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Recommendation proposal

Development of very small household Pico-hydro power generation unit.

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Submitted by

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PART –I GENERAL INFORMATION

1.	**Project Code**	
2	**Project Title**	Development of very small house hold Pico–hydroelectric power generation unit
3	**Name of Department Where the project was undertaken** **a) Name of Department** **b) Location of Project**	 Department of Electrical and Other Energy Sources Faculty of Agricultural Engineering & Technology Dr.B.S.Konkan Krishi vidyapeeth, Dapoli Department of Electrical and Other Energy Sources Faculty of Agricultural Engineering& Technology Dr.B.S.Konkan Krishi vidyapeeth, Dapoli
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6	**Objectives**	1. To develop very small household pico-hydropower generation unit. 2. To taste its performance
7	**Year of start**	**2013-14**

PART-II TECHNICAL INFORMATION

1. Background of Project:

1.1 Energy scenario

India is the fourth largest energy consumer in the world after the United States, China, and Russia. In recent years, India's energy consumption has been increasing at a relatively fast rate due to population growth and economic development. Rapid urbanization and improving standards of living for millions of Indian households, the demand is likely to grow significantly. In order to sustain the production, industries have opted for inefficient diesel-fuelled backup power. India's energy planning, which is based on the twin objectives of high economic growth and providing electricity to all, is failing to meet either. The domestic power demand of India was 918 billion units in 2012. It is expected that at 9.8% annual growth the demand will reach 1,640 billion units by 2020. India has transitioned from being the world's seventh-largest energy consumer in 2000 to fourth-largest one within a decade.

1.2 Small hydro power plants

Hydro projects in India, which are under 25 MW in capacity, are classified as "small hydropower" and considered as a "renewable" energy source. The use of small hydro power (SHP) in India goes way back in history, with the country's first SHP plant having come up in 1897. The sector has been growing rapidly for the last decade. The number of SHP plants has doubled. SHP is by far the oldest renewable energy technology used to generate electricity in India. The total installed capacity of SHP projects in India was 3,632 MW in March 2013. This is spread over 950 projects; hence, the average SHP project capacity is 3.8 MW. This does not include micro-hydelplants. The draft 12th Five Year Plan (2012-17) has, as its target, 2,100 MW of SHP capacity. The total potential country-wide capacity is estimated at 19,749 MW, of which about 1,250 MW is under development. The current total installed capacity of small hydro power plants is 3746.75 MW.The power developed by the water source in the world plays a very important role in the development of world and nations.

1.3 Classification of small hydro power plants

According to the head, small hydropower plants are classified as,

1. High head: 100 m and above

2. Medium head : 30 to 100 m
3. Low head : 2 to 30 m

According to the power generated, small hydropower plants are classified as,

1. Small hydropower project : 1 to 15 MW
2. Mini hydropower project : 100 KW to 1 MW
3. Micro hydropower project : 5 KW to 1 MW
4. Pico hydropower project : few watts to 5 KW

According to the nature of load, small hydropower plants are classified as,

1. Base load power plants
2. Peak load power plants

According to quantity of water available, small hydropower plants are classified as,

1. Run off river without pondage
2. Run off river with pondage
3. Storage type plants
4. Pumped storage plants

1.4 Pico hydropower in Konkan

The Konkan region of the Maharashtra state, receives a very heavy rainfall, in the range of 3000 mm to 4500 mm from June to September. Due to high intensity, duration and frequency of the rainfall, the electricity transmission lines get damaged due to falling of trees or bad weather. Thus the supply of electricity is hampered. Also, there are power cuts in the Konkan region, due to insufficiency of electricity. The rainwater which falls on the rooftops of the houses have a great Pico-scale hydroelectric potential. Unfortunately, the rainwater falling on rooftops eventually ends up in the runoff stream. This rainwater, which falls on rooftops possesses the potential energy. If this water is made to fall on a turbine with a high velocity, electricity can be generated. Houses in Konkan region, having an average height of 9 m, or more (ground floor, first floor and roof) and assuming a roof water collection area of about 10 × 10 m; by calculation, it is observed that, there is a potential to generate about 50 to 60 W of hydropower. This power can lit four to five LED lights of 10 W capacity each. As the height and the roof area of the building increases, the hydropower generated also increases and hence, more electrical appliances can be utilized. If during the rainy season, power cut occurs, then such a small scale hydropower generator will keep the house lit.

