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DESIGN, LOCAL MANUFACTURING, DEVELOPMENT AND INSTALLATION FOR PRACTICAL DEMONSTRATION OF VERY LOW HEAD MICRO HYDRO POWER PLANT AT CANAL IN PAKISTAN

PROF. DR. ENGR. S. M. BHUTTA

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By:

Prof. Dr. Engr. S. M. Bhutta

Faculty of Engineering & Technology International Islamic University, Islamabad

Abstract

In order to harness thousands of very low head hydroelectric potentials in the vast irrigation networks of canals and streams, we have designed, developed and demonstrated low head hydel turbine of 1.5 meter head near UET, Taxila. Now we are designing to locally manufacture very low head turbine of 1 meter head as these are not available anywhere in the world. Its necessity is dictated by the fact that I have been given LOI at Jhang Branch Canal, where head is one meter and even low. This success story will become a role model for the development of thousands of sites for rural electrification by indigenous clean, cheap and environment friendly resources.

I have also proposed to permit me to establish a Centre for Renewable Energy in order to carry out R, D&D of various types of hydel turbines & other renewable energy indigenous resources. This would help to overcome the biggest barriers in development of our 60,000MW hydel and Millions MW of Solar and Ocean potentials by addressing five E's e.g. "E" Education, "E" Energy, "E" Employment, "E" Equity and "E" Enterprise.

Introduction:

We have carried out lot of paper work, speeches, presentations for the development of hydel power in Pakistan, but our main objective is to have a product oriented R&D, design, manufacturing, installation of very low head hydel turbine to be a role model for rural development by practically demonstrating to generate electricity. I am happy to confirm by introducing this type of very low head hydel turbine at canals, streams are going to be achieved.

Therefore we are addressing five E's e.g. "E" Education, "E" Energy, "E" Employment, "E" Equity and "E" Enterprise. Through these humble efforts to get rid of menace of load shedding. Long awaited opportunity is blessed as I have been able to get LOI when Chief Minister of Punjab asked the Engineers to come forward to help to overcome load shedding during his speech at the 44th Convocation & International Seminar "Energy problems in South Asian Countries- Causes & Solution" held on 23&24 November 2011 at Lahore, organized by the Institution of Engineers of Pakistan. I had requested to Chief Minister to help me to get Letter of Interest (LOI) as Private investor because I had deposited required fee and feasibility report as per Govt. policy in September 2007. Inspite of my best efforts and promises of Punjab Power Development Board Officers, I was not issued LOI. It was kind of Chief Minister to get me LOI on 27 November 2011. The remarks of Secretary Energy (Mr. Rab Nawaz) are very encouraging as repeated below:

"Keeping in view, Dr. Bhutta's experience and stature, his request for allocation of site for the development of Low Head Hydel Plant should not be assessed on the standard parameters applicable to Private Sector Investors. We should use his expertise and commitment to develop prototype for low head Generation that can be used for our plants for community based small hydel generation units. Based on that, the site mentioned at Para-10 may be allocated to him for development of his pilot as a non-commercial enterprise for self consumption or community use.

The processing fee paid by him may be considered against this project and a letter of Interest (LOI) may accordingly be issued"

LOI issued indicated two very low head RD216+852 and RD260+000 at Jhang Branch Canal near Chiniot & Faisalabad.

Selection & Design of Turbine:

Keeping in view estimated head H as 3.82 ft and water discharge as 2367 cusec average provided by PPDB, Irrigation Engineers at RD216+385, our initial concept is to select and design very low head micro hydel Kaplan's type of turbines for RD216+385 of Jhang Branch. Similarly in the case for RD 260+000 Jhang branch where Head is only 2.86 ft and average water discharge 1988 cusec. Based upon our experience of design and manufacturer and successful demonstration of 1.3m head 2KW and 1.5m head 8KW during 2005, now we have selected very low head Kaplan's type turbine because head 'H' is very low 0.88 m and to 1.16 m but water is very high about 2400 cusec at our sites.

The features of this type of Kaplan turbines ensure a wide application according to our specific needs. For optimal utilization of information available Kaplan turbines have a flat efficiency curve resulting in a high output also at part load. Under more constant flow conditions, the Kaplan turbine with fixed distributor is a cost-effective alternative (e.g).

