Alternatively it may be exported via the national grid. Therefore it is financially advantageous to consume as much power as possible on site andonlyexport the surplus into the network.[5].

3.4. Cost.

It is considered that the location and site conditions determine a significant amount of the development cost. The final point is to calculate the cost per kWh produced by the hydro plant. In this order, an estimate cost of building the plant at the site, the annual cost of the plant and all other costs must be done. However is estimated that production of electricity from small-scale hydro would range from 0.07 – 0.15 cents per kWh [5].

4.The MAIN ELEMENTS OF HYDROELECTRIC PLANT.

4.1. Turbines.

There are two basic kinds of turbines: impulse and reaction. Impulse machines use a nozzle at the end of the pipeline that converts the water under pressure into a fast moving jet. This jet is then directed at the turbine wheel (also called the runner), which is designed to convert as much of the jet's kinetic energy as possible into shaft power. Common impulse turbines are pelton, turgo and cross-flow. In the family of impulse machines, the pelton is used for the lowest flows and highest heads. The cross-flow is used where flows are highest and heads are lowest. The turgo is used for intermediate conditions. A turgo requires at least four feet and a pelton needs at least ten feet. In reaction turbines the energy of the water is converted from pressure to velocity within the guide vanes and the turbine wheel itself. Some lawn sprinklers are reaction turbines. They spin themselves around as a reaction to the action of the water squirting from the nozzles in the arms of the rotor. Examples of reaction turbines are propeller and Francis turbines. Propeller turbines can operate on as little as two feet of head. [9].**Fig(1)** illustrate selection of turbine based on head and discharge.

4.2. Propeller-type turbines.

They are similar in principle to the propeller of a ship, but operating in reversed mode. Various configurations of propeller turbine exist; a key feature is that for good efficiency the water needsto be given some swirl before entering the turbine runner with good design, the swirl is absorbed by the runner and the water that emerges flows straight into the draft tube. Methods for adding inlet swirl include the use of a set of guide vanes mounted upstream of the runner with water spiraling into the runner through them. [10].**Fig(2)** illustrate Propeller turbines.

4.3. Penstock.

The Penstock is a tunnel that carries the water from the intake to the turbines. There are a number of factors to consider when deciding which material to use in the building of the penstock. They are surface roughness, design pressure, method of jointing, weight and ease of installation, accessibility of the site, terrain, soil type, design life and maintenance, weather conditions, availability, relative cost, and likelihood of structural damage. When considering soil type, you have to choose a material that will not be degraded or eroded by the surrounding soil. [11]. The penstock should be buried in the ground if it is possible to avoid damage in the pipe and prevent water being heated by the sun, which effects pressure. But because of steep terrain this may be impractical, lay the pipe on top of the ground and cover it with isolated shield like fiber glass. A valve should be installed just above the turbine to allow the water to be turned off when maintenance is required. [12].

4.4. Generators, Transformers, and Electricity Production.

Water flows through the turbine to turn it and its shaft to create mechanical energy that is transformed into electrical energy by the generators and transformers. Depending on the company purchased from, there are a number of different models of generators. Two main designs are the vertical or horizontal arrangements. The generator and transformer sit in what is known as the powerhouse. This is the main building of the hydropower plant. From the powerhouse there are four main wires that leave, they are three for the three phases of produced power and a ground wire common to the other three. These power lines are connected to the regional power grid. [11]

5. DESIGNING OF PROPOSED PLANT.

5.1. Site Engineering Survey.

It is the first technical task which is require before the starting of designing the plant. It is conduct an engineering survey and detailed design study. This task has basically finalized prior the designing and construction of the plant. The detailed of site engineering survey is shown in **figs. (3, 4, 5 and 6).**

5.2. Determining of Head.

In our site engineering survey we obtained the high elevation and low elevation over all months of 2009 but we take only four months (Sep., Oct., Nov. and Dec.) which the most shortage season in Iraq. The final site result of average head of water is 3.5 meter.