1.5 Hydroturbines

Hydroturbine can be defined as a rotary machine, which uses the potential and kinetic energy of water and converts it into useful mechanical energy. According to the type of energy transfer, there are two types of hydro turbines, namely impulse turbines and reaction turbines. In impulse turbines water coming out of the nozzle at the end of penstock is made to strike a series of buckets fitted on the periphery of the wheel or runner. Before reaching the turbine, pressure energy of water is converted entirely into kinetic energy. The water leaves the nozzle at atmospheric pressure. The wheel revolves freely in air. Energy transfer occurs due to impulse action. The pelton turbine and Turbo turbine fall in to this category. In a reaction turbine water enters all around the periphery of runner and the runner remains full of water. Only a part of the pressure energy is converted in the guide vanes, into velocity energy. Water acting on wheel is under pressure. A further drop of pressure takes place in the turbine runner. This pressure is greater than the atmospheric pressure. The water leaving from the turbine is discharged into the tail race through a draft tube. The draft tube is submerged deep in the tail race. Since the pressure of the water at the inlet to the turbine and outlet are different, water should flow in a closed conduit. Therefore casing is necessary for reaction turbines. The Francis turbine, Kaplan turbine and propeller turbines are Reaction turbines.

1.6 Pelton Turbines

The Pelton turbine is an impulse hydro turbine developed in 1889 by an American engineer Lester Allan Pelton. Pelton turbine is a tangential flow impulse turbine, which operates under high head of water and requires comparatively less quantity of water. Water is conveyed in penstocks from head race to the turbine in power house. The runner of the Pelton turbine consists of buckets having double hemispherical cups fitted on its periphery. The cups have a semi-ellipsoidal shape. The rear of the bucket is designed such that the water leaving the bucket should not interfere with the passage of water to the preceding bucket.

The jet strikes these cups at the central dividing edge of the front edge. The central dividing edge is also called as splitter. The water jet strikes edge of the splitter symmetrically and equally distributed into the two halves of hemispherical bucket. The inlet angle of the jet is therefore between 1° and 3º. Theoretically if the buckets are exactly hemispherical it would deflect the jet through 180°. Then the relative velocity of the jet leaving the bucket would be opposite in direction to the relative velocity of the jet entering. This cannot be achieved practically because the jet leaving the bucket then strikes the back of the succeeding bucket and hence overall efficiency would decrease. Therefore in practice the angular deflection of the jet in the bucket is limited to about 165° or 170°, and the bucket is slightly smaller than a hemisphere in size. Water, at high head, flows through the penstock and at the end of penstock, one or more nozzles are fitted to convert all the available energy of water into kinetic energy. The amount of water which discharges from the nozzle is regulated by a needle valve provided inside the nozzle. One or more water jets can be provided with the Pelton turbine depending on the requirement. The water comes out of the nozzle as jet and impinges on the buckets, causing it to revolve. The impact of water jet produces force on bucket causing wheel to rotate. The jet of water splits equally, by splitter and flows round the inner bucket surface and leaves at the outer edge of buckets.

1.7 Electricity Generator

An electrical generator is a rotational machine that converts the mechanical energy produced by the rotor blades (the prime mover) into electrical energy or power. This energy conversion is based on Faraday’s laws of electromagnetic induction that dynamically induces an e.m.f. (electro-motive force) into the generators coils as it rotates. There are many different configurations for an electrical generator, but one such electrical generator which can use in a hydroelectricity power system is the Permanent Magnet DC Generator **or** PMDC Generator**.**

Permanent magnet direct current (DC) machines can be used as either conventional motors or as DC hydro turbine generators as constructionally there is no basic difference between the two. In fact, the same PMDC machine may be driven electrically as a motor to move a mechanical load, or it may be driven mechanically as a simple generator to generate an output voltage. This then makes the *permanent magnet DC generator* (PMDC generator) ideal for use as a simple hydro turbine generator.