- Proven lent improvement based new concept.
- Completely to design and manufacture and assemble locally turbine-generator unit including belt and gear drive for immediate installation.
- Better-regulated turbine for optimal exploitation of available energy.
- Flat efficiency curve for high output and outstanding part load characteristics.
- Very low operating noise level.
- Compact, simple intake and outflow structures to reduce construction costs.
- Single-source engineering to minimize interfaces.
- Quality Assurance Programme

Generating Potential and Turbine Parameters

The total generation potential at RD 216+852 are calculated as 456 Kw and at RD260000 as 285 Kw. The Turbine selected at such a very low head is a Kaplan type and its runner dia comes to about 6 meter and speed 7 rpm for site RD 216+852 while in case of RD 260+000 the turbines runner dia is about 5.5 meters. Such a big turbine is difficult to manufacture and is not possible to be installed at the existing structure of the canal. Therefore keeping in view the existing infrastructure we have decided to design and install the separate turbines on each forebays of canal. In case of RD216+852 it is assumed that water will be equally distributed in the 8 forebays and in case of RD 260+000 water will also be equally distributed in 6 forebays.

Based upon this situation the very low head each turbines calculation shown in table I & II, in case of RD216+852 for the head 3.82 feet (1.16 m) and water flow in each forebays is about $8.2M^3$, so generation capacity is about 56Kw, speed 20 rpm and similarly for the other site of RD 260+000 where head = 2.85ft (0.868 m) and flow of water Q = $9.2M^3$, so P = 56Kw. In case of 56kw Kaplan turbine its runner dia comes to 2.2 meter so this can be manufactured locally. Some of the manufacturers have agreed to carry out their construction based upon our design and specifications as given below.

Table – I: Computation of Parameters RD 216+852

B	C	D	E	F
	Q 8.2 meter ^3 and head 1.16 m			
Power	Only Change the green cell			
Head in meter	H		1.16	m
Flow lit/sec	Q	8.2	8200	lit/sec
Effic		0.6	60	%
Power output in Kw	**P**		**55.93056**	kw
Dia of Runner		2.2	2200.0	mm
			com	
Velocity				
V			**1.444991**	m/sec
Dia of Penstock Pipe			**2688.682**	mm
RPM of Turbine	N		**20.07198**	rpm
Turbine & Generator Pulley				
Dia of Generator		0.3048	12	inches
Speed of Generator			1500	
Speed of Turbine			20.07198	
Dia of Turbine pulley		22778.02	896.7726	inches
Ratio of Turbine pully to Generator pully		74.73105	less than 6 is ok	

Table – II: Computation of Parameters RD 260+000

	Q 9.2 meter ^3 and head 0.88 m			
Power	Only Change the green cell			
Head in meter	H		0.868	m
Flow lit/sec	Q	9.2	9200	lit/sec
Effic		0.6	60	%
Power output in Kw	**P**		**46.95533**	kw
Dia of Runner		2.5	2500.0	mm
			com	
Velocity				
V			**1.24996**	m/sec
Dia of Penstock Pipe			**3062.041**	mm
RPM of Turbine	N		**15.27931**	rpm
Turbine & Generator Pulley				
Dia of Generator		0.3048	12	inches
Speed of Generator			1500	
Speed of Turbine			15.27931	
Dia of Turbine pulley		29922.82	1178.064	inches
Ratio of Turbine pully to Generator pully		98.17198	less than 6 is ok	

Turbine Parameters

The following turbine parameters are recommended for manufacturing.

		At RD 216+852	At RD 260+000
Rated discharge Total	Q	$67M^3$	$55M^3$
Rated discharge for each turbine	Q	$8.2M^3$	$9.2M^3$
Runner Dia		2.2 m	2.5 m
Rated net head	H	1.16 m	0.88 m
Rated turbine speed	n	20 rpm	15 rpm
Rated generator speed	n	1500	1500
Rated each turbine output	P	60 Kw	60Kw
Maximum turbine output	P	66 Kw	47Kw

Turbine, water control system, gear, belt drive and generator and controls, electrical panels form a complete and compact unit which is to be delivered fully assembled and works-tested. Installation at site is to be achieved in only one embedding of canal closure phase into complete powerhouse thus drastically reducing erection time and costs.

The higher power concentration achieved with these compact turbines likewise reduces construction and O&M costs. Minimal powerhouse dimensions with simple intake and outflow contours substantially reduce overall expenditures. Therefore our estimated cost of electrical generation is quite low of all turbines have a power–speed characteristic, and an efficiency-speed characteristic. For a 3.82 ft particular head they will tend to run most efficiently at a particular speed, and require the particular flow rate of big discharge for very low head. We have selected and designed these Kaplan type turbine based upon the following pre-engineering activities:-

a) Desk study + Review of international experience

b) Sketch from map and photographs

c) Interviews reports and discussions

d) Previous experiences of our R&D of Kaplan turbines

e) Information and quotations from abroad

f) Local Manufactures workshops and facilities discussed at their shop floors.

