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ASSESSMENT OF GRAVITATIONAL WATER VORTEX HYDROPOWER PLANT IN NEPAL

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Abstract - *The study presents about the technical feasibility of innovative low head turbine technology, Gravitational Water Vortex Hydropower Plant fitted with conical basin. The development of conical basin technology started in Nepal since 2013. This study presents the technical feasibility assessment of 1 kW vortex turbine system. After series of site visit, detail design of the system components was done on the basis of which, the cost estimate has been done. The estimated cost of development of the 1 kW pilot system is about 19.5 Lakh Nepali Rupees. Areas for cost reduction are also indicated. It is finally suggested that the system be developed as a research-oriented pilot project which will reveal information regarding installation of scaled up system that can produce significant amount of power for successfully covering operation and system maintenance costs.*

Key Words: Low head turbine, Gravitational water vortex turbine, Feasibility study, System Design

1. INTRODUCTION

The small or micro hydro powers are realized as one of the most prospective and promising renewable energy sources that have received significant attention for rural electrification because of its capacity to generate green energy. One of the hindrances in development of this kind of technology is the cost of civil works. It has been realized that the cost and environmental impacts of constructing a dam make traditional hydropower projects difficult to develop.

In Nepal, the hilly areas have good head of water thus conventional hydropower systems can be developed. This technology will be fruitful for plains areas (Terai-Madhesh) of Nepal. In addition, still there are certain areas in hilly and mountain regions that are difficult to be electrified because of difficulty in developing national grid and construction of conventional hydropower due to difficult geographical terrain. Thus, many rural communities of Nepal are deprived of electricity because of difficulty in development of national supply grid and difficulty in construction of hydropower structures in the area itself (AEPC, 2013). The solution to this problem is installation of new type of turbine that is economically viable and environmentally acceptable.

Gravitational Water Vortex Hydropower Plant (GWVHP) is one of such turbine technologies in which potential energy of water is converted to kinetic energy by a rotation tank (basin) and this kinetic energy of water is extracted by a turbine in the center of vortex. The operating range of GWVHP is identified by (Timilsina, et al., 2018). As seen it addresses the current gap of operation of low head hydropower systems.

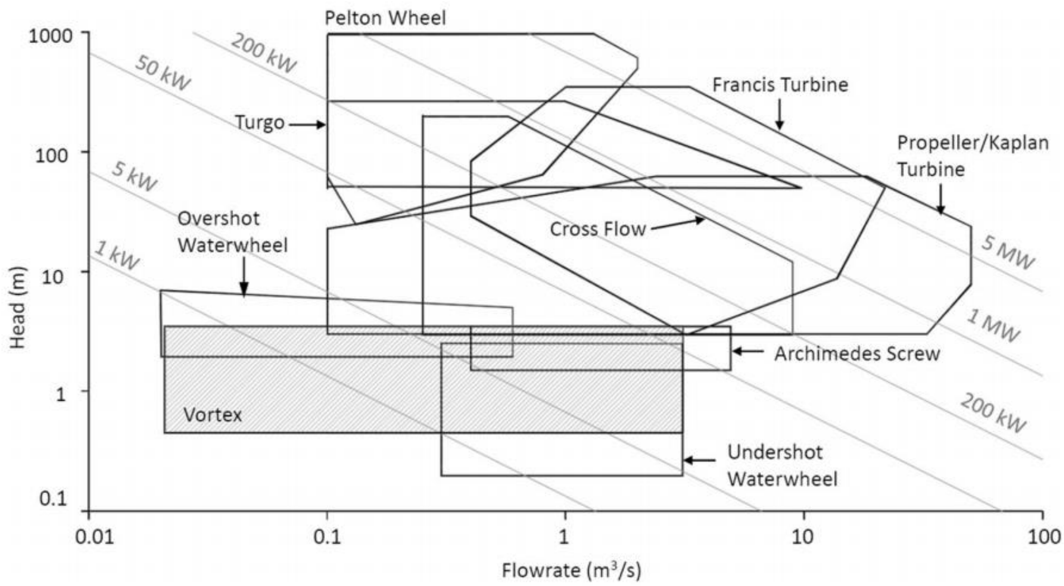

Figure 1: Application Range of Hydraulic Turbines indicating range covered by Vortex Turbine (Reproduced with permission from Timilsina et al. 2018)

This makes them suitable on rivers across the Nepal, at thousands of locations. This has the possibility of removing or reducing the need for mega hydropower stations. The installation of GWVPP can act as an exemplar project that can have huge environmental benefit with no negative environmental impact. Moreover, GWVPP is safe for fish due to low turbine speed.

