Study to Assess the Resource Potential and Planning for a Demonstration Project using Run of River Submersible Water Turbine

Study Report

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Foreword

Energy is the driving force for every activity of today’s life but its economical and pollution free availability is a big challenge. South Asian region is blessed with diversified energy a resource which needs exploration and exploitation. One of these energy resources is the hydel water.

The potential energy available in the water is being harnessed all over the world since long but the kinetic energy available in the flowing streams of water in the canals, rivers and ocean remain neglected which is now gaining attention in modern world. The way to harness this untapped energy is through submersible turbines or water current turbines, also called hydrokinetic or in-stream turbines. These turbines have been increasingly receiving interest in many parts of the world. They generate power from the kinetic energy of a flowing stream of water without the use of a dam or a barrage. Water current turbines can be installed in any flow with a velocity greater than 0.5 m/s. Because of low investment costs and lack of frequent maintenance, this technology is cost effective in comparison to other technologies. These turbines are environmentally friendly, as these have very nominal impact on the surrounding ecology. The run of river submersible turbines can be a solution for power supply in remote areas. Because of their low cost and durability, SAARC member states can manufacture or import and deploy the technology to supply the electricity to small communities living near potential locations.

In this in-house study the resource potential of upper Jhelum canal has been assessed and presented. The planning for the deployment of a 5kW floating type submersible hydel turbine at selected site has been made. In next phase, the turbine will be installed and performance studies will be conducted at various flow levels and water velocity variations etc. to ensure its suitability and reliability. Moreover, up scaling of this study report for SAARC Member States have been proposed.

(Muhammad Naeem Malik)
Director SAARC Energy Centre

Acknowledgements

This study was an outcome of the physical as well as intellectual efforts of SEC team members, without which the study might not have been completed. The team members include Mr. Muhammad Naeem Malik, Dr. Shoaib Ahmad, Mr. Salis Usman, Mr. Ahsan Javed, Mr. Suresh Shresta, and Mr. Arshad Muneer.

Moreover, I would like to thank Dr. Abid Ali, Dr. Iqbal Memon and Mr. Asim Shahzad, who helped from start to end at every stage for the completion of this study.

I would also like to acknowledge Secretary Power Board Punjab, Secretary Irrigation Punjab, I/C Nandipur Hydro Research Centre, XEN and SDO Jhelum Circle; as they extended full support in the provision of data and all relevant resources from time to time.

I would also extend thanks to Mr. Fraz Khan, Director Planning, Chief Engineer, XEN and SDO from PEDO for the provision of useful information regarding Machai Canal. Acknowledgement is also due for Mr. Malik Nadeem Awan and Mr. Rashid Malik, who provided the access to, and necessary information about the turbine available with them.

Finally, I am very grateful to Mr. Iftikhar Ahmad Randhawa, Chief Engineer Punjab Energy Development Board, for reviewing this study report and incorporation of very valuable inputs.

Dr. Muhammad Nawaz Akhtar

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Abbreviations and Acronyms

Abbreviation:	**Explanation**
AC	Alternative current
AEDB	Alternative Energy Development Board, Pakistan
AGMA	American Gear Manufacturer`s Association
BR	Brown Red wire color coding
BRG	Brown Red Green wire color coding
EIRR	Economic Internal Return Rate
EPC	Engineering procurement construction
GmbH	A German company with limited liability (Limited Coy)
IESCO	Islamabad Electric Supply Company
KHPS	Kinetic hydropower system
kW	Kilo Watt
kWh	Kilo Watt hour
KVr	Kilo Volt ampere (reactive)
M	Meter
M3/s	Cubic meter per second
NPW	Net Present Worth
NEPRA	National Electric Power Regulatory Authority of Pakistan
NTDC	National Transmission and Dispatch Company
MW	Mega Watt
MWh	Mega Watt hour
O&M	Operation and maintenance
PEDA	Punjab Energy Development Agency
PEDO	Pakhtoonkhawa Energy Development Organization
PF	Power Factor
POSIT	Programme to successfully implement technology transfer

PPDB	Punjab Power Development Board, Pakistan
PPIB	Private Power Infrastructure Board, Pakistan
RD	Reduced distance (Short Ft.)
RY	Red Yellow wire color coding
RPM	Revolution per minute
SAARC	South Asian Association for Regional Cooperation
SOP	Sequence of Operation
UJC	Upper Jhelum Canal
USD	United states Dollar
YB	Yellow Brown wire color coding

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EXECUTIVE SUMMARY

The Study to Assess the Resource Potential and Planning for a Demonstration Project using Run of River Submersible Water Turbine has been conducted to determine that if and how much renewable electrical power could be generated on commercial-scale, from the kinetic energy of flowing water in the canals and rivers in Pakistan and its up scaling for rest of the SAARC member states.

To start this study, a desktop survey was conducted to explore the resource potential of rivers and canals in Pakistan; 10 rivers and 55 canals were thus identified. In order to enhance the vision and select the most appropriate site, three of these canals were personally visited along with IST team e.g. Upper Jhelum Canal, Ghazi Barotha Canal and Machai Canal to explore their potential.

During the initial survey of these three canals, it was found that Ghazi Barotha Canal has outstanding characteristics. It originates from Indus River (Ghazi) with a water flow velocity of 1.8 m/s, depth of 9 m and width of 100 m while it runs for 52 km. But the problem with this huge resource potential was that it is a power canal already producing 1,450 MW and supposed to be less accessible for research interventions.

The Upper Jhelum Canal was visited and after initial survey, it was found that this canal originates from Jhelum River at Mangla Dam with a water flow velocity of 1.12 m/s, depth of 2.86 m, width of 68.6 m and runs for 127.4 km.

Similarly, Machai Canal was visited which originates from Swat River with a water velocity of 1 m/s, depth of 2 m, width of 6 m and runs up to 42 Km. This canal has a good resource for potential energy, due to which Khyber Pakhtunkhwa Development Organization (PEDO) commercialized its power potential resource and till now, one hydel power plant of 2.6 MW and another with 1.5 MW capacity are in operation and two more are in construction phase. Resource potential of kinetic energy also exists but it is of low value due to exploitation of potential energy. Moreover, to avoid erosion of canal banks, the velocity of water has been reduced by creating steps in the canal at different locations.