Technical Feature of Proposed Very Low Head Turbines

As shown in the sketches and drawings of this type of turbine consists of a propeller similar to a ship's propeller, fitted inside a housing conned with the penstock water inlet, its shaft taken out where the tube changes direction. Four blades will be used, because of very low head. Water flows is regulated by use of wicket gates just upstream of the propeller. The part-flow efficiency characteristic tends may be poor. This turbine is a fixed-blade turbine, since the profile geometry of the blade does not change. The blades are profiled to optimize the effect of pressure lift forces acting on it, so that blades offer best efficiency but are more easily

fabricated. This kind of design is considered economical for micro-hydro to optimize for low cost and ease of fabrication being the priorities.

The effective head driving the runner will be increased by the inducement of a partial vacuum inside the easing. This is done by fitting a draught tube below the runner which remains full of tail water at all times. Any decrease in the level induces a greater vacuum which is limited by the use of an air bleed valve in the casing.

Draught Tube's Importance

The proposed turbines will benefit from an enclosure below the runner known as draught tube. One purpose of the draught tube is to maintain column of water between the turbine outlet and the downstream water level. The second purpose is the recovery of velocity energy or kinetic energy in the water leaving the runner. Since water has to leave turbine runner at a relative high velocity in order to exit from the turbine, it still possesses a substantial proportion of the available kinetic energy. To recover this energy efficiency, the water velocity must be reduced gradually while friction losses are minimized. If the velocity is not reduced, water would jet out of the turbine outlet into the trail race and energy would be lost as turbulence in the tailrace.

This recovery of velocity head will be obtained by a gradual increase in the cross-sectional area of the draught tube, resulting in a gradual reduction of the velocity. In general the diameter of tube outlet is about twice that of its inlet, and the angle between opposite walls of an expanding draught tube should be 7^o and 20^o to give optimum energy recovery. Manufacturers will be given design to supply a correct draught tube accordingly to our detailed specification for the construction. The draught tube usually contains pressure below atmosphere (a partial vacuum) so the outlet must remain below the water surface at all times to prevent air from being sucked into the tube and displacing the water column. The difference in level between runner exit and tail water level is called the static suction head.

The use of draught tube with turbines requires knowledge of a cavitation limits. The turbine manufacturer will be advised on correct position of the runner above and below tail water level to avoid cavitation. In short, the maximum allowable distance in meters between the runner and tail water level (Z_{max}) is given by

$$Z_{max} = H_a - H_v - o_{TC}H$$

Where H_a is atmospheric pressure expressed in meters. H_v is the vapor pressure in meters of water at the site water temperature, H is the net head in meters, and o_{TC} is value which the manufacturer can provide. Z_{max} will be positive in case where the runner will be positioned below this value of Z_{max} as cavitation is to be avoided.