When a DC machine connect direct to a current supply, the armature will rotate at a fixed speed determined by the connected supply voltage and its magnetic field strength thereby acting as a “motor” producing torque. When the armature rotate mechanically at a speed higher than it's designed motor speed by using rotor blades, then effectively this DC motor convert into a DC generator producing a generated emf output that is proportional to its speed of rotation and magnetic field strength.

Generally with conventional DC machines, the field winding is on the stator and the armature winding is on the rotor. This means that they have output coils that rotate with a stationary magnetic field that produces the required magnetic flux. Electrical power is taken directly from the armature via carbon brushes with the magnetic field, which controls the power, being supplied by either permanent magnets or an electromagnet.

The rotating armature coils pass through this stationary, or static magnetic field which in turn generates an electrical current in the coils. In a permanent magnet DC generator, the armature rotates so the full generated current must pass through a commutator or slip-rings and carbon brushes arrangement providing electrical power at its output terminals.

1.8 V belt and Pulley

The belts are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. The amount of power transmitted depends upon the following factors: 1. the velocity of the belt. 2. The tension under which the belt is placed on the pulleys. 3. The arc of contact between the belt and the smaller pulley. 4. The conditions under which the belt is used. It may be noted that (a) the shafts should be properly in line to insure uniform tension across the belt section. (b) The pulleys should not be too close together, in order that the arc of contact on the smaller pulley may be as large as possible. The pulleys should not be so far apart as to cause the belt to weigh heavily on the shafts, thus increasing the friction load on the bearings. (d) A long belt tends to swing from side to side, causing the belt to run out of the pulleys, which in turn develops crooked spots in the belt. (e) The tight side of the belt should be at the bottom, so that whatever sag is present on the loose side will increase the arc of contact at the pulleys.

For selection of a belt drive following are the various important factors upon which the selection of a belt drive depends: 1. Speed of the driving and driven shafts, 2. Speed reduction ratio, 3. Power to be transmitted, 4. Centre distance between the shafts, 5. Positive drive requirements, 6. Shafts layout, 7. Space available, and 8. Service conditions.

The V-belt is mostly used in factories and workshops where a great amount of power is to be transmitted from one pulley to another when the two pulleys are very near to each other. The V-belts are made of fabric and cords moulded in rubber and covered with fabric and rubber (a). These belts are moulded to a trapezoidal shape and are made endless. These are particularly suitable for short drives. The included angle for the V-belt is usually from 30° to 40°. The power is transmitted by the wedging action between the belt and the V-groove in the pulley or sheave. A clearance must be provided at the bottom of the groove in order to prevent touching of the bottom as it becomes narrower from wear. The V-belt drive may be inclined at any angle with tight side either at top or bottom. In order to increase the power output, several V-belts may be operated side by side. It may be noted that in multiple V-belt drive, all the belts should stretch at the same rate so that the load is equally divided between them. When one of the set of belts break, the entire set should be replaced at the same time. If only one belt is replaced, the new unworn and unstretched belt will be more tightly stretched and will move with different velocity.

2. Technical Details of Project:

The materials and methodology adopted for development and testing of pico hydroelectric power generation unit.

2.1 Design of pelton turbine

The Pelton turbine was designed for high efficiency and at a Pico hydropower scale (Nasir, 2013).The design details and specifications of Pelton Turbine are as given below.