The field study made by the research team carried out the feasibility study of the project. Identifying *Thakurdwara, Bardiya* as one of the potential sites, feasibility study of the project was carried out considering general principles of micro hydro power as published by (Harvey, 1993). Specific study about this system in Nepal are carried out by (Bajracharya & Chaulagai, 2012), (Dhakal, et al., 2013), (Dhakal, et al., 2015) and by (Sapkota, et al., 2016). The main objective of this study is to assess technical as well as financial feasibility of gravitational water vortex hydropower plant.

2. Methodology

The study team carried out various technical measurements in the field. Various field measurements like the width and the topography of the canal existing structures and suitable site of the powerhouse building were studied. The project site can be reached after about 40 min ride from *Aambassa* which is an hour and few minutes ride from *Kohalpur, Bardiya*. Alternatively, the project site can be accessed from *Guleriya* through earthen road. The survey was conducted by using a total station and tape. Public involvement was also made during the survey work. The general public meeting was called after the survey work. The length and the alignment of the transmission and distribution line were measured. Socio-economic, environmental and other information were collected by involving the public experts during the campaign.

The norms of the Government of Nepal, have been used for detail cost estimation and cost analysis of the proposed GWVHP system. Likewise, local prevailing rates have also been considered while analyzing the rates. Since the proposed GWVHP system is a community-owned scheme, all the rates for the scheme have been worked out taking into consideration the availability of the local construction materials and labor. Further, the rate of the skilled and unskilled manpower has been taken based on the local practice in the community. The rate of the electromechanical equipment was taken from the current price quotation of the manufacturer/installer. The costs are only indicative and close approximation, hence, should be used only for a budgetary purpose. The costs of electromechanical equipment may vary according to change in the market price in the given time.

2.1 Location

The project site can be reached after about 40 min ride from Aambassa which is an hour and few minutes ride from Kohalpur, Bardiya. Alternatively, the project site can be accessed from Guleriya through earthen road.

2.2 Flow measurement

This is an irrigation canal derived from Karnali river. The majority of command area lies in Bardiya district. It is a perennial stream having relatively stable flow round the year. The stream has a gentle slope on the project site and it ultimately meets with Karnali river. The discharge of the river was measured by using the current meter and was found to be 1.5 m^3/s. Design discharge has been taken as 0.18 m^3/s.

2.3 Hydrology

The irrigation canal has a net command area of 1300 hectares. Since the water source of the irrigation canal is the Karnali river, the available flow is almost constant throughout the year. So, the flow available in the stream is sufficient to meet the design discharge.

2.4 Current energy situation

Major sources of energy are firewood and kerosene. People use firewood for cooking and heating purposes. Kerosene is used for lighting. Hence the village is back in the energy sector.

2.5 Water right issue

The proposed GWVHP scheme will not cause any conflict among the villagers in connection with water right issue. The volume of water disturbed by the GWVHP is very minimal. Also, there will be no disturbance to the irrigation system during cultivation season. So, there is no problem regarding water uses.

3. RESULTS AND DISCUSSION

3.1 System Design

3.1.1 Design flow, gross head and power output

Karnali river is the source of discharge and sufficient discharge is available in the canal throughout the year. The design discharge was taken as 0.18 m^3/s. The gross head of the scheme is 1.2 m. The details are same as of the pilot project.

The output power of the scheme is:

Power (P) = 9.81 *$Q_{designed}$*H_g = 2.12 kW

Where,

$Q_{designed}$ = Designed discharge (in m^3/s) = 0.18 m^3/s

Hg = Gross head in (m) = 1.2

Considering the system efficiency as

η = Overall efficiency of the system = 53 %

Power output from scheme = 1.1 kW

3.1.2 Civil components (Design and sizing of hydraulic parts)

Gravitational Water Vortex is a new type of technology. Due to its nature of the operation, it requires very less civil structures. The nature and requirement of civil structures differ drastically from the traditional micro hydro civil components. The objective of the trash rack is to convey water. It will serve to convey water from forebay to the intake of the system. The walls of the intake system will be 0.2 m thick brick walls with cement concrete lining. The conical basin shall be coupled with the intake system at the exit of the intake system.