Hence, Upper Jhelum Canal was selected to calculate the total theoretical resource potential. Office of the XEN Irrigation Jhelum was visited to study the L-Section of the Upper Jhelum Canal and important parameters were studied and collected. During this effort it was observed that there are two water flowing velocity levels in this canal, one under the bridges at 4 level-water crossings with a measured velocity of 3.6 m/s and the other in the rest of the canal with a velocity of 1.22 m/s.

Therefore, resource potential of this canal considering the kinetic energy of flowing water was calculated at different locations. The total theoretical resource potential was found as **44.66 MW**, Technical Potential of **13.38** MW and an Economic Potential of PKR 1005 Million annually which is

a reasonably attractive figure and needs exploitation of this huge resource to be harnessed with proper planning and execution of a pilot project to demonstrate the technology to convince all the relevant stake holders as well as realization of the concept, accordingly.

This study also presents planning method for the installation and demonstration of a project by using run of the river Submersible water Turbine employing kinetic energy of water. For this demonstration project, a 5 KW submersible water turbine made by Smart Hydro Power GmbH is identified.

Moreover, up scaling of this study report has been proposed for each of the SAARC Member State, where applicable, by customizing UJ Canal, a success story.

At the end of this study, conclusions and recommendations have been added to move further in this direction.

Dr. M. Nawaz Akhtar

Chapter: 1 INTRODUCTION

1.1 BACKGROUND AND PURPOSE OF THE STUDY

Water current turbines, also called hydrokinetic or in-stream turbines, have received a growing interest in many parts of the world. These turbines generate power from the kinetic energy of a flowing stream of water without the use of a dam or a barrage. Water current turbines can be installed in any water body with a flow velocity greater than 0.5 m/s. Because of low investment costs and lack of frequent maintenance, this technology is cost effective in comparison to other options. Throughout the globe many different concepts have been developed to utilize power of water streams. Submersible turbine is one of those concepts. These turbines are environmentally friendly, having very nominal impact on the surrounding ecology. The run of river submersible turbines can be a solution for power supply in remote areas. Because of their low cost and durability, SAARC member states can utilize this technology to supply the electricity to small communities living near feasible locations.

The energy flux from the water stream is dependent on the various parameters, including density, cross-sectional area and velocity cubed. The best performance is achieved from smooth linear flow of water at high velocity. The flow characteristic of a river stream can vary on seasonal as well as on daily basis. So, determination of resource potential to select suitable site for installation is a pre-requisite.

In this in-house study, proposed under SEC thematic area of Programme to Successfully Implement Technology Transfer (POSIT), the resource potential of a nearby canal named Upper Jhelum Canal, originating from Mangla Dam has been assessed and deployment of a submersible Hydel Turbine at Jaggu water level crossing (RD 123050) near Village Jaggu, Tehsil Kharian District Gujarat has been planned. SEC

1.2 OBJECTIVES OF THE STUDY

Following are the objectives of the study:

- Exploration of the potential sites by measuring its resource potential.
- Identification of suitable sites on the selected canal.
- Detailed planning for the installation of the turbine on selected site.

1.3 SCOPE OF THE STUDY

Following is the scope of this study:

- This study is focused on the total resource potential of Kinetic Energy in the upper Jhelum Canal.

- Based on the results achieved theoretical, technical and financial resource potential has to be identified for this canal.
- Planning has to be carried out for the installation of a submersible turbine at Jaggu Water level Crossing of the Upper Jhelum canal.

1.4 METHODOLOGY, APPROACH, CONSIDERATIONS AND LIMITATIONS

Approach and Methodology

This study comprised a desktop survey to explore the resource potential of rivers and canals in Pakistan; for which 10 rivers and 55 canals were identified. In order to enhance the vision and select the most appropriate site, three out of those 55 canals were personally surveyed along with IST team e.g. Upper Jhelum Canal, Ghazi Barotha Canal and Machai Canal to explore their respective hydrokinetic potential. As a result of the desktop survey and subsequent field visits, Upper Jhelum Canal, with a water flow velocity of 1.12 m/s, depth of 2.86 m, width of 68.6 m and length of 127.4 km was found out to be most appropriate for the study purposes, and it was selected to calculate the total theoretical resource potential. The resource potential of the upper Jhelum Canal was assessed by calculating the kinetic energy available in the flowing water. Details of the canal are attached as Annex- A.

Ghazi Barotha Canal has outstanding characteristics but it is a power canal already producing 1,450 MW, and supposed to be less accessible for research interventions. Similarly, Machai Canal, originating from Swat River also has a good resource for potential energy, but due to exploitation of potential energy and to avoid the erosion of the canal banks the velocity of water have been broken down by creating steps in the canal at different locations. Thus, these two canals were not selected for the study.

Considerations

Following were the main considerations while conducting this study;

a. Measurement of required parameters e.g. flows of water (m^3/s), velocity of water (m/s), depth of water (m), consistency (availability in days).
b. Assessment of the possible utilization potential.
c. Assessment of the acceptability potential of the local population, local/regional governments, and their administrative support.
d. Approachability to the potential site for the manpower, machines and security threats involved if any during construction and for the life cycle of the plant.
e. Availability of infrastructure near the potential site for the grid connectivity or transmission lines for the end users.

Limitations

Following were the limitations while conducting this study;

i. This canal was designed in 1906, so the original design parameters and data were not available.
ii. Later on, several revisions were incorporated which were difficult to be incorporated.
iii. The canal geometry was not well maintained accordingly.
iv. The required instrumentation was not available like velocity meter of good quality, depth meter, flow analyzer etc.
v. The flow of water in the canal was mostly intermittent.
vi. Unavailability of required time as well as financial resources.

