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Free Hydropower Generation System Controlled by IoT

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Abstract - *The paper gives total information of hydropower plant, which is operated by using a hydraulic ram pump and also it a better solution for remote areas where their transmission is not yet reached. The ram pump is used to increase the head of falling water by lifting the water from low head to high head. The ram pump makes the process of power generation continuous and works a long time with less maintenance. As this system doesn't require an external source of energy it makes some free energy available for existing hydropower plants. The hydraulic ram pump works with falling water and a water hammer effect. This hydropower plant system can be used in remote areas which require less power requirement and components can be easily manufactured as like ram pump. Though the installation cost is high, the running cost is low. The paper also shows the design and performance of the hydraulic ram pump Proposed hydropower plant does not consume any fuels hence it is eccofriendly and pollution free. Moreover, an IoT-based system that can easily monitor any unwanted Problems occurring while operation the total system is controlled by electronic iot based controllers.*

Keywords:- Hydropower, Ram Pump, Hydroelectric Power Plant, Iot.

1. INTRODUCTION

We are living in a world where sustainable energy sources and renewable energy sources are required for economic development, for human welfare, and the environmental balance of our society. [1,2] Hydropower is the best renewable source of energy among all other renewable sources of energy and it is an economical, nonpolluting, and eco-friendly electro power generating system. By taking the advantage of falling water due to gravity electricity is being produced. Hydropower generates the energy of around 24% of the world's total energy. Hydro-electric power is more consistent than the solar power generation system as it produces electric power in day & night time also unlike solar power which can produce only in the day time.[3] The electric power developed by small water-falls, tributaries, and rivers in micro-hydro power generation systems are capable of producing an output power up to 5-6 KW, enough to supply a rural community village which has small electricity consumption. This system does not consume any fossil fuels hence, the hydropower generation system does not contribute to the depletion of fossil fuels also in pollution[2]. The hydropower plant works on the principle in which the potential energy of water in the reservoir is converted into kinetic energy which is further converted into electrical energy with the help turbine, generator, etc. some of the major component HPP are Dam or reservoir, penstock, turbine, generator , prime mover. [1] as shown in figure1

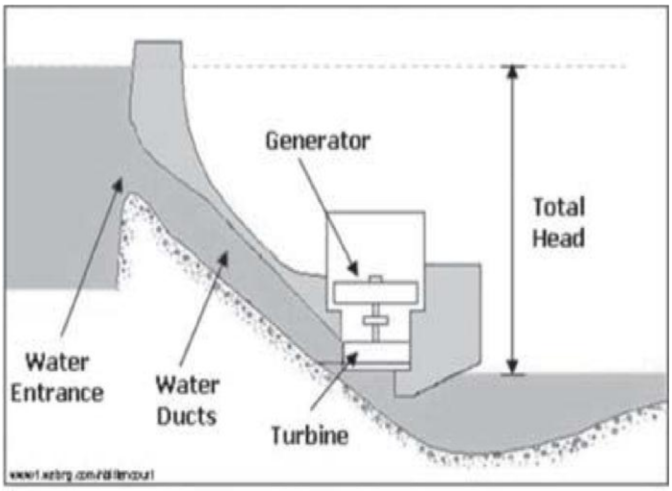

Fig-1: representation of a hydroelectric power plant[11]

Some micro-hydroelectric power generation plants are reversible, in that water is used again for power generation, pumped from the lower reservoir to the upper reservoir by using electricity when demand is low[1]. Whenever a demand is high reversible pumped hydro storage consumes external energy so the efficiency of hydropower plants decreases as the input energy is increasing[9]. To overcome this problem, we have to go for alternative energy resources in which energy is generated naturally like solar energy, wind energy, etc. The hydraulic ram pump is working on the kinetic energy of falling water and can be used as a small hydropower plant to pump the water at the desired elevation[10]. Ram pump has only two moving parts waste valve and delivery valve, pressure chamber, delivery, and supply pipe as shown in Figure 2 This pump uses the water hammer effect so that enough pressure created to lift some amount of input water to a desirable height which is higher the source of water. this pump has an attraction that it doesn't consume any external energy and work continuously if there is a continuous flow of water.[5]