3.1.3 Forebay

The water in front of intake will serve as a forebay for the system.

3.1.4 Trash rack

The objective of the trash rack is to protect the whole system from logs and other large waterborne objects from entering the canal. In addition to this, it will dissipate the energy of incoming water to ensure that flow in the system will be as designed. The slope of the trash rack will be 1:3 for all trash racks. Angle sections will be welded to form a single structure to form a trash rack.

3.1.5 Intake System

The water passes tangentially through the notched canal and flows around the basin and finds its exit at the hole at the bottom of the basin. The length, breadth, height and notch of the canal, top diameter of the basin and the exit hole at the bottom are the important parameter that should be considered in the design of basin and canal.

The design of basin and canal were for the flow rate of 180 l/s = 0.18 m^3/s.

The velocity of flow through the canal has been assumed to be 1 m/s.

Then the area of cross section is A = Q/v = 0.18/1 = 0.18 m^2

Let the width of the canal be 600 mm then the height of the canal must be 250 mm to prevent the overflow of the water we take factor of safety of 2.

Therefore, the height of the canal = 250*2 = 500 mm

3.1.6 Dam

A structure a like dam is already present in the existing structure. This will serve the purpose of increasing gross head and also accumulate water for the power production purpose.

3.1.7 Basin

The rotation tank for the GWVPP system shall be made up of the concrete structure. The site is risk-free from high floods since the flow is controlled throughout the year. The size of the concrete basin is designed to meet the requirement of head drop and flow in the hydropower. The basin would be strong and sufficiently waterproof to prevent the dynamic pressure and impact of flowing water in the basin.

The design of basin is based on the conical design proposed by (Dhakal, et al., 2015).

The diameter of basin at the top is 2000 mm.

For cylindrical basin, to maximize the power output, the range of orifice diameter to basin diameter ratios lies within 14–18%. (Mulligan & Hull, 2010).

Diameter at the bottom = 0.18*2000 = 360 mm

Height of the canal = 1 m

Height of the basin (conical part) = 900 mm

Total height of the basin = 670 + 900 = 1570 mm

Hence, the conical basin has been sized as per our research. The diameter of the cylindrical part is 2 m, and the exit hole is 0.36 m. The cone angle is thus about 40 degrees.

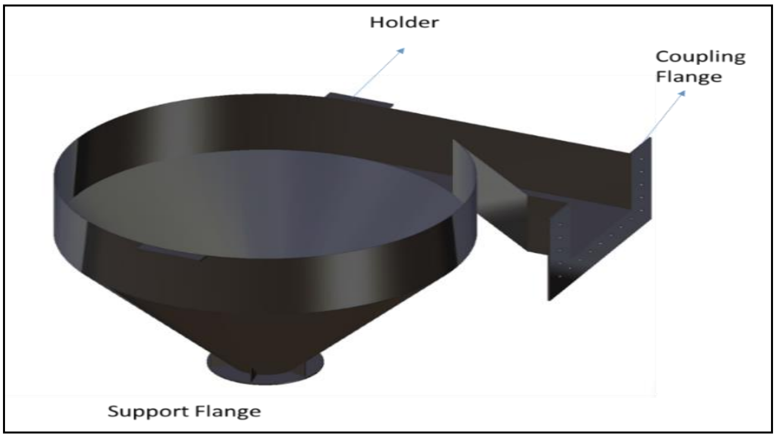

Figure 2: Conical basin with nomenclature

3.2 Mechanical components

The requirements of mechanical components are also greatly reduced in this system than that of Screw turbine system. Systems like flushing gates, penstock, valves, etc. are not necessary. The components required are:

3.2.1 Flow regulating gates

Two gates are proposed in the structure. One is placed at the intake of the turbine. This will regulate flow to the turbine and closed when turbine maintenance is required (which is very minimal). So, this gate will act like valves in the conventional type GWVHP systems. The other gate will regulate the bypass flow in the stream.

3.3 Turbine Runner

The runner is an important part of the GWVPP that is used to extract the power from the swirling water and convert it into the shaft power. Though runner of GWVPP is also an impulse type of turbine, it is different from generally available impulse turbine like cross flow, turgo due to the rotational flow of the water. The design of runner is based on the flow rate, head and position of the runner. Moreover, the design parameters of the runner are derived from the project done at Department of Mechanical Engineering Pulchowk Campus by Sapkota et al (Sapkota, et al., 2016). The design parameter used were inner diameter, outer diameter, height, inlet and outlet blade angle, tapered angle, number of blades, and impact angle.