Power Plants Parts and Components to be Locally Manufactured and Assemble

In take unit

Stop log and gates, trash rack, trash rack cleaner

Turbine

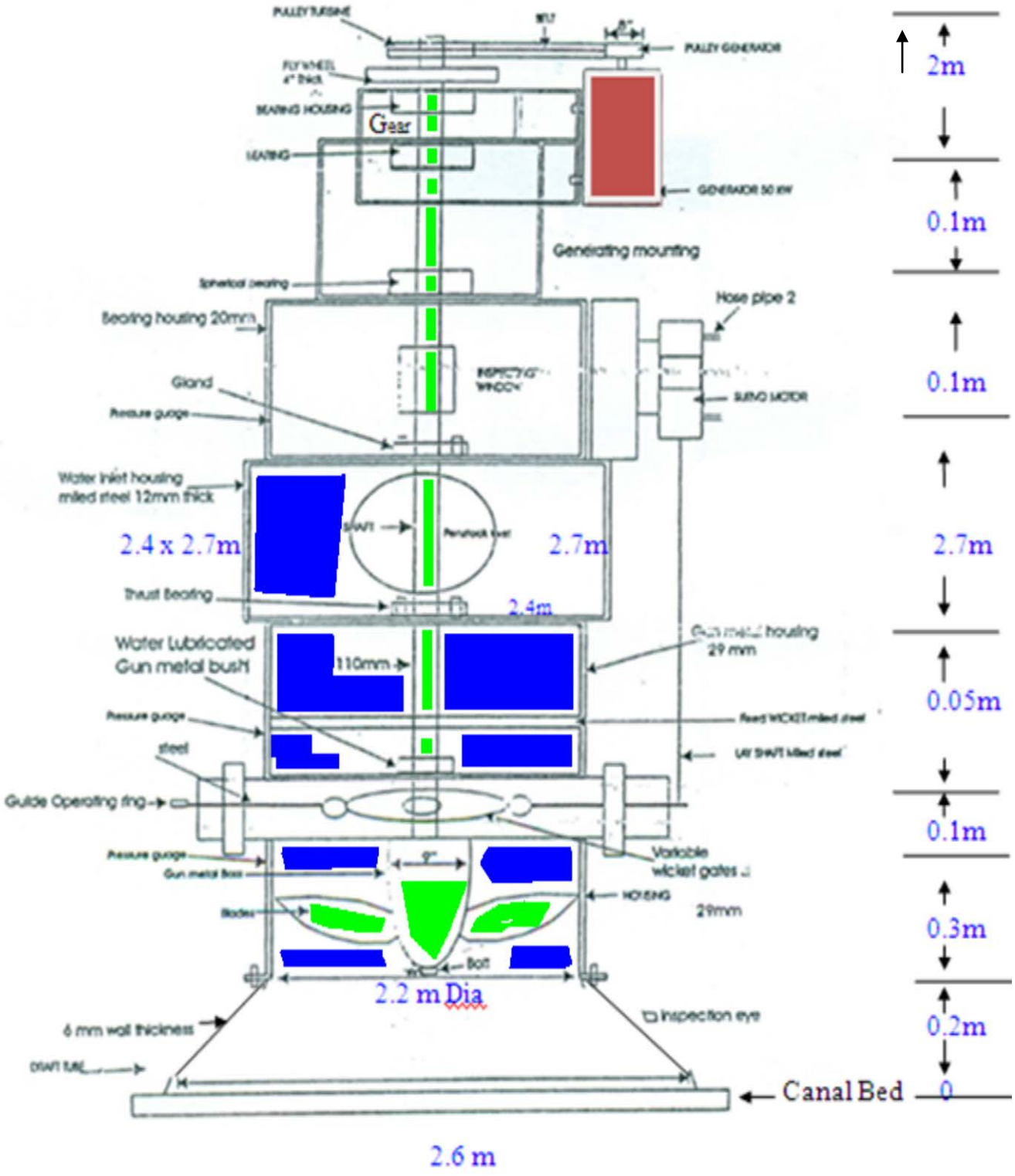
Rotor housing, dismantling joint, draft tube, bearing, wicket gate