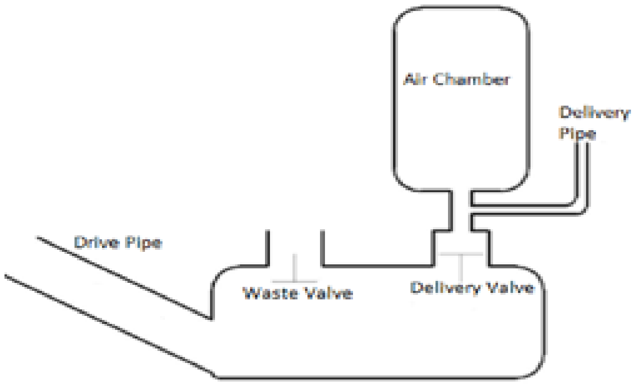

Fig-2: representation of a ram pump[11]

2. COMPONENTS USED IN FREE HYDROPOWER GENERATION SYSTEM AND WORKING

2.1 Construction and Working

2.1.1 Material for Construction of Ram Pump

The material that we can use is Unplasticized PVC because of its properties like noncorrosive, longlasting(50 years). Pipes are strong and light having specific gravity one-fifth of cast iron. Only care should be taken for the joints in transit condition as the soundness of material depends on its joint areas.[5] Table 1 shows the various parts which are involved in the construction of a hydraulic ram pump.

2.1.2 Working

a) Working of Ram Pump

Head allowed to flow through the drive pipe and then inlet of the hydraulic ram pump. When the velocity reaches the high value the waste valve or check valve closes. The inertia of water causes the flow in a forward direction towards the check valve and it opens the check valve. The force applied by the water cause compression of air in the pressure chamber and due to this air, the water is elevated by the delivery pipe for the desired use. The backflow of water is restricted by the check valve. At same time, pressure in drive pipe suddenly reduces to low due to this waste valve opens and water flow from source to ram pump beginning a new cycle. Average of 100-120 cycles per minute can be occur. Depending upon conditions such as head, flow, and the size of the ram. [4] The system is shown in figure2.

2.3Working of Proposed System

Initially, Hydropower is generated by using the rainwater stored in the reservoir. The water in the reservoir is having the potential energy, when waterfall on the turbine due to the hydraulic action the kinetic energy cause the turbine to rotate, and this rotary motion is used to generate the electricity by using the generator. Hydroelectric power can be produced with the help of a generator by connecting the turbine shaft to the generator. The generator produces electricity using electromagnetic induction[4]. The water after generation of power is stored in a storage tank given to the hydraulic ram pump which lifts some amount of water at the hydraulic head of the dam or reservoir. [9] As shown in fig3

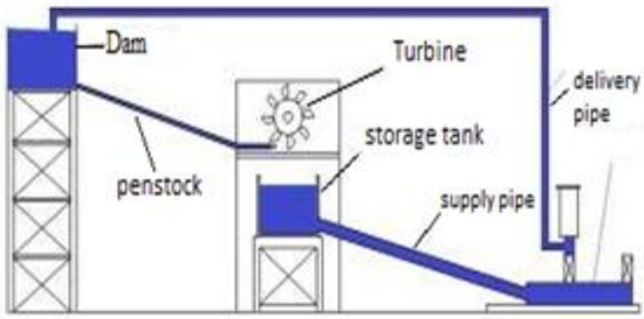

Fig: 3 Represntation of Free Hydropower Generation systems [9]

Table -1: Part Used in Ram pump

Sr no.	Part name	Description	Quantity
1	Pressure chamber	UPVC pipe	1 piece 2.5inch
2	Reducer	UPVC pipe	2inch *1/2 inch
3	Tee joint	UPVC pipe	1 inch
4	Air vessel cap	UPVC pipe	2 inch
5	Non-return valve	Brass	2 pieces as 1 inch
6	PVC pipe cutter piece joint	UPVC pipe	As per the requirement of supply and delivery Usually 4 to 5 pieces
7	Nozzle for pipe connection	UPVC pipe	2 each size as per supply pipe Diameter
8	Supply tank	Plastic	30 liters
9	Delivery tank	Plastic	30litres