Chapter: 2 SUBMERSIBLE TURBINES

Any hydel/hydro turbine which is fully submerged in the flowing water stream of a canal, river or ocean is called a submersible turbine. Every such turbine is capable of producing electric power utilizing relatively low-speed, unidirectional rotation under a low head pressure and/or low velocity water flow. The turbines consist of a rotating wheel/shaft with 3-4 airfoil-shaped blades mounted transversely to the direction of water flow for rotation in a plane parallel to the water flow. These turbines convert hydel energy in the waterway current/water stream into mechanical energy that may transfer it through the turbine shaft to a cylindrical permanent magnet generator which converts mechanical energy in the form of RPM and torque into electricity. Electricity from the variable speed electric generator is controlled, synchronized, conditioned and transformed into utility-grade electricity using a power electronics system in each module (Google-Patents).

2.1 TYPES OF SUBMERSIBLE TURBINES

Submersible turbines can be categorized into two types based on the type of hydel energy they employ to convert into electrical energy. These are, the turbines using kinetic energy of water and the turbines using potential energy of water. In this study we focused only on the turbines using kinetic energy of flowing water stream.

2.1.1 Submersible Turbines using kinetic Energy of water

The Submersible Turbines using kinetic Energy of water again may be subdivided into two categories;

a. Floating type of submersible turbines.
b. Fully submerged submersible turbines

2.1.1.1 Floating type Submersible Turbines

This type of water turbine extracts kinetic energy from a flowing stream of water in a natural nullah, canal or river, and converts it into electrical energy that can be utilized by domestic utilities, small scale industries as well as remote access utilities. The integrated floats on the top side of the turbine serve to keep the turbine in the same position by floating in the water stream. The turbine adjusts its position moving up or down as per the seasonal water flow variations. The water flowing naturally in the range of around 1 to 3.5 meters per second is lightly accelerated through a rotor axially aligned with the flow direction. This induced acceleration is achieved by using specially designed shroud to induce a downstream pressure drop behind the turbine. The rotor itself is connected by a direct axial drive to an underwater generator and is protected with an integrated cage from the debris flowing in the incoming water stream. Fig. 2.1 shows different parts of this turbine. These turbines are generally of small scale due to limitations of floats and balancing (1-25 KW).

Smart Hydro Power GmbH, a German Company has developed a floating type turbine for rivers and canals using permanent-magnet underwater generator which provides 5 kW 3-Phase AC power, sufficient to satisfy the electrical requirements of an average home, small scale agricultural utilities and industrial applications.

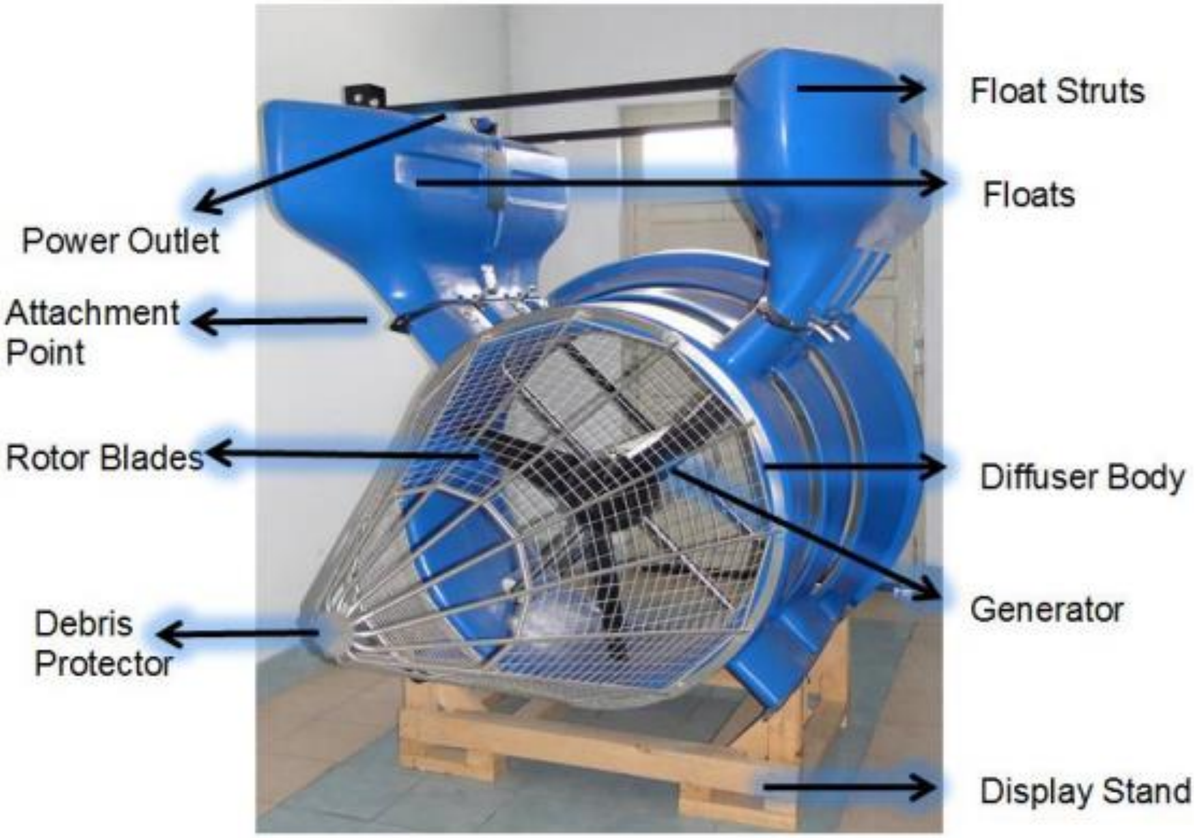

Figure 2-1: 5KW floating type submersible turbine developed by Smart-Hydro Germany.

These turbines are especially beneficial for remote areas without the electrical grid connectivity but where availability of flowing water streams in the form of nullahs, canals and rivers exists. For people in these areas, electricity has to be supplied by either massive extensions to the grids themselves or by decentralized, or often these come in the form of a diesel generator. The added benefit of these turbines is that their installation and evacuation from the canal/river is very simple.

2.1.1.2 Submerged Submersible Turbines

These turbines are fully submerged in the flowing stream of water in the natural nullahs, canals, rivers and ocean currents. Such a Kinetic Hydropower System (KHPS) is a water-to-wire system utilizing horizontal-axis turbines that convert the kinetic energy of fast-moving (> 1 m/s) water currents into clean renewable electricity. The KHPS can be placed in tidal, river and canal resources. It is installed fully under water, invisible from shore, and does not require any dams or impoundments.