Specification of the proposed turbine:

Type	: Gravitational Water Vortex Turbine
Turbine Shaft Power Output	: 1 kW
Turbine RPM	: 70 rpm
Shaft Orientation	: Vertical

3.3.1 Power Transmission and Drive system

The function of the drive system is to transfer mechanical energy from the Turbine shaft to the generator rotor at recommended speed. Hence, the rated speed of the turbine was taken to be 75 rpm and the generators rated mean speed is 1500 rpm. So, the speed ratio is 1:20. For this, a planetary gearbox with hardened gear teeth is recommended after consulting with the manufacturing companies. The gears might develop wear and fatigue after some period of operation. A self-oiling mechanism should be incorporated in the system with properly graded oil.

The design of shaft is based on design guidelines from Shigley's mechanical engineering design (Budynas & Nisbett, 2011). The mechanical power that the runner can produce and the speed at maximum efficiency are given by,

Power, P= 1 kW = 1000 W

Rotational Speed, N = 70 RPM → $\omega = 2\pi N/60 = 7.33$ rad/s

Then the torque produced by, Torque (T) = P/ω = 137 Nm

Taking factor of safety (n) = 3

The ultimate yield strength of the mild steed is S_e = 241 MPa and K_{fs} =1.58

The diameter of the shaft for the given torque is given by,

$$d = \left(\frac{32n}{\pi S_e} K_{fs} T\right)^{1/3}$$

$$d = \left(\frac{32*3}{\pi*241*10^6} * 1.58 * 137\right)^{1/3} = 30\text{mm}$$

The length of the shaft from the pulley to the bearing below the basin is 1550 mm.

The transmission system is needed if the shaft speed does not match with the specified speed of the generator. The design of transmission is based on design guidelines from Shigley's mechanical engineering design (Budynas & Nisbett, 2011).

The speed of Runner shaft = 70 RPM and the speed of generator = 1400 RPM

Gear ratio = 1400/70 = 20

Using flywheel as a transmission system, it is difficult to maintain gear ratio in single stage, therefore, it is suitable to increase speed in two stage and the near value of the two-stage gear ratio is given by,

$G_s = \sqrt{\text{(gear ratio)}} = \sqrt{20} = 4.47$

According to the market availability of pulley of the nearest gear ratio is 4.5 having diameter 4 inches and 18 inches. Hence, d = 4 inch =101.6 mm and D = 18 inch = 457.2 mm

Design of first stage:

The system has to operate under a low power then taking shock factor K_s=1.12 and Factor of Safety n = 1.2 and sheave pitch diameter of 5.4 inches = 137.16 mm. The type of V-belt used in the system be B93 as power is in range of 760-19000-watt range

$L_p = L + L_c = 93+1.8 = 95$ inch

The distance between pulleys C is given by,

$$C = 0.25\{\left[L_p - \frac{\pi}{2} * (D+d)\right] + \sqrt{\left[L_p - \frac{\pi}{2} * (D+d)\right]^2 - 2(D-d)^2}$$

$$C = 0.25\{\left[95 - \frac{\pi}{2} * (18+4)\right] + \sqrt{\left[95 - \frac{\pi}{2} * (18+4)\right]^2 - 2(18-4)^2}$$

C= 29.4 inch = 747 mm, then C is equivalent to 750 mm

Peripheral Speed of the belt V = πDN/60 = 1.67 m/s

$\theta_d = \pi - 2\sin^{-1}\frac{457.2-101.6}{2*750}$ = 2.66 rad

exp [0.5123(2.66)] = 3.9067

From the design data hand book for V= 1.67 m/s and sheave pitch diameter 106.8mm H_{tab}= 1.89Hp = 1410W

From the design data hand book for warp angle 2.66*180/ π =152.4 degree, K_1= 0.97 and K_2= 1.10

