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Design and Performance Evaluation of Pico Hydropower Generation

Mala Bukar, Abba Aji Suleiman
Department of Electrical and Electronics Engineering, Ramat Polytechnic Maiduguri, Borno State, Nigeria

Abstract: *The study carried out design and performance evaluation of Pico Hydropower generation. A Pico hydro power plant is a green energy that consumes small streams to generate electricity without depends on any source of non-renewable energy. To accomplish the design and evaluation of the system, water was harvested from rooftops during rainfall and channeled into a tank on a stand at the side of the story building the tank discharges water through a pipe to the nozzle which then narrows the flow of water to the Pelton turbine as the water jet from the nozzle hits the Pelton turbine, it produces power to the shaft connected to the electric generator which then produces electrical power. The Pico size hydropower system directly connected to a small variable speed an electric generator which is capable of supplying the power needed for minimal but very essential like phone charging, however, the position of water being storage tank is mainly at the uppermost in the building, storage water potential energy is connected into kinetic energy. The Pico scale power systems performance was investigated using excel spreadsheet where all the mathematical expressions were programmed and the efficiency was varied to obtain the efficiency. The operating efficiency was found to be within the range of 50% and 80% while the Pico hydro generator produces power between 300W and 1000W with the generator running at about 70 r.p.m by estimation.*

Key words: *Efficiency, Generation, Hydropower & Pico*

BACKGROUND OF THE STUDY

A Pico hydro power plant is a green energy that consumes small streams to generate electricity without depends on any source of non-renewable energy. It is used for hydroelectric power generation of under (5KW) these generators have proven to be useful in small, remote communities that require only a small amount of electricity and also fore front of these option because it is considered as the most cost-effective to provide electricity for rural areas, and to enable energy to be derived from extremely low head and how streams of IL/s respectively.

Pico hydro is a term used to distinguish very small scale hydropower with a maximum electrical output of five kilowatts (5 KW) it is good technique of providing electricity to the off-grid remote and isolated regions that suffer energy deficit. Typical Pico hydro generator is designed and supported by electrical converting system, battery and safety equipment so that it can be installed at the at the residential water pipeline. In Pico hydropower generation, the environment impact is negligible since large dams are not involved, and the schemes can be managed and maintained by the consumer

STATEMENT OF PROBLEM

1. Pico hydropower plant, these are biomass and traditional source of energy used mostly in rural areas and also renewable energy which develop in capital intensive and take time to develop (financial cost however, despite its high upfront costs it is sustainable and reliable. in line with grid connection, it can supply power to hundreds.
2. Financial constrain and time to develop the maintenance of pico hydropower plant.
3. Pico hydro power plant, the output is limited by local condition of height and amount of water available

MATERIAL AND METHOD

The water flowing area was figured out and the average power consumption of the place. the head and the flow rate of the water were also ascertained. Head was considered as the difference in elevation between the headwater surface of the storage tank above and the tail-water surface below the hydro-power plant. The flow rate of the water depends on the nozzle diameter, total length, number and type of fittings, the elevation head of the water tank and the difference in pressure head. Pelton wheel turbine was selected based on the available head and flow rate.

A Pico is the unit use of measurement in a metric system denoting of 10-12 Pico is a memories used to describe the four element of a good clinical fore ground such as P stand for population/patient, and problem, I stand for intervention, C stand for control/comparison, and O stand for output or outcome.

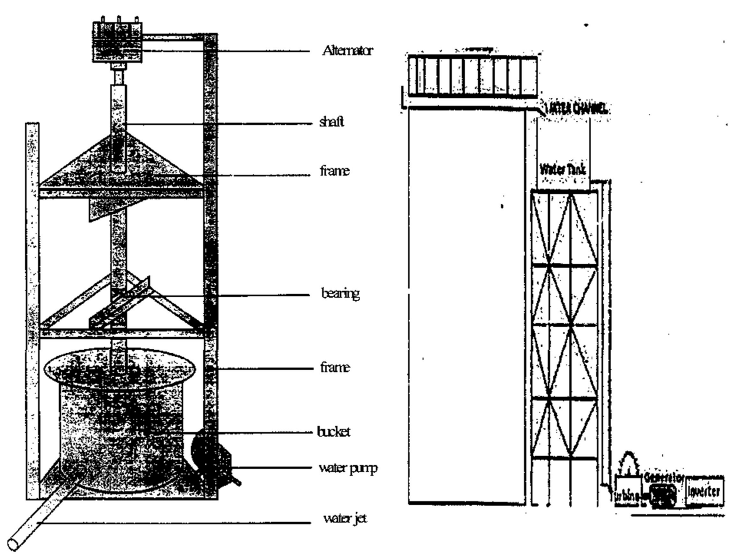


Figure 1: Schematic Diagram of Pico Hydropower System

THE MODEL PICO HYDROPOWER SYSTEM

Water was harvested from rooftops during rainfall and channeled into a tank on a stand at the side of the story building the tank discharges water through a pipe to the nozzle which then narrows the flow of water to the Pelton turbine as the water jet from the nozzle hits the Pelton turbine, it produces power to the shaft connected to the electric generator which then produces electrical power.