5.3. Power House.

To assess the suitability of a potential site, a site survey carried out, to determine actual flow and head data. The best location information can be obtained from the geographical survey of the site. So we selected the location of the proposed plant near the barrage at the right side of the river 100 m away from the barrage as shown in **fig. (7)**.

5.4. Selection of Turbine.

Turbines are more appropriate for electricity generation and are usually more efficient. There are many technical options were considered during the technical assessment. We choose the Propeller Turbine in our plant. It is one type of the reaction turbines which is convenient for the low head of about (3-10) meters like Fallujah barrage, the Propeller Turbine would produce better efficiency and provide lower generation cost compared to other turbines. An advantage of reaction machines is that they can use the full head available at a site and because of our stable

Head and flow we don't need to adjust the flow which is important in impulse types.

5.5. Penstock.

In our plant we choosed a PVC as a material of the penstock (to avoid eroded) with a diameter of one meter. A penstock is installed at the lower end of the gate provided with mesh filter at the intake to prevent debris and fishes as the water flows from reaching to turbine, laid it on top of the ground and covered it with fiber glass to prevent water being heated by the sun.

5.6. Determining of Flow.

From equation (1) we determined the flow as follow

$Q = 0.61 \times A \times \sqrt{2gH}$

$Q: flow\ in\ m^3/sec.,\quad A: crosscsection\ area\ of\ penstock = 0.5^2 \times \pi = 0.785m^2$

$g: gravity\ in = 9.81\ {}^{m}/_{sec.^2},\quad H: head = 3.5\ meter$

$Q = 0.61 \times 0.785 \times \sqrt{2 \times 3.5 \times 9.81} \approx 4\ m^3/sec$

5.7. Determining of Power.

From equation (2) we determined the power as follow

$P = 4 \times 3.5 \times 10 \times 1000 \approx 140\ KW$

5.8. Generator.

Electricity is generated when the turbine drives the generator. There are basically two kinds of generators that can be used for AC power: induction generator and synchronous generator. Regular Synchronous Generators which have specifications as in **Table (1)**are the optimum choice for our plant.

5.9. Governor.

This device ensures that the generator is not affected during load changes. It can be hydraulic, in which case the flow of water is regulated when the load changes; or electronic, in which case ballast or dump load is activated when the load changes. The type of governor used depends on the generator. In electronic control, the synchronous generator requires an Electronic Load Controller (ELC). When this equipment is not used, effectively the load on the machine cannot be changed, which means that all appliances must be kept on for the entire time and switched off only when the system is shut down. The other option is to manually control the flow so that the voltage and frequency are kept constant when the load is changed.

6. RESULTS.

a) From the site engineering survey
   Head of water (H) = 3.5 meter.
b) Flow of water Q = 4 m^3/sec.
c) The power P = 140 KW.
d) The type of turbine is (Propeller Turbine).
e) The material of penstock is (P.V.C), and the diameter is 1 meter.
f) The generator is (Synchronous Generator).

7. REFERENCES.

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Table(1): Specifications of Regular Synchronous Generator [13]

Synchronous Generator	
Frame Type	Drip Proof
Rotor Type	Revolving Field Type
Number of Poles	6 poles
Synchronous Speed	1000 min^{-1} 50Hz
Type of Rating	Continuous
Rated Voltage	220 Volt
Number of Phases	Three Phase
Frequency	50 Hz
Excitation System	Brush-Less Type