1. Assume the head 9 m. Discharge of water of roof size 10 m x 10 m for 2 hours = 1 lps
2. Water horse power from 1 lps =Q (lps) x9.8 x H
   = 88.29 W.
3. Output power in watt = Q (lps) x H (m) x ŋ x 9.81 efficiency =60%
   = 1lps x 9.1m x 0.6 x 9.81
   = 53.56 watt
4. Absolute velocity of Jet = Cv*√ 2gh Cv = Velocity coefficient
   =0.98
   =13.02 m/s
5. Absolute velocity of vane= Speed ratio x Absolute velocity of vane
   =0.5x13.02 m/s=6.01 m/s

6. Velocity of vane = πDN/60 where n= 300rpm

D = 41.38 cm

7. Diameter of vane(D) = 42cm

10. Diameter of jet (d) = 1 cm = 10mm

11. Jet ratio (m) = D/d

= 42/1 = 42

12. Number of bucket = 0.5 m + 15

= 36

13. Bucket width = 5 x d

= 5 x 1 = 5.0 cm

14. Bucket depth = 1.2 x d = 1.2 cm

2.2 Development of turbine

Development of the turbine A 10 m long and 60 mm diameter UPVC (Un-plasticized Poly Vinyl Chloride) pipe was sheared perpendicularly into 36 cylindrical pieces, each having 65 mm length, using a hacksaw blade. The pieces were sheared at a plane, 5 mm apart from the diametrical line of the cylinder, so that two un-identical (large and small) cups were obtained. This process was done by a shaping machine. A v-groove was made at one end of the cup, using a hand abrasive cutter. The internal angle of the v-groove was 55° while the length of the base of v-groove was 50 mm. The stainless steel sheet was cut into 36 pieces using a sheet cutter. The dimension of each piece was 70 mm × 35 mm. Two holes were drilled into each stainless steel piece, exactly at the centerline, parallel to the length (70 mm) of the piece at a distance of 15 mm from extreme ends. The sheet pieces were then subjected to the deforming force of a mechanical press, such that, a splitter shape was formed (the sheet was pressed parallel to the breadth (35 mm) of the piece at 3 points: 2 drilled points and the midpoint on the length). The stainless steel splitters were mounted on the concave side of the cups and were fixed by stainless steel screws. The cups were attached one after the other, on the periphery of the wooden runner, with the help of stainless steel screws (2 screws per cup). This was carried out by using a protractor and dividing the circular face of the runner into 36 equal parts (each part subtending 10° at the center). A 32 mm hole was drilled into the wooden runner at its center, by using a lathe machine. Using lathe machine, hub and shaft were manufactured out of mild steel. The hub shaft was made to penetrate the hole made on the center of the runner, using a mechanical press. The hub flange was attached to the wooden runner using stainless steel screws, so that, the runner and the hub would behave as a single rotating unit. A key hole was drilled into the turbine shaft, in order to fix it inside the hub shaft. The turbine shaft was made to penetrate the hub shaft. Both the shafts were aligned, such that, the drilled holes on the hub shaft and the turbine shaft would match. A long bolt was made to penetrate the key passage. The bolt was tightened with a nut and it was 16 ensured that, the runner, the hub and the turbine shaft were rotating as a single unit. The two ends of the shaft were mounted inside the bearing bushes of the pedestal bearings. Two P-205 pedestal bearings, having 25 mm internal diameter of bearing bush were used. The turbine was painted with red oxide and paint, in order to protect it from water.

Plate 1 Developed Pelton turbine

Pedestal bearing: Two P-205 pedestal bearings, having 25 mm internal diameter of bearing bush were used. The turbine was painted with red oxide and paint, in order to protect it from water.

Plate 2

2.3 Selection of generator

Permanent Magnet Direct Current Motor (PMDCM) was used as generator (ISBN: 81-219-1142-7) with following specifications.

Specification of PMDC motor

Table 1

Sr.No.	Particulars	Details
1	Make	Revolution technology
2	Power	90 W
3	Output rpm	1500 rpm
4	Input Voltage	12 V
5	Stall Current	7.5 A
6	Shaft length	100 mm
7	Shaft diameter	20 mm

Testing of generator

Testing of PMDC was carried out. The shaft was rotated at different speeds. The voltage, current were noted and power was calculated for different speeds.