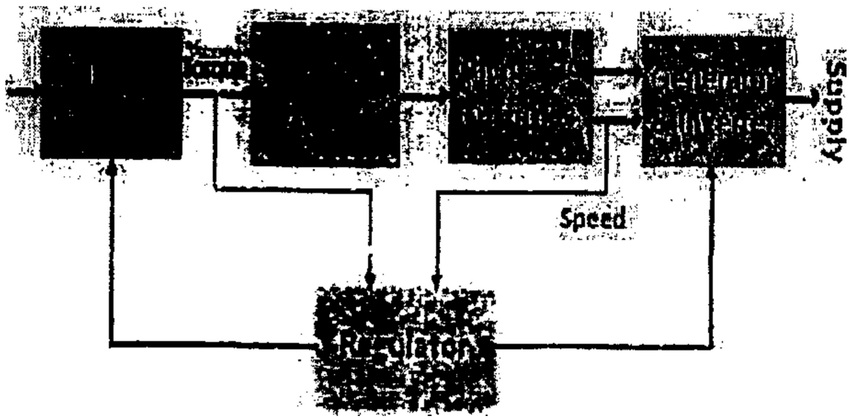


Figure 2: Block Diagram of Pico Hydropower System

SPECIFICATION OF THE MODEL PELTON WHEEL TURBINES COMPONENTS

The water falls from a head (H) at a flow rate (Q), the Pelton wheel run at a certain specific speed (Ns) to transfer torque (T) to the electric generator to produce power (P) the expected output produced by the system is power = 1000W. The distance from the base of the collecting tank to the jet nozzle was considered to be a head of 12m. Performance depends on hydraulic pressure and flow. The head is the energy per unit weight of water. The static head is proportional to the height difference of the falls. The dynamic height depends on the speed of the moving water. Each unit of water can do a lot of work, which corresponds to its weight multiplied by the head. The methodology used in this section is as adopted from earlier models of small hydro turbine power system

CALCULATION OF DIAMETER OF PELTON RUNNER

The power available from the waterfall energy was calculated from the flow and density of the water, the height of fall and the local acceleration due to gravity. In SI units, the performance in terms of Power expressed as:

Ptj = destiny x acceleration due to gravity x C^2 x H x Q

$$Q = \frac{1000}{(1000X10X0.982x10)} = 0.0104m2/s$$

Specific Speed, Ns of the turbine

$$\underline{N_2 = 25.49x\ n}$$

$$(1000\ x\ 10\ x\ 0.982\ x\ 10) = 0.0104m3/s$$

While; nj = number of turbine nozzle = 1

$$N_3 = 65.3$$

N = Speed of the turbine

$$= NsxH^s/_4/P_{ti}$$

$$= 65.3xl0^5/_4P_{ti}$$

$$= 36.72rpm$$

$$F(x) = N_3 + \sum(nf)$$

$$n=l$$

$$N_2 = 85.49xnj$$

$$H\ 0.234$$

Given Q = flow rate of the water from the head = 0.0104m3/s

Dr = diameter of pelton runner = 300mm =0.3m

And the diameter of jet Dj = 20mm = 0.02m

CALCULATION OF WATER JET VELOCITY THROUGH THE NOZZLE

The expression for water jet through the nozzle with a velocity Vj in m/s is given as:

$$V^1 = C_{x\ x}\ 2xgxH$$

$$= 13.86m/s$$

CALCULATING THE BUCKET DIMENSION

The expression for calculating bucket axial width is given as

$$B_w = 3.4xDj$$

$$= 0.068m$$

The expression for calculating bucket radial length is given as

$$B_1 = 3xD_j$$

$$= 0.06m$$

CALCULATING THE BUCKET DEPTH

The expression for bucket depth is given as:

$$B_d = 1.2\ xD_j = 0.024m$$

CALCULATING THE NUMBER OF BUCKET

The expression of number of bucket is given as:

$$N_b = \frac{Dr}{2D_j} + 15 \quad = 22.5$$

Here it is clear the use 22 buckets will make the Pico hydropower efficient for the proposed power generation of Ikw.