The KHPS are being designed with an imperative for simplicity and scalability to minimize O&M

costs and maximize applicability. Turbines can be scaled to a range of sizes and arrays in various configurations, allowing for power provision ranging from distributed generation in urban and village settings to base power generation at more remote deep-water locations.

Moreover, Smart Hydro Power GmbH, has also developed a fully submerged turbine for rivers and canals using permanent-magnet underwater generator which provides AC power. Such multiple turbines can be integrated into an expandable system with an off-grid solution, grid-connected and hybrid version. The turbine can be placed on the bottom of the river or canal and can deliver maximum power output at a water velocity of 3.1 m/s. The parts of this simple turbine have been labeled in Fig. 2.2 below.

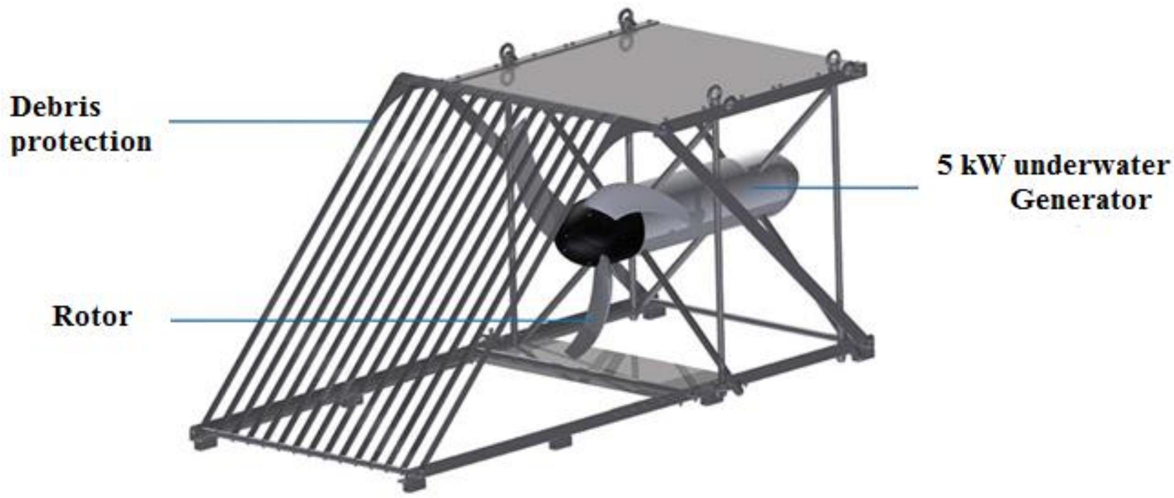

Figure 0-2: 5 KW Fully Submerged Submersible Turbine developed by Smart Hydro Power.

(Smart Hydro, 2017)

The central component of the KHPS is a horizontal-axis turbine equipped with an open three-bladed rotor. The turbines are designed to self-rotate into the prevailing current (like a weathervane) so that the blades are optimally aligned to generate energy. In tidal settings the turbines passively, yaw (turn ~170 degrees) to generate power from both the ebb and flood tidal flows.

The rotating motion of the blades drives an induction generator, located within the main body of the turbine, to generate electricity, which is transferred to onshore equipment via an underwater cable. The blades rotate at a slow and steady rate of approximately 40 RPM, well below normal water vessel propeller speeds.

The specifications of this turbine have been presented in Table: 2.1 below.

Table 2.1: Specifications of the 5 KW Submerged Submersible Turbine (Smart Hydro, 2017)

S. No.	Power Output	250 – 5000 W
1	Dimensions	Length: 2640 mm Width: 1120 mm Height: 1120 mm
2	Rotational speed	90 – 230 rpm
3	Weight	300 kg
4	Number of rotor blades	3
5	Rotor ø	1000 mm
6	Required Max. Velocity	3.1 m/s

Upfront Cost

The upfront cost of these turbines is little higher than the conventional potential hydel turbines due to small scale but if we account for the total cost including infrastructure required for the potential hydro turbines than the submersible hydrokinetic turbines may become competitive with conventional turbines. Moreover, the time required for installation in case of submersible turbines is negligible as compared to the conventional turbine. Also, the cost of building related infrastructure is not required for the submersible turbines. Generally, the upfront cost of these turbines lies from USD 2500-3000/kW.

Maintenance requirements

These turbines are simple in design and rugged in construction which is why they do not require regular maintenance for initial years after installation.

2.2 SUBMERSIBLE TURBINES IN SAARC REGION

A 5 KW demonstration project was completed in 2014, by an Indian company "The Meeco Group, Meeco India Pvt. Ltd, for the Punjab (Indian) Energy Development Agency (PEDA) Chandigarh India to show a new kinetic micro hydropower energy technology in the state of Indian Punjab by setting up a submersible turbine made by Smart Hydro Power GmbH, near Sirhind Canal Eastern Punjab India. This remote power generation solution, was aimed to allow PEDA to make use of its natural resources and to provide energy for agricultural or lighting applications, rural communities or industrial utilities located near the turbine'. (Singh, 2017).

2.3 SUBMERSIBLE TURBINES AVAILABLE IN THE WORLD

Following are the examples of submersible turbines installed in the oceans, rivers and canals throughout the world.

a. Japanese company Ibasei recently devised a tiny underwater turbine that can be placed along a riverbank or canal to generate 250W electricity without harming the environment.

b. Tocardo will deploy five 300 kW-rated T2 bi-directional turbines in Canada in late 2017. The turbines will be attached to Tocardo's patented Semi-submersible Universal Foundation Platform Structure to form a 1.5 MW system held in place by Catenary Mooring Systems.
c. Gen5 KHPS turbine 35 KW (5 m class) by Verdant Power USA. (Verdant Power, 2017).

Chapter: 3 SELECTION OF SITE FOR SUBMERSIBLE TURBINE

Site selection for the installation of submersible turbine using kinetic energy of water is very important because a lot of factors are to be considered before making the selection.