2.4 Design of Power Transmission System:

V belt type section is selected IS: 2494 – 1974). According to 12 V 90 W PMDC generator specification V Belt and Pulley Drive system is Design.The prototype of the power transmission system is at plate 2

- As per turbine design output speed of turbine shaft (N1)is 300rpm
- From 12 V 90 W PMDC generator specification input speed of generator shaft including sleep losses should be(N2) is 1500 rpm
- Let Diameter of the turbine pulley (D2) is50.8mm (2 inch)
- From velocity ratio diameter formula, diameter of the generator pulley(D1) will be 355.6 mm (14 inch)
- Length of v belt is 1480 mm (58 inch)
- Width of belt is 13 mm
- Thickness of belt is 8 mm

2.5 Prototype of power generation unit

The developed Pelton Turbine (PT) was fixed on the MS frame of size 40 x40 x5 mm and 25x 25 x 5 mm. The diameter of PT shaft was 25 mm. The shaft was fixed on the frame using pedestal bearings. The PMDCM was fixed such that its shaft was parallel to the shaft of PT. The centre to centre distance between two shafts was 406 mm. The PT was connected to the PMDCM shaft by belt and pulley. The diameter of

PT shaft pulley was 356 mm while that of on PMDCM shaft was 51mm. Hence, the speed ratio was 6.98≈ 7. The overall dimensions of the developed power generation unit was 820x400x105 mm. The prototype of developed pico-hydro power generation unit is shown at Plate.2

2.6 Assembling of the penstock pipe

The 140 mm diameter HDPE pipe was attached to the main water supply, with the help of a 63 mm × 50 mm reducer. The empty was attached to the HDPE pipe on the other end. The bushing was attached to the empty and the hose nipple was attached to the bushing. The hose nipple was fixed on the frame by a nut and bolt arrangement, so that the line of jet could be varied. The diameter of hose nipple (Jet diameter) was 10 mm.

Developed Pico-Hydro Power generator unit

Plate.3 Small pico-hydro power generation unit

Plate 4

3. Results and Discussion

3.1 Testing of generator

The details of speed of generator shaft, voltage and current are given in the following table. For each individual speed, the power was calculated and tabulated.

Testing result of PMDCM (generator)

Permanent Magnet Direct Current Motor can be used as generator (ELIMO 90 4FH) therefore following specification PMDC motor is selected for developed pico hydropower generator.

Testing of Permanent Magnet Direct Current Motor cum generator is carried out in the workshop of College of Agricultural Engineering and Technology, Dr. B.S.K.K.V., Dapoli. with the help of lathe machine at maximum load. Following result is obtained.

Plate 5

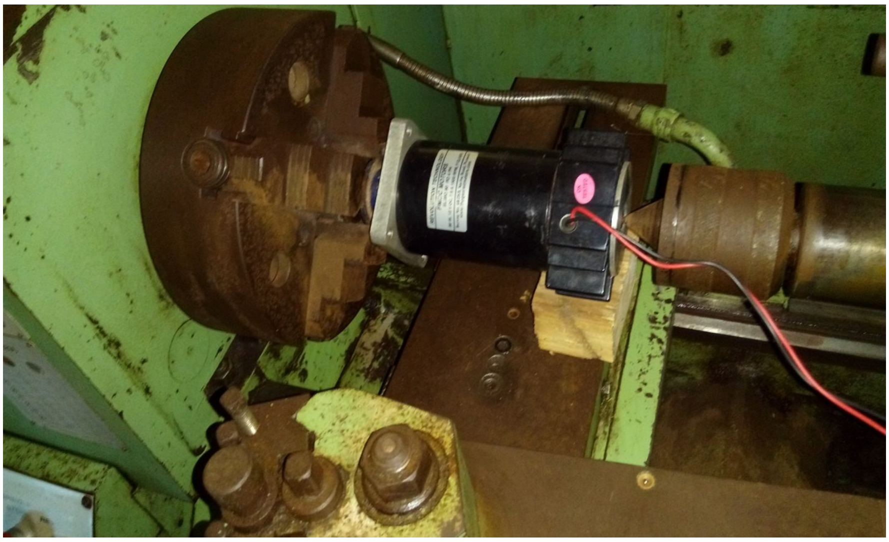


Table 2

Sr.No	Generator shaft rotation	Voltage rotation (Volts)	Current reading (Ampere)	Power, (watts)
1	215	3	1	3
2	440	4	1	4
3	730	5	2	10
4	950	7	3.5	24.5
5	1100	8	4	32
6	1200	10	4	40

From above it was observed that generator shaft should rotate at least at 1200 rpm to get desired output.