Governor

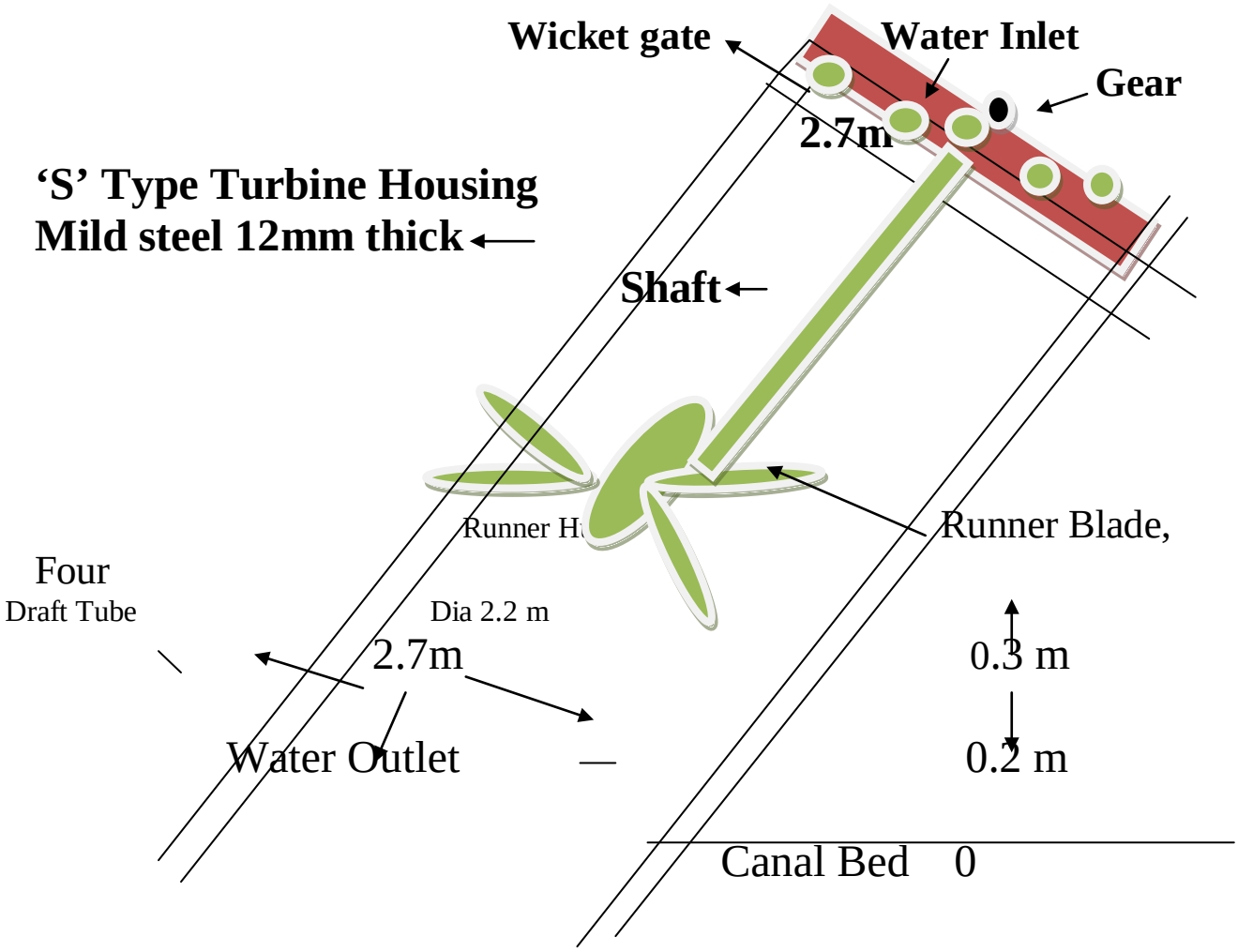
As and when if required

Pulleys & Gears

Turbine side pulley, generator side pulley, electrical generators, panels, synchronization system, electrical cables and power dispersal arrangements



Drawing of TURBINE and SYSTEM for Electrical Generation



Conceptual Design of Very Low Head Hydro Turbine

Technical Description of Very Low Head Turbine

Brief technical descriptions given to manufacturers:-

1. **Turbine housing:** S type mild steel, welded, consisting of intake channel tube with connecting flange and cleaning opening, with bearing brackets and generator based frame with gear, pullies, belt tensioning device, external intake channels, gate, internal guide vane, bearing housing, all connecting flanges to be machine-faced.
2. **Turbine shaft:** Carbon steel or other suitable material and size
3. **Turbine Shaft Bearing:** Low-maintenance grease lubricated roller bearings, the main bearing on pulley side to consist of axial and radial bearing, guide bearing on the runner side, including all lubricating conduits.

4. **Bearing sealing:** Guide bearing sealed by means of a sliding ring seal
5. **Runner blades:** Special profile mild steel or gun metal four blades fixed on the runner hub by means of attachment screws or welded.
6. **Runner hub:** Mild steel or gun metal to house the runner of 2.2m
7. **Guide vans:** Three-dimensionally bent, made of Spherodical iron.
8. **Discharge ring:** Spherodical iron or steel
9. **Draft Tube cone:** Mild Steel, welded, S type partly straight, with dismantling flange and inspection eye.
10. **Gate & valve:** To be installed for the closing of the water flow and discharge of the turbine intake flange, including hand lever, gate for channel and valve if required.
11. **Gear and Belt drive:** Suitable gear and pullies and belt with leather-coated running surface; pully made of steel.
12. **Corrosion protection:** All connecting elements in contact with water to be made of rustproof material. As far as steel parts are not galvanized, all the polished surfaces to be derusted by sandblasting. All the steel parts in contact with water to be provided with two priming coats of zinc dust (2x40 my) and with three antifouling top coats based on Epoxy-pitch. The surfaces in contact with air are provided with two priming coats of zinc dust and two top coats with Epoxy-two components lacquer.

Conclusion:

There are no commercially available very low 1m head hydel turbines throughout the world to use for the development of our site of very low head hydel potentials. Therefore based upon our seven years of R, D&D experience of 1.3 meter head of 2KW and 1.5m head 8KW hydel power plants, we have plans to get our 1 meter head hydel turbine to be locally manufactured. Based on our design. Our team is fully confident to develop, manufacture and install at our allocated site of very low head hydel 1 meter fall so that Pakistani Engineers take lead in the world.

I request to all the engineers and community to guide me and pray for our success so that we give a gift as a role model to harness the thousands of hydel sites in canals and streams for the cheap and clean electricity for rural development by implementing five E's e.g. "E" Education, "E" Energy, "E" Employment, "E" Equity and "E" Enterprise.



Locally Design and Manufactured Very Low Head 1.5 meter
8 KW Micro Hydro Turbine



Locally Fabricated Blades of 1.5 meter
Very Low Head Kaplan Turbine