3.1 EXPLORATION AND CONSIDERATION OF THE POTENTIAL SITES

A desktop survey was conducted to explore the resource potential of rivers and canals in Pakistan; 10 rivers and 55 canals were thus identified as presented in the Annexure- I, Page: 43. Generally, the velocity of water in the irrigation canals is kept below 1.5 m/s to avoid the erosion of banks/sides of the canals. But at different locations of canals, like at originating points, under the bridges, level crossings and distribution channels the velocity of water increases due to the decrease in the area of cross section available for water flow and inclination levels etc.

A preliminary survey of short listed canals was required to explore and measure the potential of attractive locations. In order to enhance the vision and select the most appropriate canal/site, three of these canals were personally visited along with IST team e.g. Ghazi Barotha canal, Upper Jhelum Canal and Machai Canal to explore their potential.

Figure 0-1: View of the Ghazi Brotha power canal originating from Ghazi Town

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During the initial survey of these three canals, it was found that Ghazi Barotha canal have outstanding characteristics. It originates from Indus River (Ghazi) with a water flow velocity of 1.8 m/s, depth of 9 m and width of 100 m while it runs for 52 km. But the problem with this huge resource potential was that it is a power canal and was already producing 1,450 MW electrical powers and is less accessible for research interventions as shown in Fig. 3.1.

The Upper Jhelum canal originates from Jhelum River at Mangla Dam with a water flow velocity of 1.12 m/s, depth of 2.86 m, width of 68.6 m and runs for 127.4 km, as shown in Fig.3.2.

Figure 3-2: Upper Jhelum Canal at water level crossing Jaggu Head works.

The Upper Jhelum Canal is located on two rivers Jhelum and Chenab in the north of Punjab province, Pakistan. It runs from Mangla Dam to the Chenab River. Floodwater nullahs drain through the Upper Jhelum Canal into the Jhelum. ((Wikipedia, 2017)

Similarly, Machai canal originates from Swat River with a water velocity of 1 m/s, depth of 2 m, width of 6 m and runs up to 42 Km. This canal has a good resource for potential energy, due to which Pakhtoonkhawa Development Organization (PEDO) commercialized its power potential resource and up to now one hydel power plant of 2.6 MW and another with 1.5 MW capacity are in operation and two more are in construction phase while resource potential of kinetic energy also exists but of low value. Due to exploitation of potential energy the velocity of water has been broken down by creating steps in the canal at different locations.

Figure 0-3: View of the Machai canal showing the steps created to decrease the velocity of water

3.2 CRITERIA FOR THE SELECTION OF A SITE

Confirmation of the following parameters is required for the targeted site;

a. **Velocity of water (m/s)**: The velocity of water (m/s) in the canal or river might be within the given range of the available turbine and generally it may not be less than 0.5 m/s. This parameter is most critical.
b. **Depth of water (m)**: The depth of water (m) is also critical in case of submersible turbines using kinetic energy of water, so that the turbine blades might be submerged in the flowing stream of water in the canal or river.
c. **Width of Canal (m)**: The width of the canal or river plays an important role to the extent of number of turbines in one array. Hence, wider water channels have more potential by accommodating more turbines in the single array multiplied by the number of arrays along the entire canal or river.
d. **Consistency** (**days**): The above-mentioned parameters might be available for sufficient number of days and at least 250 days annually.
e. **Utilization Potential (kW)**: The possible utilization potential of the electrical energy might be ensured; either it is domestic, agricultural, commercial or industrial.
f. **Acceptability Potential:** Acceptability/willingness of the local population, local/regional governments, and their administrative support might be ensured.
g. **Approachability**: The approachability to the potential site for the manpower, machines should be ensured.

h. **Security at the site:** Security threats involved if any during construction and for the life cycle of the plant might be assessed and as a counter action to safe guard, the required mechanism might be explored, accordingly.

i. **Grid Connectivity**: The available infrastructure near the potential site for the grid connectivity or transmission lines for the end users might be ensured or planned.

j. **Commercial Viability**: The commercial viability, in terms of competitiveness and room for power evacuation and utilization must be available /ensured.

3.3 COMPARISON OF POTENTIAL CANAL/SITES

By analyzing and comparing all above-mentioned parameters discussed in 3.2, for the Upper Jhelum Canal, the Machai Canal and Ghazi Barotha canal, and their relevant attributes have been presented in Table 3.1.

Table 3.1: Comparing attributes of Upper Jhelum Canal, the Machai Canal and Ghazi Barotha canal

Canal / Site	Upper Jhelum Canal	Machai Canal	Ghazi Barotha canal
Velocity of water (m/s)	1.12	0.7	1.8
Average depth of water (m)	2.9	2	9
Discharge (m^3/s)	250	40	1600
Width of canal (m)	68.6	6	100
Length of canal (m)	127.4	42	52
Consistency (days)	335	250	365
Utilization Potential (kW)	Good	Good	Good
Acceptability Potential	Good	Good	Good
Approachability	Good	Fair	Good
Security Threats	Safe	Mild	Safe
Grid Connectivity	Good	Good	Good
Commercial Viability	Yes	Yes	Yes

a. As the authorities of the Ghazi-Barotha canal may not be willing to give permission for the Installation of submersible turbine within the canal; hence this site is not feasible in spite of all positive attributes.
b. Similarly, all of the attributes of Upper Jhelum canal were superior to those of the Machai canal like velocity of water, depth, width, length of canal, approach ability, security situation etc. and daily discharge as presented at Annexure- XI.

3.3.1 Result of the selection

By analyzing and comparing all above-mentioned parameters discussed in 3.2, for the three canals; Upper Jhelum Canal became the most feasible canal for the installation of submersible turbine utilizing kinetic energy of water.

Hence, Upper Jhelum Canal was selected to calculate the total theoretical resource potential. Office of the XEN Irrigation Jhelum was visited to study the L-Section of the Upper Jhelum Canal and important parameters were studied from the respective drawings. There are 4 similar water level crossings and 8 siphons in the entire canal.