$H_a = K_1K_2H_{tab}$ = 0.97*1.15*1410 = 1573W

$H_d = H_{nom}\, K_s\, n$ = 1000*(1.5) (1.5) = 2250W

The number of belts is given by,

$N_b \geq H_d / H_a = 2250/1573 = 1.43 \rightarrow 2$

From design data hand book, K_c= 0.965. Thus, centrifugal force is given by,

$F_c = 0.965(1.67/1000)^2 = 2.69*10^{-6}$N = 0 N

$$\Delta F = \frac{63025 * 2250/2}{1750 * \left(\frac{18}{2}\right) * 746} * 4.45 = 26.85N$$

$$F_1 = 0 + \frac{26.85 * 3.91}{3.91 - 1} = 36.07N$$

$$F_2 = F1 - \Delta F = 36.07 - 26.85 = 9.22N$$

$$F_i = \frac{F_1 + F_2}{2} - F_c = \frac{36.07 + 9.22}{2} - 0 = 22.64N$$

Now factor of safety of the designed value is given by,

$$n_s = \frac{H_a N_b}{H_{nom} K_s} = \frac{1573 * 2}{2250 * 1.12} = 1.25$$

Since, the factor of safety is greater than 1 therefore, the designed values are safe.

Design of the second stage:

The process of design is the same as that of the first state but due to the change of distance between the two pulleys and speed that causes a certain alteration in the calculation. The system has operated under a low power then taking shock factor K_s=1.12 and Factor of Safety n = 1.2 and sheave pitch diameter of 5.4 inches = 137.16mm. The type of V-belt used in the system be B120 as power is in range of 760-19000 watt range.

Speed of second stage = 70*4.5 = 315 RPM

$L_p = L + L_c = 158+1.8 = 160$ inch

Distance between pulleys C is given by,

$$C = 0.25\{\left[L_p - \frac{\pi}{2} * (D+d)\right] + \sqrt{\left[L_p - \frac{\pi}{2} * (D+d)\right]^2 - 2(D-d)^2}$$

$$C = 0.25\{\left[160 - \frac{\pi}{2} * (18+4)\right] + \sqrt{\left[160 - \frac{\pi}{2} * (18+4)\right]^2 - 2(18-4)^2}$$

C= 61 inch = 1550mm

Peripheral Speed of the belt $V = \pi DN/60 = 7.54$ m/s

$\theta_d = \pi - 2\sin^{-1}\frac{457.2-101.6}{2*1550} = 2.91$ rad

$e^{[0.5123(2.91)]} = 4.44$

From the design data hand book for V= 7.54 m/s and sheave pitch diameter 170mm

H_{tab}= 2.605hp = 1943W

From the design data hand book for warp angle

2.91*180/ π =167 degree, K_1= 0.97 and K_2= 1.15

$H_a = K_1 K_2 H_{tab} = 0.97*1.15*1943 = 2167W$

$H_d = H_{nom} K_s n = 1000*(1.5)(1.5) = 2250W$

The number of belts is given by,

$N_b \geq H_d / H_a = 2250/2167 = 1.04 \rightarrow 2$

From design data hand book, K_c= 0.965. Thus, centrifugal force is given by,

$F_c = 0.965(7.54/1000)^2 = 54.86*10^{-6}N = 0$ N

$$\Delta F = \frac{63025 * 2250/2}{1750 * \left(\frac{18}{2}\right) * 746} * 4.45 = 26.85N$$

$$F_1 = 0 + \frac{26.85 * 3.91}{3.91 - 1} = 36.07N$$

$$F_2 = F1 - \Delta F = 36.07 - 26.85 = 9.22N$$

$$F_i = \frac{F_1 + F_2}{2} - F_c = \frac{36.07 + 9.22}{2} - 0 = 22.64N$$

Now factor of safety of the designed value is given by,

$$n_s = \frac{H_a N_b}{H_{nom} K_s} = \frac{2167 * 2}{2250 * 1.12} = 1.71$$

Since, the factor of safety is greater than 1.2 therefore, the designed values are safe.

Design of bearing

The shaft is supported on bearing due to the presence of different type of the load and torque involved the design of bearing should be executed to select the suitable bearing. The design of bearing is based on design guidelines from Shigley's mechanical engineering design (Budynas & Nisbett, 2011).

Inner diameter (ID) = 30 mm, Speed of the shaft = 70 Rpm and Torque transmitted = 137Nm

Application factor is taken as a_f = 1.2 and desired Life of bearing L_d = 10000 hour

Reliability of both bearing = 0.90Then the reliability of single bearing be at least $\sqrt[4]{0.90}$ = 0.97

The bearing at the top of the shaft was roller bearing and the bearing at the bottom of the shaft is a tapered roller bearing.