CALCULATING THE NOZZLE DIMENSIONS

The expression for water flow rate through the nozzle is given as:

The expression for nozzle area Aj is given as:

$$Qn = V_1 \text{ x } A_1$$

The expression of nozzle area Aj is given as

$$_{Aj} = n \text{ x } D2$$

$$1.257xl0^{-2}\ 2m^{-2}$$

$$Qn = 13.86xl.257xl0^{-2}$$

$$= 0.0174m^{3/s}$$

Given;

D_{pn} = diameter of penstock = 25mm diameter pipe.

D_j = diameter of water jet = 20mm = 0.02m

β= nozzle tapper at angle =15

The expression for calculating nozzle length, Ln is given as:

$$L_n = \frac{D_{pn} — D_1}{\text{Tan}\beta}$$

CALCULATING OF BUCKETS DISTANCE BETWEEN THE RADIUS CENTER OF MASS TO THE CENTER OF THE RUNNER

The radius of bucket centre of mass to the centre of runner is given as:

$$R_{hn} = 0.47xDi$$

$$= 0.141m$$

CALCULATION OF THE FORCE ON EACH BUCKET

F_d = pw x Qn x V^2

= 3342.53JV

The require force in each bucket is:

Fdy = Fs x Safety factor

= 3342.53x3.5

= 11698.87N

CALCULATING THE MAXIMUM TURBINE EFFICIENCY

The expression for calculating input power to the turbines:

$$Pti = \frac{pwxQ_1xV^2}{2}$$

= 998.89w

And the power output generated by the turbine as:

Pti = pw x Q_1, x V_{ty} x {(V_1 + V_{ty}) (1 + ¥ x xcos β3)}

Runner tangential velocity V_{ty} n ND_y /60

= 23.56m/s

RECALL, ¥ roughness coefficient of the bucket (0.98)

θ = Angle of Depletion between jet and bucket 180°- θ

θ = (160° to 170°)

θ =180°-160° = 20°

Pto = 1000 x 0.0104 x 6.3756 x (13.86 - 6.3756)(1 + 0.98 x cos 20°)

=457w

SHAFT

The overall efficiency ђ is assumed to be 70%, which is within the specification range.

Radial shaft velocity; $w = \frac{2\pi N}{60}$

= 157.08 rad/s

Power = torque radial shaft velocity

i.e P=T w

T = P/w

T= 1000/157.08 = 6.366N/m

The working shear stress, θ = N^{d3}

Where d = diameter of the shaft,

Allowable working shear stress, $\theta\ \frac{\text{Ultimate shear stress}}{\text{Factor of safety}}$

M_1 = (M_1 is the maximum allowable torque)

The specified ultimate shear stress for the mild steel shaft is 220mpa and the selected factor of safety is 15

$$\theta = \frac{200\ xl0^6}{15} = 14667.67 N/m^2$$

$$D = \frac{16N_s}{xd} \qquad = \frac{16x\ 15}{xx\ 14667.67}$$

D = 0.1733m

Shaft diameter, d = 173mm

Therefore, d = 200mm is used for design purposes

PARAMETER IN SUMMARY

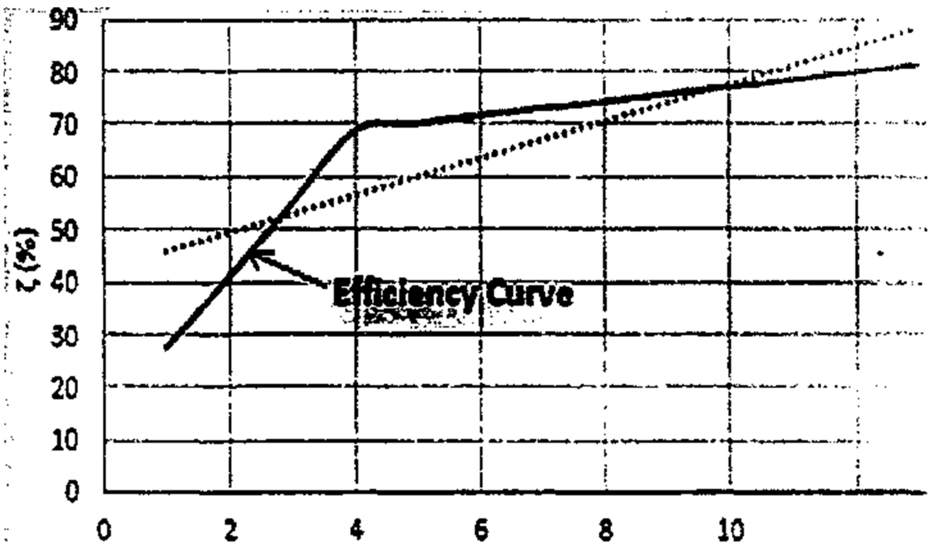
The summary of the calculated design parameters is as represented in table 1 below.