This location of the canal was found feasible for the installation of the submersible turbine due to following reasons;

a. The velocity of water in the main stream of the canal was collected as 1.12 m/s.
b. The velocity of water in the channels under the bridge on the slope was measure as 3.6 m/s which is considered a useful velocity for power generation.
c. There are 17 such channels under the same bridge.
d. There is a hydro monitoring station having a building and associated staff to assist in all related activities.
e. There is a raised siphon (concrete x-section) of length 73.2 m near to Jaggu where 114 small turbines can be installed.
f. On both sides of the canal there is rural population as well as a distribution network of electricity for net metering and vice versa utilization etc.

There is a very good metaled road access for every type of vehicles and a busy road as well.

3.4 DESCRIPTION OF THE SELECTED SITE

Channel No.7 under the bridge at water level crossing at Jaggu (RD 123050), near Village jagggu, Tehsil Kharian, Distt Gujrat), is the site selected for the installation of submersible turbine using kinetic energy of water due to following attributes suitable for the available model turbine shown in the Fig. 2.1;

a. Velocity of water flowing stream = 3.6 m/s. [Measured jointly by Irrigation, IST and SEC]
b. Depth of water = 1.1 m

c. Consistency (availability of above-mentioned parameters in days) = 335 Days

d. Assessment of the possible utilization potential of electrical energy: Requirement of electricity at the canal monitoring station at Jaggu is appropriate (3 KW).

e. Assessment of the acceptability potential of the local population, local/regional governments, and their administrative support: During the survey and discussions with the local authorities it was confirmed that local population is keenly looking for any alternative source of power because the availability of electricity through grid is intermittent and unreliable.

f. Evaluation of the approachability to the potential site for the manpower, machines: As there is a barrage having heavy gates, crane availability and approachability, controlling and maintenance infrastructure, metaled wide roads, associated staff and a thickly populated area around so approachability and working environment is good.

g. Assessment of the security threats involved if any during construction and for the life cycle of the plant: No threat at all as the site is 24 hour under guard and under monitoring by the associated staff.

h. Assessment of the available infrastructure near the potential site for the grid connectivity or transmission lines for the end users 11 KV Grid lines are available on both sides of the canal supplying electricity to the domestic, cottage industry as well as agricultural utilities. Moreover, canal monitoring station building at a distance of 100 meter has electricity connection, with 3 KW electrical loads.

Chapter: 4 ASSESSMENT OF RESOURCE POTENTIAL

India and Pakistan are blessed with a good irrigation canal system. Moreover, Afghanistan, Bhutan, Nepal, Bangladesh and Sri Lanka have rivers and canals carrying hydrokinetic electrical power potential that can be harnessed, accordingly. The flowing water in canals and rivers carries kinetic energy in it which can be harnessed by the utilization of suitable and appropriate submersible turbines.

Generally, the hydrokinetic turbine shown in Fig. 2.1 operate on the same principle as that of wind turbines hence similar design concepts may be employed. The difference is that the density of water is 850 times greater than the density of air hence; this turbine requires a water velocity of 3-4 m/s. Therefore, the energy in the given flow of water stream for hydrokinetic turbine is 850 times greater than a wind turbine for the same air flow.

4.1 TYPES OF RESOURCE POTENTIAL

The Resource Potential in the canals and rivers can be categorized as follows;

a. Theoretical Potential
b. Technical Potential
c. Economical Potential

4.1.1 Theoretical potential

The theoretical potential is the annual average amount of physical energy that is hypothetically available. The theoretical potential of a hydrokinetic resource can be calculated by following considerations;

- The average flow rate of water (m^3/s)
- The change in hydraulic head between the beginning and end of canal (m)

4.1.2 Technical Potential

The technical potential is the portion of a theoretical resource that can be captured and converted into electricity using a specific technology. (Office of Energy Efficiency and Renewable Energy, 2017)

The technical potential of a hydrokinetic project can be calculated by following considerations;

- Velocity of water flowing stream
- Width of canal or river
- Depth of water
- Rotor diameter of turbine
- Inter Turbine spacing in the arrays
- Longitudinal turbine spacing between two arrays
- Temperature of water
- Availability of resource in days
- System and topographic constraints

- Land use constraints
- System performance, etc.

4.1.3 Economical Potential

The economic potential is a metric that attempts to quantify the economically viable electricity generation available in a canal, river or any hydrokinetic resource. Economical potential is the subset of the technical potential. (Austin Brown, 2013)

The Economical potential of a hydrokinetic project can be calculated by following considerations;

- Projected cost of the project
- Projected power from the project
- Availability of water resource in days
- Availability of plant factor
- Upfront tariff
- Annual O&M cost
- Annual revenue
- Annual profit

4.2 CALCULATION OF THEORETICAL RESOURCE POTENTIAL OF SELECTED SITE

Calculation of Theoretical Potential of Selected Site is essential before proceeding further in the direction of utilization of any resource**.** Hence, this potential of the Upper Jhelum Canal has been calculated.

4.2.1 Approach to Calculate Theoretical Resource Potential

A survey was conducted to measure the following parameters to calculate the Theoretical Potential of Electrical Power from the Upper Jhelum canal.

- Flow of water/discharge (m^3/s)
- Velocity of water (m/s)
- Depth of water (m)
- Availability of water in days over the year

Then Theoretical, Technical and Economical potentials of the upper Jhelum canal were calculated as presented in the preceding sections.

4.2.2 Calculation of Theoretical Potential

To calculate the theoretical Potential of Upper Jhelum Canal, its geographic and parametric study was done based on the data available in the office of XEN Upper Jhelum Canal. After going through this exercise it was decided that study may be narrow down to this canal considering the scope of study as well as the financial and time resources available for this study.

This canal has total length of 127.4 Km. It also supplies water for two Hydro power stations namely Rasul and Shadiwal having power potential of 22 and 12 MW respectively.

There are 4 water level crossings for the flood water nullahs on the entire length of the canal. One of the water level crossings is situated at Jaggu (RD 123+050 feet) which is approximately 8 Kms from GT road towards Mangla.

The existing parameters of Upper Jhelum canal are very fascinating for hydro power projects e.g. velocity of water, flow, width, depth, slope etc. as mentioned in the Table: 4.1.