3.2 Testing of developed pico hydro power electric power generation unit

The nozzle arrangement at the bottom of the penstock pipe was aligned properly. It was ensured that all the connections on the penstock pipe were watertight. The electrical wiring between motor and multimeter was checked. The load was provided by electric bulbs, All the rotating parts are lubricated. The flow was initiated by opening a flow control valve from head of 9 m. Water rushed through the penstock pipe of 140 cm, exited from the jet of 1cm and hit the turbine. Using a flow water meter connected to the penstock 1 lps flow was measured. The flow was allowed to hit the turbine. It was ensured, that the line of jet was tangential to the turbine and was passing through the midpoint of the buckets. Using a non-contact tachometer, the maximum rotations of the motor shaft and the turbine were recorded in rpm. The maximum readings of the ammeter and the voltmeter were also recorded. Power generated was calculated by multiplying values of the ammeter readings and voltmeter readings. The tachometer, ammeter and voltmeter readings were taken at the same time, after every 10 seconds. The details are depicted at Table 3. It was replicated 10 times. The flow was ceased by closing the flow control valve.

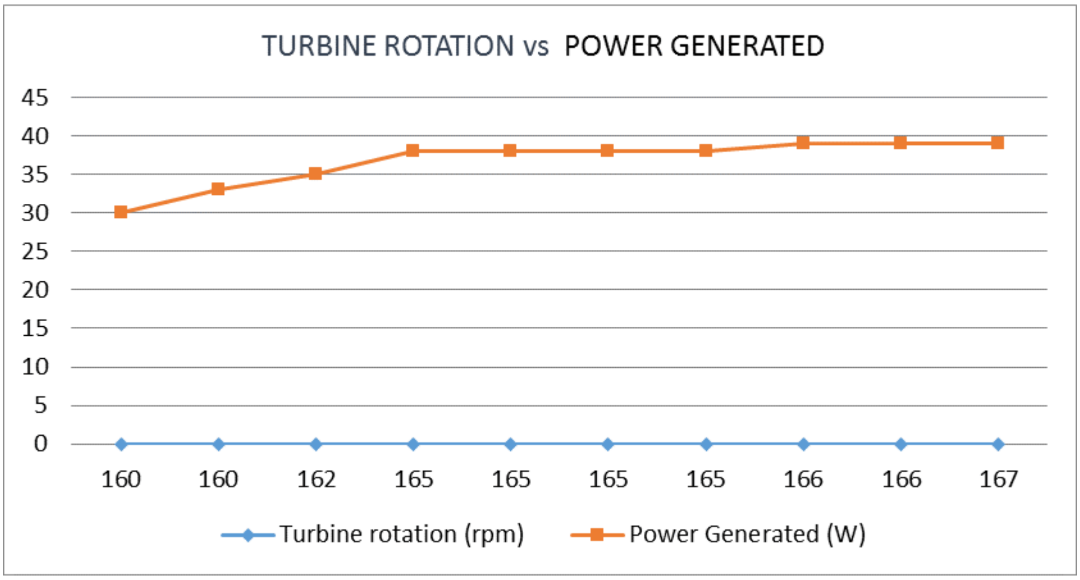
Table 3 Power generated at 1 lps flow rate under 9 m head

Sr. No	**Turbine shaft rotations (RPM)**	**Voltage (V)**	**Current (A)**	**Power Generated (W=V×I)**
1	160	12	2.5	30
2	160	13	2.5	33
3	162	14	2.5	35
4	165	15	2.5	38
5	165	15	2.5	38
6	165	15	2.5	38
7	165	15	2.5	38
8	166	15	2.6	39
9	166	15	2.6	39
10	167	15	2.6	39

It was observed that, for a constant 1 l/s flow under a head of 9 m, the turbine was rotating these rotations were multiplied by the belt and pulley and were given to the generator shaft. The generator induced electricity, which was measured by ammeter and voltmeter. The power generated varied from 30 W to 39 W, and the average power was calculated as 37 W.