Fig -3: Name of the figure[9]

3. INTERNET OF THINGS (IOT)

Technology has become a very important part of every kind of profession nowadays. IOT makes the hydropower system more efficient, helps them work in higher speed, increases the output power etc Implementation and use of IoT on dams: enables creation of databases of reliable instruments which can give more precise evaluation of the dam safety. Internet of Things (IOT) is a network of physical objects in which electronics are incorporated, as well as software and sensors that allow users to obtain timely and accurate data through services for data exchange between manufacturers, users or other connected devices. Reliable data could enable users to react in the right way at the right time, in case of critical situations or natural disasters and in rural areas. The sensors used in proposed system are water level indicator, water flow meter, ph sensor, solenoid valvae,etc.[4]

This system consists of a sensors, an microcontrollers. The three sensors: the level sensor detects the appropriate water level due to seasonal fluctuating water levels because the unit will not generate power when there is too little water and cannot power-up the turbine; the water flow sensor measures how much water has moved through; the pH sensor measures the hydrogen-ion activity in water to maintain the durability of the system over-time. IoT-based system that can easily monitor any unwanted problems. [2]

4. METHODOLOGY

4.1DESIGN FACTORS

The main factors are considered while designing the hydraulic ram pump :

The calculations are done on approximate basis.

Firstly, it is required to determine the total head and full so that a L/D ratio is to be determined.

In our project, we kept fall as 1m and delivery at about 2.5m.

Fall = 1m

Lift = 2.5 m

Dia. of supply pipe = 0.0250 m= 1"

Dia. Of delivery pipe= 0.0125 m= 0.5"

Length of pipe = 4 m

Hence L/D Ratio = 8/0.01250 = 180(150-1000)

Air Vessel = 2.5" * 35"

Dia. Of waste valve=1"

Now,

STEP: 1

SDR = da / s = 50/3 = 16.67 =17

Where,

s = wall thickness

da = outside diameter

We have diameter 50 mm diameter

Permissible wall thickness :-

Compressive strength(σv) = 50N/mm^2

$\sigma_{zul} = \sigma_v / c_{min} = 50/2 = 25$ N/mm^2

$$S_{min} = \frac{P \times da}{(20 \times \sigma zul) + P}$$

$$= \frac{12.4 \times 60.2}{(20 \times 25) + 12.4}$$

$= 1.2$ mm

The Inertia Pressure is given by,

$$P_i = \frac{V}{\sqrt{\frac{g}{w}\left(\frac{1}{k}+\frac{D}{TE}\left(1-\frac{1}{2m}\right)\right)}}$$

$$= \frac{4.25}{\sqrt{\frac{9.81}{9789}\left(\frac{1}{2.20*(10-9)}+\frac{0.025}{(0.003*1200*(10-6)}\left(1-\frac{1}{8}\right)\right)}}$$

= 1.24 N/mm^2 = 12.4 BAR

Where,

V= Velocity of water in supply pipe
G= Acceleration due to gravity
K= Bulk modulus of the water
D= Diameter of supply pipe
T= Wall thickness
E= Young's Modulus for the uPVC pipe

STEP: 2

$$Q = \frac{\pi}{4} D^2 * V$$

Where, D = Dia. Of pipe
V = Velocity of water in pipe
& n = No. of strokes of delivery value

$Q = \frac{\pi}{4} 0.0250^2 * 4.25$

= 8.34 x 10^{-3} m^3/s ……………………………..(1)

STEP: 3

Firstly, we need to calculate Vmax the maximum velocity of water in hydram.