The maximum radial load that the bearings receive from the pulley is

$F_{rA} = F_1 + F_2 = 36.02+9.22 = 45.24N$

The maximum axial force that the bearing receives

F_{ae} = weight = 70*9.81 = 687N

Since the bearing at bottom receives thrust and bearing at top receives radial loading. Therefore, we select Ball Bearing at top of the shaft and tapered roller bearing at the bottom of the shaft. The dimensionless design life for cylinder bearing is

$X_D = 60L_Dn_D/L_{10} = 60*10000*70/10^6 = 42$

The catalog rating should be equal to or greater than

$$C_{10} = a_f F_D \left[\frac{x_d}{x_o + (\theta - x_o)(1 - R_D)^{\frac{1}{b}}}\right]^{1/a}$$

$$C_{10} = 1.2 * 45.24 * \left[\frac{42}{0.02 + 4.439(1 - 0.97)^{\frac{1}{1.483}}}\right]^{3/10}$$

C_{10} = 214 N

The absence of thrust component makes selection procedure simple. From the design data hand book a single row deep groove ball bearing C_{10} =4.49 KN having the designation of **61806** was selected.

For a selection of tapered roller bearing, F_{rA} is clearly less than F_{ae} lower bearing carries the net thrust load. Therefore, the dynamic equivalent load is,

$F_{eA} = 0.4\ F_{rA} + K_AF_{Ae} = 0.4*45.24+1.5*687 = 1050N$

The catalog rating of the tapered roller bearing must be equal to or greater than,

$$C_{10} = 1.2 * 1050 * \left[\frac{42}{4.48(1 - 0.97)^{\frac{1}{1.483}}}\right]^{3/10}$$

C_{10} = 5.012 KN

From design data handbook the single row tapered roller bearing having C_{10} = 35.8KN having the designation of **32006 X/Q** was selected.

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3.4 Electrical components

3.4.1 Generator

An induction motor can be used as a generator in micro hydro installations as it doesnot have brushes or other parts that need maintenance and is less expensive. Capacitor banks are required for generating reactive magnetizing current in order to create rotating field.

An asynchronous induction generator of 3 phases is designed for this scheme and the specifications are as follows:

Capacity: 1 No of 1.5 kW

Type: Squirrel cage generator with delta connected capacitor bank

No of Phases	: 3
No of poles	: 4
RPM	: 1500
Connection	: Delta
Frequency	: 50 HZ
Efficiency	: 85 %

The generator has been sized considering the nature of the ELC, the power factor, altitude correction factor and temperature.

3.4.2 Governing system

The governing system in power generation matches the load with the generation so that there is no imbalance. Governing can either be achieved by controlling the inlet water flow to the turbine or by controlling the power output (Alternate Hydro Energy Centre, 2002), (Thapar, 2002). The governing system used in GWVHP is non-flow controlling type i.e. use of dummy load to dissipate the unused power. Induction generator controller and ballast load are used together in order to maintain the regulated voltage level and frequency by maintaining a nearly constant load on the generator. Switching of ballast load takes place accordingly based on the load consumed by the targeted customer. The excess load is supplied to ballast load thus maintaining voltage level and frequency. Main voltage level, Ballast voltage level, load current and Energy meter are integrated on an induction generator controller for the purpose of monitoring of generation unit.