The relationship between turbine speed and power generated is depicted in Fig. 1.

Fig-1. Graph of turbine speed (rpm) Vs power generated (W) for 1 l/s   w under 9 m



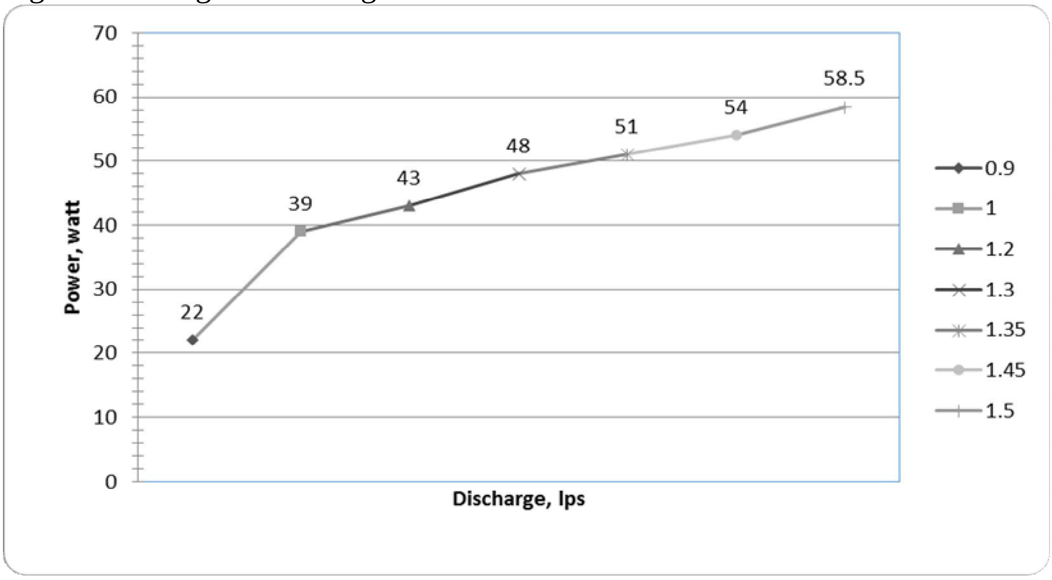
The generated power (39 W) was slightly less than that calculated (54 W). Therefore maximum power generation efficiency of developed pico hydroelectric power generation unit under 9 m head for 1 l/s is (39/54*100) 72 %.

In order to find out the maximum power generation efficiency of developed pico hydroelectric power generation unit further performance evaluation is carried out by varying the flow of water from 0.9 to 1.5 l/s at different head. Average results which were recorded after the testing of the pico hydroelectric power generation unit by varying the flow of water from 0.9 to 1.5 l/s at constant 9 m height is shown in table 4.