Vmax = $\sqrt{2gHs}$

Where,
Hs = height of supply tank from pump =1m
C_v =Velocity coefficient = 0.96
G= acceleration due to gravity =9.81 m/s^2
Vmax =0.96 *$\sqrt{2*9.81*2.5}$ = 4.25 m/s.

To calculate the velocity of fluid flow in delivery pipe.
Vd= $\sqrt{2gHd}$ = $\sqrt{2*9.81*2.5}$
= 6.72 m/s.
Where, Hd = Height of the delivery pipe.

STEP: 4
In order to ascertain the nature of flow that whether it is laminar or turbulent.
To find Reynolds's number,
Re =V_s/ v
= 4.24 / 0.801*10^{-6}
= 5293383.271……………………………………(3)
v = kinematic viscosity and at T= 30° C,
v for water = 0.801*10^{-6} m^2/s.
For smooth pipes,
Blasius suggested that for turbulent flow,
$f = \frac{0.316}{Re\ 0.25}$
= 0.316 / 5293383.27$^{0.25}$
=0.006…………………………………………………(4)

STEP: 5
The Darcy-wersbach formula is the basis of calculating the loss in head for fluid flow in pipes by,
1. Head loss = $= f * \frac{L}{d} * (\frac{vd^2}{2g})$
$= 0.006 * \frac{1}{0.0250} * (\frac{4.25*4.25}{2*9.81})$
= 0.5 m…………………………………………………(5)

The velocity of flow in T-junction
Vr = $(\frac{Q}{As})$
= $(\frac{8.34*10^{-3}}{\frac{\pi}{4}*0.0250^2})$
= 4.25 m/sec ………………………………………….(6)

Now,
2. Head loss at T-junction due to sudden enlargement.
H_{LT} = $(\frac{(Vd-Vs)^2}{2g})$
= (6.72 - 4.2)^2 / 2* 9.81
= 0.16 m ………………………………………………..(7)

3. Friction losses,
Hf= k*$(\frac{v^2}{2g})$
k= [k_T + $k_{90\ elbow}$ + $k_{impulse\ value}$]
Hf= [(0.42*3) + (0.66*2) + 0.35] * (4.25^2 / 2*9.81)
= 0.14 m ……………………………………………………(8)

4. Other losses of head as in pipe fittings
H_L = k_t * (v^2 / 2g)
Where,
k = resistant coefficient for PVC
HL = 0.42 * (4.25^2 / 2*9.81)
= 0.18 m

5.Total losses = Head loss +H_{LT} +H_f +H_L
= (0.5+0.16+0.14+0.18)
= 1.12 m ……………………………………………………(9)

STEP: 6
Now, to find acceleration,
H-F * $(\frac{L}{D} * \frac{V^2}{2G})$ – LOSSES = $\frac{L}{D} * \frac{dV}{dT}$
2.5-1*(8/0.05)*(4.25^2/2*9.81)-(3.51) = (8/0.050)* $\frac{dV}{dT}$
3.77-0.0378=(15/0.076)* $\frac{dV}{dT}$
1.35m/sec^2 = $\frac{dV}{dT}$ ……………… (10)

STEP: 7
Now, drag force is given by,
F_d = c_d*A*ρ*$\frac{Vt}{2g}$
=0.62*(π/4)*0.050^2*1000*(4.25/2*9.81)
=0.26N

STEP: 8
The force that accelerate fluid
F= m_a = ρ*A*L*$\frac{dV}{dT}$
= 1000*(π/4)*0.050^2*8*1.35
= 21.2 N………………(11)

STEP: 9
Pressure at point is obtained by dividing F by area
$P_3 = \frac{F}{A} = \frac{21.2}{(\frac{\pi}{4})*0.0252^2}$ = 9.797 KN/m^2
=0.010 BAR

STEP: 10
P= ρ*g*Q*h
=1000*9.81*2.5*1000*1.93*10^{-3}
P = 47.33 W

STEP: 11

To Calculate Efficiency

$t_1 = L_1 * \frac{V_{max}}{(H_d - hs)*g}$

This formula is based on the empirical relationship between head of supply and the length of supply, it is suggested that,