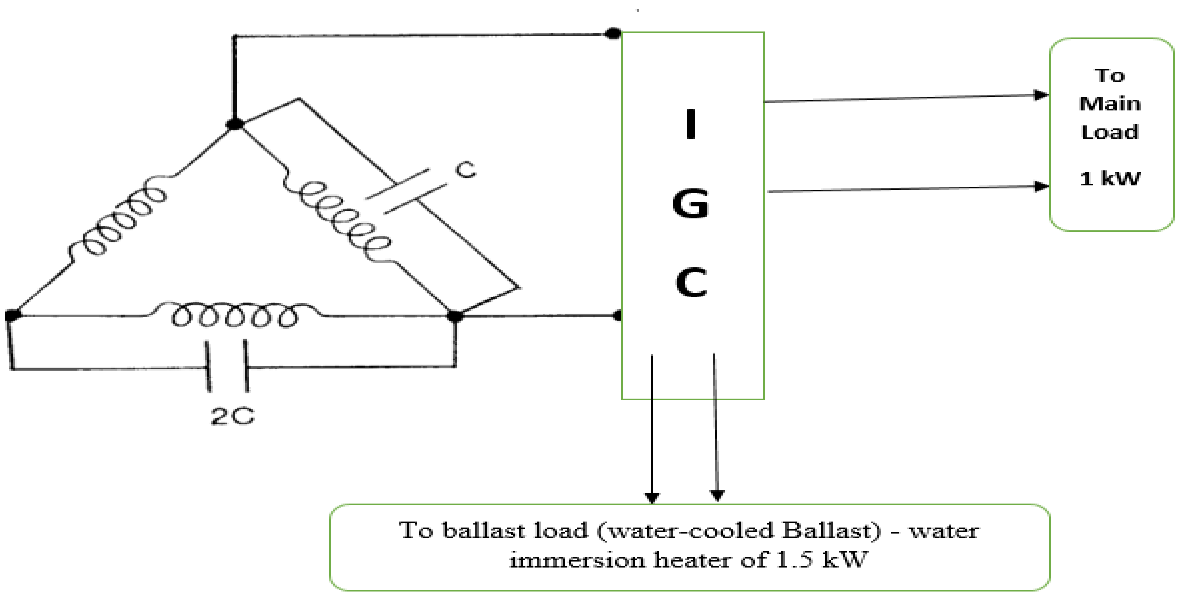

Figure 3: Governing system used in GWVHP

3.4.3 Control and protection system

125 Ampere TP MCCB is provided for short circuit protection. In addition to it, over/under frequency relay, over/under voltage relay and overcurrent relay provides a signal to contactor on undesired situation thus isolating the generation and distribution units. For the connection of the generator to the main panel board, Induction generation controller and Ballast, it is recommended to use 70 mm^2 armored copper cable. 95 mm^2 aluminum cables will be used to connect the powerhouse and the first pole of the transmission line. All the electrical components should be checked before the energization of the system.

3.4.4 Earthing

The purpose of earthing is to protect the electromechanical equipment from lightning. There will be two earthing sets in powerhouse for the protection of equipment's and remaining earthing sets will be required in the transmission and distribution. Copper plate earthing of size 600 mm x 600 mm x 3 mm connected by Copper wire 8 SWG, would be used for all earthing. The earthing pit would be minimum of 3 m depth filled with alternate layers of salt, fine silt and charcoal.

3.4.5 Transmission and distribution

This generally includes the part from first pole supplied from control unit to the end uses. The span of distribution lines depends on the distance of load from the source. The distribution can be single phase or three phases depending on the load. In this case, the end loads are mills which require three phase power hence, the distribution line being three phase four wire systems. The details of distribution are as follows: -

Distribution voltage : 400 V line to line

Distribution Type : Three Phase Four Wire

Insulator : Shackle insulator

Pole : 8-meter Tubular Steel Pole

Length of Transmission Line: 400 m

Distance between poles : 45 m

No. of Poles : 10

Other Accessories : Stray Wire

3.4.6 Insulators

Shackle type insulators have been proposed for this system, which are common for low voltage distribution system. Shackle Insulators are used at the end of distribution lines or at sharp turns where there is excessive tensile load on the lines. These insulators can be mounted either in the vertical or horizontal position.

3.5 Estimation of Work Volume

The quantities have been estimated and presented in Table 1 for civil components, Table 2 for mechanical components and Table 3 for electrical components.

Table1: Quantity Estimate of civil components

S. N.	Civil Work	Unit	Surface Area	Depth	Total Volume	Remarks
1	**Site Clearance**	sq.m	200			Site clearance around site
2	**Foundation Excavation Work**					
	Part 1		14	0.7	9.8	
	Part 2		20.8	0.3	6.24	
	Total	cu.m			16.04	

	Stone Pitching / Soiling Work	cu.m			15.14	
	Brick Work (Foundation Part)	cu.m			0.9	
3	**Brick Wall around periphery**	cu.m	23.15		5.55	Outer Wall (9.2+9.2+4.75)
4	**Stair Case**					
	Brick Wall				2.876	
	Filling Work	cu.m			7.348	
	PCC Work	cu.m	4.852	0.05	0.4852	0.11*11+2.32+ 0.11+1.212
5	Support Wall (Brick), beside drop Chamber	cu.m			1.5	Two numbers
6	Filling work in drop chamber and side chamber civil work	cu.m			5.3	
7	The top layer of Chamber PCC Work	cu.m			0.88	
8	RCC Wall	cu.m			0.6	
9	Guide Wall (Brick)	cu.m			0.6	
10	Tailrace (PCC)	cu.m			0.52	