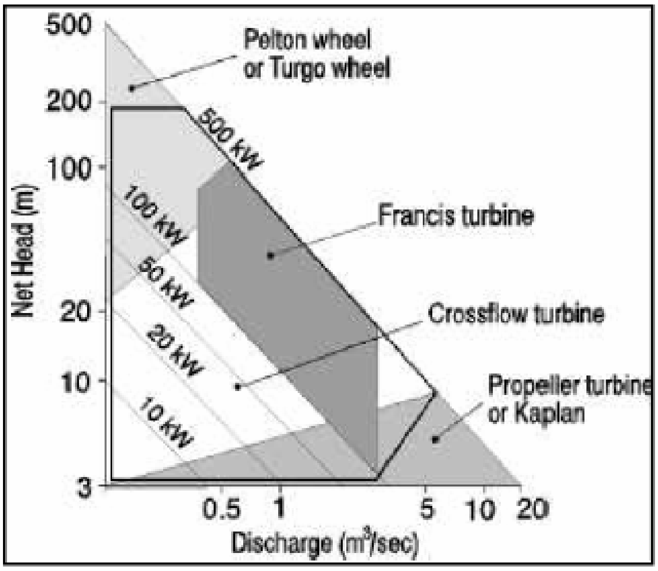
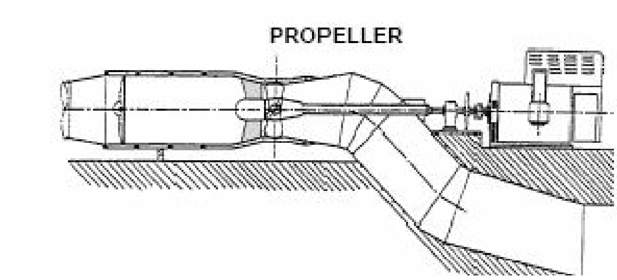


Figure (1): turbine selection based on head and discharge.[10]



Figure(2): propeller turbine[10]

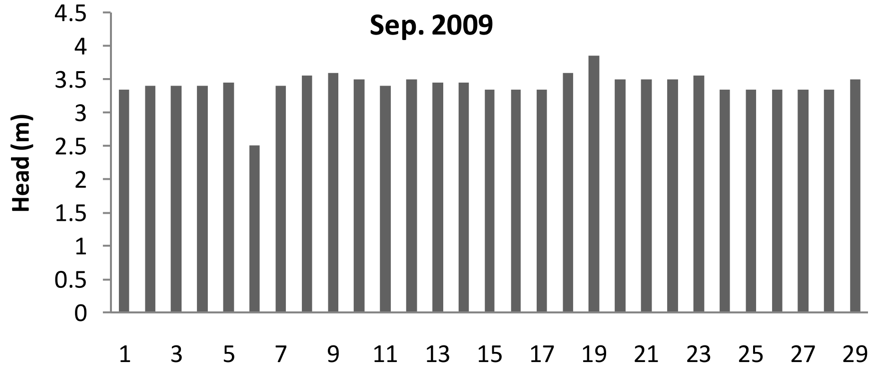


Figure (3): Head in September.

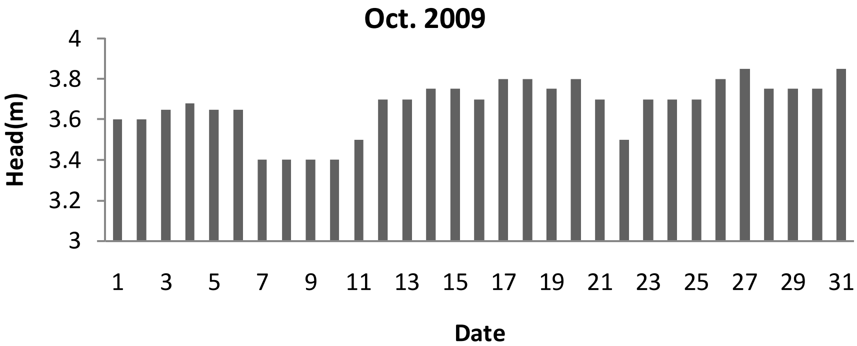


Figure (4): Head in October.

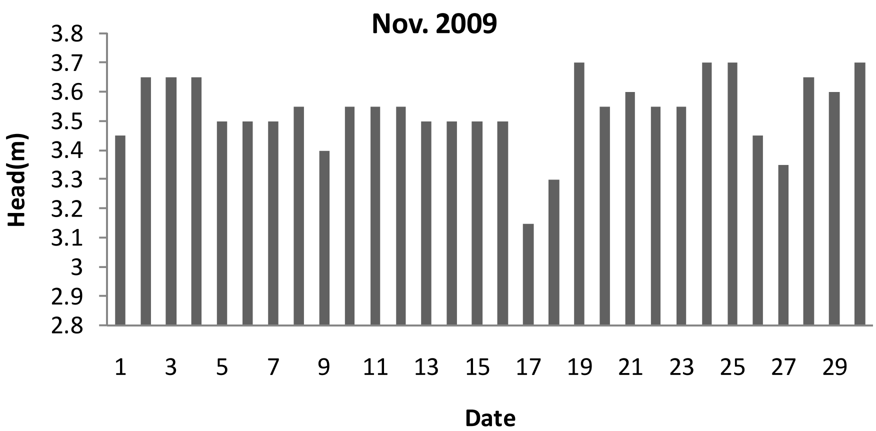


Figure (5): Head in November.