Table 4.1: Existing parameters of Upper Jhelum canal

Parameters	**Two sections of Upper Jhelum canal**	
	Head Reach[1] up to 74.4 km	**Tail Reach[2] 74.4-127.4 km**
Discharge, Q (m^3/s)	250	223
Bed, width, B (m)	68.6	65
Full Supply Depth, (m)	2.8	2.8
Side Slope	1.5	1
Longitudinal Slope (l/Slope)	6667	6667

Hence, the theoretical hydrokinetic power in a canal was calculated based on the data available in Table: 4.1, by utilizing the following expression;

$P_{th} = \gamma\ Q\ \Delta H$ ………………………………………Eq-1….. (Water energy)**,** (Mantilla, 2016)

Where, γ = the specific weight of water [9789 N/m^3]….. (VCalc)

Q = the flow rate of water (m^3/s)

ΔH= the change in hydraulic head between the beginning and end of canal (m).

Reference Table: 3.1 and Table: 4.1, this canal extends up to 127.4 km and has two sections with different geometries and water flow rates. Hence, we have to calculate the theoretical power potential for the two sections separately.

The first section is designated as Head Reach (Starting point of the canal) up to 74.4 km and

The 2nd Section is designated as Tail Reach (The last point of the canal) 74.4-127.4 km

4.2.2.1 The Head Reach Theoretical Resource Potential (P^H_{th})

By putting the respective values in the Eq-1

γ = 9789 N/m^3

Q= **250 m^3/s**

ΔH= 11.16 m………… [Slope (1/6667) x length (74400)]

We get P^1_{th} = 9789 x **250** x 11.16 W

= 27311 KW

= **27.31 MW**

4.2.2.2 The Tail Reach Theoretical Resource Potential (P^{T}_{th})

By putting the respective values in the Eq-1

γ = 9789 Nm^{-3}

Q= 223 m^3/s

ΔH= 7.95 m………… [Slope (1/6667) x length (53000)]

We get P^{2}_{th} = 9789 x 223 x 7.95 W

= 17354 KW

= **17.35 MW**

The total Theoretical Resource Potential of this canal, $P_{th} = P^{1}_{th} + P^{2}_{th}$

= 27.31 MW + 17.35 MW

P_{th} = 44.66 MW

4.2.3 Calculation of Technical Potential (P_{tech}) e

For this purpose the canal have been divided into following 3 sections due to parametric variations;

(i) 4 Water level crossings
(ii) 18 siphons
(iii) Main canal

The following parameters were collected from the drawing of L-Section and measured jointly by Irrigation team, IST and SEC officials.

At Jaggu level Crossing, RD: 123050 (Distance from Mangla Dam in short ft.)

Width of Canal = 68.6 m

Water Depth = 2.8 m

Channel width under the bridge = 6.1 m

No. of channels under the bridge = 17

Water level in the channel = 1 m

Velocity of water in the channel on the slope = 3.6 m/s [Measured]

4.2.3.1 Calculation of Technical Potential under the bridges at level crossings of the canal (P^{B}_{tech})

Considering the above-mentioned parameters of the Jaggu level crossing and taking a working model of a submersible turbine developed by Smart Hydro, as shown in Fig. 2.1 and its operating curve shown in Fig. 4.1, which can produce 5 kW of electrical power;

Calculation of the potential of electrical power generation under this bridge, where;

Width of one channel = 6.1 m

Rotor diameter of the turbine = 1m

The minimum distance between two turbines = 2.5 m [(Abid, 2014)]

The number and spacing of turbine units may be estimated using turbine spacing across the channel with a 0.5D to 3D gap between turbines, where D is the turbine diameter. (The National Acedmies Press, 2013)

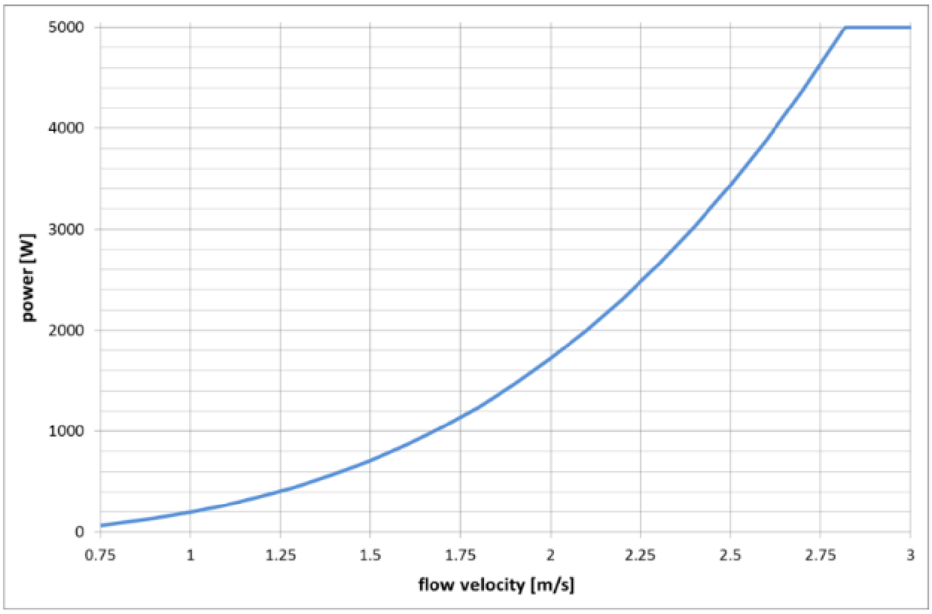

Figure 0-1: Operating curve of 5 KW SMART Hydrokinetic generators

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Figure 0-2: Turbine distribution with in one channel under the bridge at Jaggu level crossing

In this way, number of turbines that can be accommodated in one channel, as shown in Fig. 4.2 = 2

Total number of channels under the bridge = 17

Total number of turbines under the bridge = 17 x 2

= 34

Total number of similar level crossings in the upper Jhelum canal (n) = 4

Total turbines on the 4 level crossings = 34 x 4

= 136

The Technical Potential for 136 turbines can be calculated by using the turbine as a model for calculations with rotor diameter of 1 m as shown in Fig. 2.1 Page. 5. and using Fig. 4.1 as characteristic curve of this turbine which shows that at a water velocity of 3.6 m/s this turbine will produce 5 KW electric power.