Table2: Quantity Estimate of mechanical components

S.N.	Description	Unit	Quantity
1	Vortex Runner with shaft and bearing and induction generator to be fixed in the frame as per drawing	Set	1
2	Pulley system as per drawing	Set	1
3	Trash Rack	Nos	2
4	Sluice Gate	Nos	2

Table3: Quantity Estimate of electrical components

S.N.	Particulars	Specifications	Unit	Quantity
1	Three Phase Induction generator with a capacitor bank	Induction generator: rated to continuously deliver 1.2 kW, 230/400 volts, 50 Hz, 1500 rpm, 3 phase, Capacitor excited, Connection Star, Insulation class F, Environmental Protection: IP 23	set	1
2	Ballast Load (Dumped load)	Three phase resistive ballast load of 1.2 kW, with a resistive heater (air heater type with a frame)	lot	1
3	Three phase Induction generator voltage controllers	1 kW, 3 ph, 230/400 volts, with monitoring meters with main volt, ballast volt, load current and energy meter	set	1
4	Protection Devices	Over/ Under voltage, Over/Under Frequency and Over Current by the contactor	lot	1
5	Cable	25 mm^2 4 core copper armored cable, for interconnecting generator, control panel,	m	25

		ELC, ballast, sensors etc., all complete		
6	Earthing Arrangement (Plate Earthing)	8 SWG copper earth wire, 3*600*600 mm copper plate as earth electrode with necessary coal, lime, salt, nut, bolts, washer etc. all complete.	Set	5
7	Main Distribution Board	HRC fuse type, 3 phase 63 amp, including MCCB with 10 kA breaking capacity	Set	1
8	Distribution Poles	6 m HT 3 Phase, Electric Pole 1 fold, 2 bolt joint, At Top 125 mm OD, thickness 3 mm and 3 m long, At Bottom 125 mm OD, thickness 3 mm and 3 m long	Nos.	20
9	ACSR Conductor	Squirrel	m	1970
10	Shackle Insulators	Medium size shackle insulator (600gm), Dimension (75 mm x 90 mm) applicable in Weasel and Rabbit Conductor	Nos.	60
11	Stay set	5/8"x1500 with plate size of 5 x 250 x 250 mm (Stay wire size 7/14)	Nos.	12
12	Lightning arrestors: with necessary stand and accessories, all complete	Three Phase, 0.5kV, 50HZ with ISO 9001 Certified Manufacturer.	Nos.	7
13	Service cable	3/18 cable for connecting from distribution pole to household	m	160

3.6 Estimated Cost of Development

The quantity estimate done was circulated to three different manufacturers/ developers and the lowest quoted by them are selected and listed in Table 5.

Table 5: Estimated cost for development of Vortex Turbine system

S. No.	Description	Cost
1	Civil Works	640,064.00
2	Mechanical Works	148,000.00
3	Electrical Works	215,100.00
4	Tools and Spare Parts	42,000.00
5	Transportation Cost	300,000.00
6	Site Supervision	300,000.00
	Sub - Total	1,645,164.00
	VAT 13 %	213,871.32
	Contingency (5 %)	82,258.20
	Grand Total	1,941,293.52

Thus, the total cost of development of the system is around 19.5 Lakh Nepali Rupees. Considering a flat rate tariff of NRs. 10 per kWh, and 10 hours of daily operation, the revenue collected from power sold will only be NRs. 100 per day, thus monthly income of NRs. 3000 only. With this much amount per month as revenue, the system can be rendered infeasible.

However, considering the research and development aspects of the turbine system, it is much necessary to develop the system. The constructed system will reveal information about the technical feasibility revealing the technical problems that arise due course of operation of the system. It would be recommended to develop the system as research project with power being sold to generate revenue for operation purpose of the system.

4. CONCLUSIONS

On the basis of above study, it can be seen that the cost of development of the turbine system is very large. As the system is only of 1 kW, the system needs to be developed as research-oriented pilot project only. It was found that the major share of the total cost is on the civil part and is in transportation. Locally constructed equipment and construction using locally available materials might lessen the total cost of the system. Furthermore, installation of this project shall open door for installation of scaled up scheme that can generate significant amount of power.

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