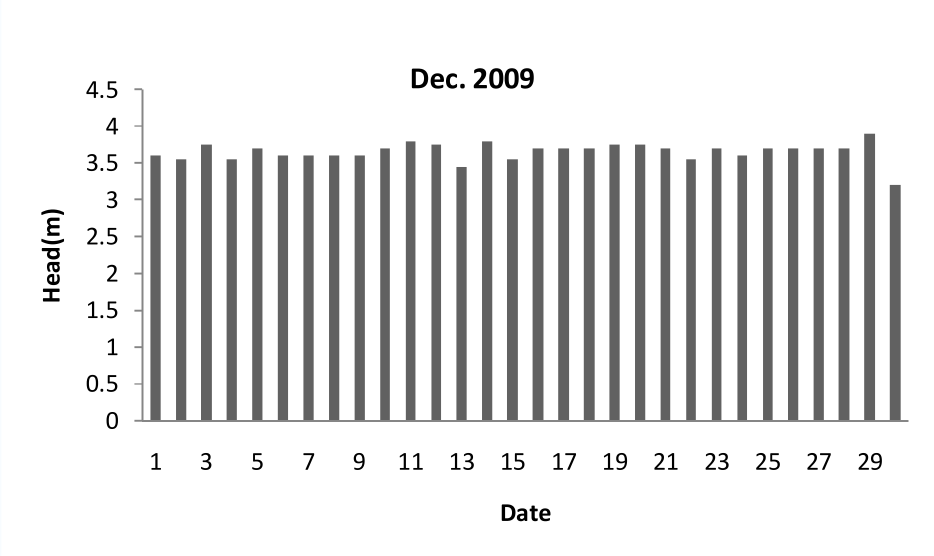


Figure (6): Head in December.

Figure (7): Satellite picture shows the proposed location to the power house.

تصميم وانشاء محطة كهرومائية صغيرة على سدة الفلوجة

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الخلاصة.

يتجه العالم ألان إلى الطاقة المائية لتوليد الطاقة الكهربائية وبشكل كبير جدا لأعتبارات عدة أهمها إن هذه الطاقة هي من الطاقات النظيفة والمتجددة إضافة إلى توفرها بشكل معقول. لذا تم التوجه إلى إنشاء محطات كهرومائية صغيرة ذات طاقة محدودة يمكن ربطها عبر الشبكة الوطنية أو تقوم بانجاز تغذية مناطق محدودة لتخفيف الحمل على الشبكة الوطنية إضافة إلى قلة تكاليف إنشائها وتكاليف القدرة المجهزة. وبما إننا ألان احوجما يكون إلى هذه المواصفات في هذه المرحلة ولتوفر المجاري المائية والسدات والنواظم في محافظة الانبار فقد تم بناء هذا البحث. قمنا في هذا البحث باختيار سدة الفلوجة لإقامة محطة كهرومائية عليها وتم إجراء المسح الجغرافي والهندسي على موقع السدة وتم تسجيل مناسيب هذه السدة على مدى سنة كاملة وتبين ان ارتفاع الماء فيها لايقل عن 3.5 متر لذا تم اختيار المعدات اللازمة لبناء محطة كهرومائية ذات طاقة مقدارها (140) كيلوواط مستعينين بكتلوكات لشركات عالمية معروفة ومعتمدة عالميا.

الكلمات الرئيسية: سدة الفلوجة، محطة كهرومائية صغيرة، 140 كيلوواط، تصميم، مسح موقعي.