Table 4

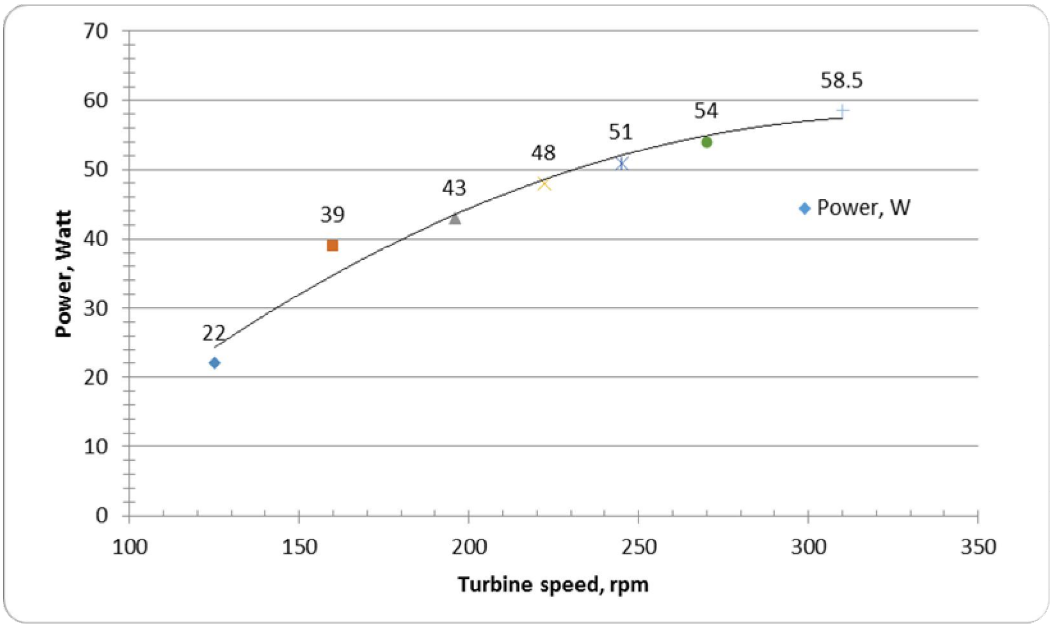
S.N	Discharge, lps	Pressure, kg/sq cm	Turbine speed, rpm	Power, W
1	0.9	0.8	125	22
2	1	0.9	160	39
3	1.2	1.2	196	43
4	1.3	1.4	222	48
5	1.35	1.6	245	51
6	1.45	1.8	270	54
7	1.5	2	310	58.5

Fig-2. Discharge vs Power generated



It was observed that the turbine was start rotating from 0.9 l/s up to 1.5 l/s. The Speed of turbine remains constant from 1.5 l/s after achieving constant speed, at which maximum power generated was 58.5 W.

Fig-3. Turbine speed vs Power, W



It was observed that , the turbine was start rotating at 0.9 l/s at 0.8 kg/sq cm pressure with revolution of 125 rpm . The Speed of turbine remains constant at 310 rpm with 1.5 l/s at 2 kg/sq cm pressure . Power generated was veried from 39 watt 58.5 watt.

4. Cost estimation of developed Picohydro power generation system

Total cost required for development of pico-hydro power generation unit was given as follows

Table: 5

SN	Material	Quantity	Rate, Rs	Cost, Rs.
Frame				
1	MS angle, 4 cmx4cmx 5 mm	10 kg	60 per kg	600/-
2	MS angle, 2.5 cmx2.5cmx3mm	2.8 kg	60 per kg	168/-
3	Pulley, MS sheet, V-belt and miscellaneous			500/-
			Total	1268/-
			Fabrication cost, @30 % material cost	380/-
			Total frame cost	1648/-
Turbine				
4	wooden piece 40cmx40cmx5cm	1	200	200/-
5	Turning charges	1 job	150/-	150/-
6	Wooden plate turning tracing and 32 mm drilling	1 job	230/-	230/-
7	CPVC pipe	3 meter	147 /meter	440
8	Bearing P-205	2 nos	225/-	550/-
9	Screw	11/2	14 /dozen	168
			Total turbine cost	1738/-
Other material				
10	PVC coupler	3nos	17	51/-
11	Reducer	1no		35/-
12	Joint clip	4 no	25/-	100/-
13	3” x2 1” couple	1no	14	14/-
14	11/2” hdpe pipe	1m	85/-	85/-
15	2” 21/2 “reducer	1 no		30/-
16	35 watt bulb	2 no	90/-	180/-
			Total other material cost	495/-
Generator				
17	Generator (DC motor)	1 no	4800/-	4800/-
			TOTAL	8681/- Rs.9000/-

5. Findings

1. The exhaustive trial of developed pico-hydro power generation unit was taken on specially designed PMDC generator of (90 W, 1500 rpm).
2. Maximum power generated by developed pico-hydro power generator at 1 l/s and 9 m head was 39 watt with 72 % efficiency.
3. Minimum power generated at 0.9 lps (22 W) and maximum power generated at 2 lps (59 W).

Recommendation:

Dr. B.S.K.K.V. Developed pico-hydroelectric power generator using 9 m head and diverted flow through 14 cm diameter pipe having jet of 1 cm is recommended for 39 watt power generation.

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