$L_1 = 2.5 * H$

$L_1 = 2.5*1$

$= 2.5m$

$t_1 = 2.5 * \frac{4.25}{(2.5-1)*9.81} = 0.722$ sec

$t_2 = L_2 * \frac{V_{max}}{(H_d - h)*g}$

$= 1 * \frac{4.25}{(2.5-1)*9.81} = 0.28$ sec

Where,
L1 = Length of supply based on empirical head and length of supply
L2 = Length of pump
t1 = Time taken for impulse valve to close or delivery valve to open
t2 = Time taken for delivery valve to close
H = supply head
Hd =Height of tank from river
Vmax= maximum velocity

One beat is equal to t1+t2
1 beat =0.722+0.28
=1.010 sec
Since n is the no. of beats/min

$n = \frac{60}{1.010} = 59.4 \approx 59$

STEP:12

We then calculate the flow rate of the water flowing at waste valve

$Qw = \pi * r^2 * L * \frac{n}{60}$

Where,
Qw= flow rate of waste water
R= the radius of waste valve
L= length of hydram
n= 59

$Qw = \pi * (0.025/2)^2 * 1 * 59/60$

$= 1.93*10\text{-}3$ m3/sec

To find the head loss coefficient (M)

$M = \frac{f*L*V*V}{2*g*D} = \frac{0.011*4.25*4.25*1}{2*9.81*0.050} = 0.2$

STEP: 13

Next, we will find vol. of waste water (vol)w

$(Vol)w = \frac{L_s * A_s}{M} * \log\left(\frac{1}{1-\mu}\right)$

We have,
Hd= height of delivery tank =2.5m
Ld=Length of delivering pipe from hydram=2.5m
dd= dia of delivery pipe=0.076
Ls= length of supply pipe=4m
ds= dia of supply pipe =0.02508

Vmax=4.25 m/sec

$\mu = \frac{M*Vmax^2}{2*g*H_d}$

$= \frac{0.2*4.25^2}{2*9.81*2.5} = 0.07$

$(Vol)w = \frac{L_s * A_s}{M} * \log\left(\frac{1}{1-\mu}\right)$

$= \frac{1*\left(\frac{\pi}{4}\right)*0.050^2}{0.2} * \log\left(\frac{1}{1-0.07}\right)$

= 0.5 liter

Then we calculate the volume of delivery water (Vol)d

$(Vol)d = \frac{L_s * A_s}{M} * \ln(1+\beta)$

$= \frac{2.5*\left(\frac{\pi}{4}\right)*0.025^2}{0.2} * \ln(1+0.07)$

=0.15 liter

$\beta = \frac{M*Vmax^2}{2*g*H_d} = \frac{0.2*4.25^2}{2*9.81*2.5}$

= 0.07

The delivery flow rate can be calculated as below,

$Q_d = \frac{Q_w * Vol_d}{Vol_w}$

Where,
Qd= delivery flow rate (m3/sec)
Qw= waste flow rate (m3/sec)
Obtained earlier = $1.93 * 10^{-3}$ m^3/sec

$Q_d = \frac{1.93*10^{-3}*0.41}{0.3}$

= 1.36 lit/sec

The efficiency of hydram can be defined as below, using D'rankine formula,

$$E(\text{rankine}) = \frac{Q+hd}{(Q+Qw)*H}$$

$Q = Q_d = 1.363$ lit/sec
$Q_w = 0.15$lit/sec
$H_d = 1.5$m
$H=(h_d+h_s) = 1.5+1=2.5$ m

$$E = \frac{2.63*1.5}{(2.63+1.93*(10-3))*2.5}$$

=59.95%
=60%

5. RESULT AND ANALYSIS

The relation between power, head and flow is shown in the equation which is given by,

$$P = H \times Q \times g \quad (1)$$

Formula used to calculate the fall and Elevation is shown in equation

$$Vol \times (h / H) \times \eta = Q' \quad (2)$$

The vital factors to be considered while calculating the power are mainly the flow and head. Flow is the volume of water which is stored and re-directed to turn the blades (shaft). The head is the height at which the water will fall. With the increase in the flow there will be rise in the water head which give rise to higher energy to convert into electricity. Therefore flow is proportional to the head and the power as shown in equation 1 and 2.