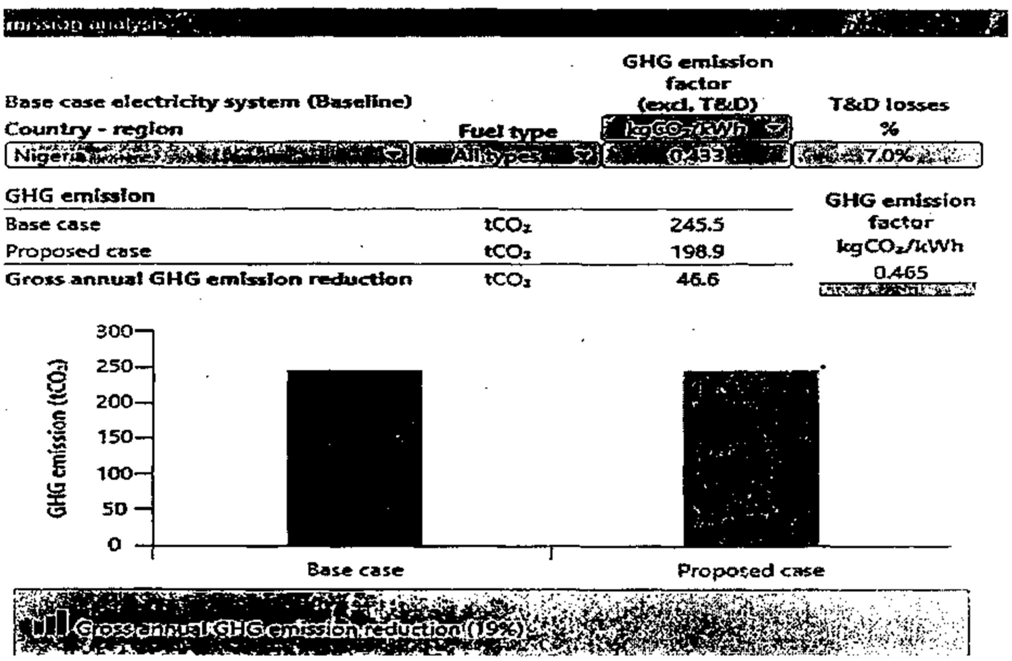
Table 1 parameters of the model Pelton wheel turbine as obtained from design calculation

Se/N	Parameters	calculated
1	Flow rate, Q	0.01403 m3/s
2	The velocity of the water jet through the nozzle	13.86m/s
3	The diameter of Pelton runner, Dr	0.3m
4	Bucket axial width	0.68m
5	Bucket radial length	0.06m
6	Bucket depth	0.024m
7	Number of bucket	22
8	The radius: centre of the bucket to the centre of the runner	0.141m
9	Runner tangential velocity	23.566m/s
10	Force on each bucket	11698.87N
11	Bucket roughness coefficient,	0.98
12 -N	Deflection angle between bucket and jet,	160 to 170
13	The torque produced by the shaft	6.366N/m

PERFORMANCE ANALYSIS

The Pico scale power systems performance was investigated using excel spreadsheet where all the mathematical expressions were programmed and the efficiency was varied to obtain the efficiency curve of the designed Pelton wheel assuming linearity and neglecting external forces that may be exerted on the system during operation. The operating efficiency was found to be within the range of 50% and 80% while the Pico hydro generator produce s power between 300W and 1000W with the generator running at about 70 r.p.m by estimation.





Estimate reduction in green emission for the design system

CHAPTER FIVE

CONCLUSION

A research work has been carried out on the construction of Pico hydropower generation plant the study has been successfully achieved. A Pico hydropower is a source that utilities the mechanical energy of water strolling down from an elevated head an electric generator thus producing electricity, small hydropower turbines are rotated by a relatively low pressure head and usually generate low energy outputs therefore by design the run water from the building rooflines are collected and passed through down point into an elevated tank and then the height of the bottom of the tank gives the required head to spin the micro fund and then to generate a Pico level energy. The Pico size hydropower system directly connected to a small variable speed an electric generator which is capable of supplying the power needed for minimal but very essential like handset charging, however, the position of water being storage tank is mainly at the uppermost in the building, storage water potential energy is connected into kinetic energy.

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