Hydro power turbine generators are very efficient when compared to wind turbine generators and solar panels. Efficiency of around 70% can be obtained which means remaining energy is lost in converting the mechanical energy to electrical energy. From the equation (2) the total power generated in the model is calculated. The water which is elevated is the total head in which it impinges on the water turbine blades to rotate the shaft which generates the electricity. Table 2 shows the total amount of power generated.

Table 2: Determination of the elevated height of water

Sr .no	Inlet height fall(m)	Input flow rate lit/min	efficiency %	Output flow rate lit/min	Total head (m)
1	1	0.5	60	1.5	2.5

Table 3: Water generated in a hydroelectric plant

Sr. No	Water Head (m)	Flow rate (litres/min)	Power generated (W)
1	0.75	8	2.2
2	1	9.38	3.33
3	1.25	9.59	3.34
4	1.5	10.23	4.66

Table 4 : Calculated values for ram pump

Parameters	Values
Drive pipe diameter	0.025m
Drive pipe length	4m
Speed of diaphragm	59 beats/min
Flow discharge in drive pipe	2.3 l/min
Total head losses in the system	3.51m
Force on waste valve	0.12 bar
Pressure at waste valve	3668 kN/m^2
Power developed by the hydram	1.273 kW
Hydraulic pump efficiency	60 %

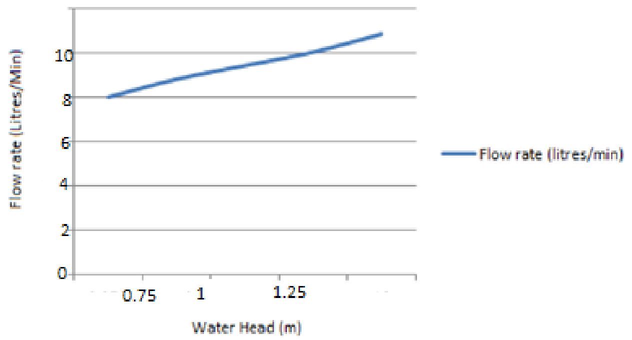

Figure 4: Variation of Flow rate of water with the water head

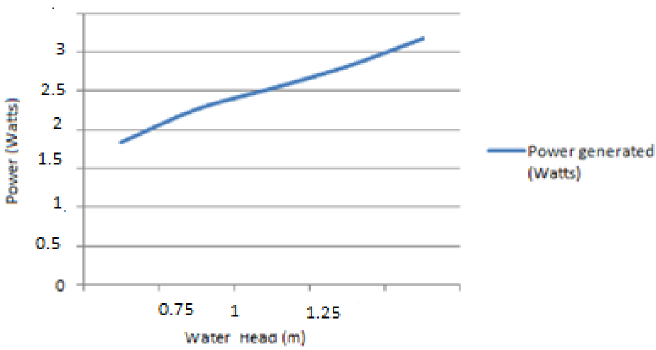

Figure 5: Variation of power generated in the system with the water head

Figure 5 and 6 shows the variation of water flow rate and the power generated in the system with the water head. It shows that as there is a rise in the water head or the elevation of the water, there is a increase in the flow rate and power generated. Figure 8 shows that there is a rise in the power generated with the increase in the flow rate.

Nomenclature:
Q= Water Discharged from reservoir 1, litre/min
h= supply head, m
H= delivery head, m
P=Power generated, W
Q'= Discharge at the outlet into reservoir 1, litres/min
g= Acceleration due to gravity, m/s2
η= Efficiency of the hydram, %

6. FUTURE SCOPE

- This project can be implemented on larger scale where there is scarcity of energy or where energy is available intermittently.
- Design can be modified with focus on obtaining maximum output from available head.
- Alternative material can chosen which is more cost effective, durable and reliable.

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