Turbine operational efficiency given by manufacturer = 98%

Power produced under the bridges = 136 x 5 x .98 Kw

= **666** Kw

Assuming losses in cascading and transmission@10% = 66.6 Kw

(P^B_{tech}) = **666-66.6** Kw

Power produced by 136 turbines in 4 water level crossings = **0.6 MW**

Net power produced under the bridges (P^B_{tech}) **= 0.6 MW**

4.2.3.2 Calculation of Technical Potential on the Siphons (P^{s}_{tech})

There are 18 siphons in the canal which are also attractive for the installation of similar turbines. The proposed schematic array of the turbines that may be installed on one of the siphon head near Jaggu Level Crossing, have been shown in the Fig. 4.3.

Width of the siphon = 68.6 m

Width of one turbine = 1m

Number of turbines that can be installed in one row = 68.6 / (2.5+1)

= 19

Figure 4-3: Proposed schematic arrays of the turbines that may be installed on one of the siphon head

The length of the Siphon = 91.5 m

Let each row be at a distance of 15D (15x 1m) from each other,

Then total rows of turbines = 91.5/15

= 6 rows

Total number of turbines on one siphon = 19 x 6

= 114

As there are 18 siphons in the entire canal, hence total turbines = 114 x 18

= 2052

By using the proposed model turbine with;

Rotor diameter = 1 m

Max. Power = 5 KW

Reference, characteristic curve of this turbine in Fig. 4.1.

At a water velocity = 1.22 m/s

The expected power from this turbine = 200 W

Total power from the siphon = 200 x 2052 W

= 410 KW

Let, losses in cascading and transmission@10% = 41 KW

Net power from the siphon = 410-41 KW

=369 KW

(P^s_{tech}) = **0.37 MW**

4.2.3.3 Technical Potential in the main canal other than bridges and siphons (P^M_{tech})

As the entire canal consists of two sections due to different set of parameters, hence

Let, Technical Potential in the Head Reach up to 74.4 km **=** $(P^M_{tech})_H$

And Technical Potential in the Tail Reach from 74.4 -- 127.4 km **=** $(P^M_{tech})_T$

The Technical Potential in the main canal can be calculated by using following equation;

$P = ½[\xi\ pV^3(NA_r)]$……………………………………………………………Eq-2

(The National Acadmies Press-2013)

Where,

P = the extractable power from the flowing water in the available X-section of this canal (in one row) with given parameters in the Table.4.1.

ξ = the turbine efficiency (assumed to be 0.3, 30% at other than rated water flow velocity)

p = the density of water (998 kg/m^3)

V = the velocity of flowing water (1.12 m/s)

N = Number of turbines that can be installed in one row = 68.62 / (2.5+1) ……..(Abid-IST).

Number of turbines that can be installed in one row = 19

Hence, a turbine having rotor diameter of 1 m developed by Smart hydro Power using as a model for calculation in this canal. The proposed schematic arrays of the turbines that may be installed in the main canal have been shown in the Fig. 4.4.

A_r = the swept area of the turbine ($\pi/4 \times (1)^2$, 0.785 m^2)

By putting the values in Eq-2 we get,

$P = ½[0.3 \times 998 \times (1.12)^3 \times 19 \times 0.785]$

= 3136 W

Power produced in one row = 3.13 KW

Let each row be at a distance of 30 D (30 x 1 m) from each other

Then number of rows in the Head Reach section = 74400/30

= 2480

No of rows missed by roads & Bridges @10% = 248

No of rows accounted for on Siphons @ 6*9 = 54 (Accounted 9/18 siphons in Head Reach section)

No of rows accounted for under Level Crossing Bridges = 4

Net No. of rows in 1st section of main canal = 2480-(248 +54 +4)

= 2174

Total power from Head Reach section $(P^{M}_{tech})_H$ = 3.13 x 2174

= 6804 KW

= **6.8 MW**

4.2.3.4 Technical Potential in the Tail Reach from 74.4- 127.4 km = $(P^{M}_{tech})_T$

It can be calculated accordingly;

Length of Tail Reach = 53 km

Hence, a turbine having rotor diameter of 1 m can be easily accommodated in the entire Tail Reach of this canal.

A_r = the swept area of the turbine ($\pi/4(1)^2$, 0.785 m^2)

Width of the Tail reach = 65 m

Width of one turbine = 1m

Number of turbines that can be installed in one row = 65 /(2.5+1)

= 18

By putting the values in Eq-2 we get,

$P = ½[0.3 \times 998 \times (1.12)^3 \times 18 \times 0.785]$

= 2971 W

= 2.9 KW

Let each row be at a distance of 30D (30x 1 m) from each other

Then number of rows in the Tail Reach section (53 Km) = 53000/30

= 1766

No of rows missed by roads & Bridges @10% =176

No of rows accounted for on Siphons @ 6*9 = 54 (Accounted 9/18 siphons in Head Reach section)

Net No. of rows in 1st section of main canal = 1766 - (176 +54)

= 1536

Total power from Tail Reach section $(P^{M}_{tech})_{T}$ = 2.9 x 1536

= 4454 KW

= **4.45 MW**

Total power from rest of the canal = $(P^{M}_{tech})_{H} + (P^{M}_{tech})_{T}$

(P^{M}_{tech}) = 6.8 + 4.45

= **11.25 MW**

Technical resource potential of the entire canal = $(P^{B}_{tech}) + (P^{S}_{tech}) + (P^{M}_{tech})$

= **0.6 + 0.37 + 11.25** MW

= **12.22 MW**

Losses in cascading and transmission@10% = 12.22-1.22 MW

Net power from the canal = **11 MW** (approximately)

The proposed schematic arrays of the turbines in the main canal have been shown in Fig. 4.4. Therefore, by the installation of appropriate turbines on the above-mentioned locations 11MW power may be extracted from the upper Jhelum Canal which can satisfy the general house hold requirements of 5500 families @2 KW each and 550 tube wells or small industries @ 20 KW each.

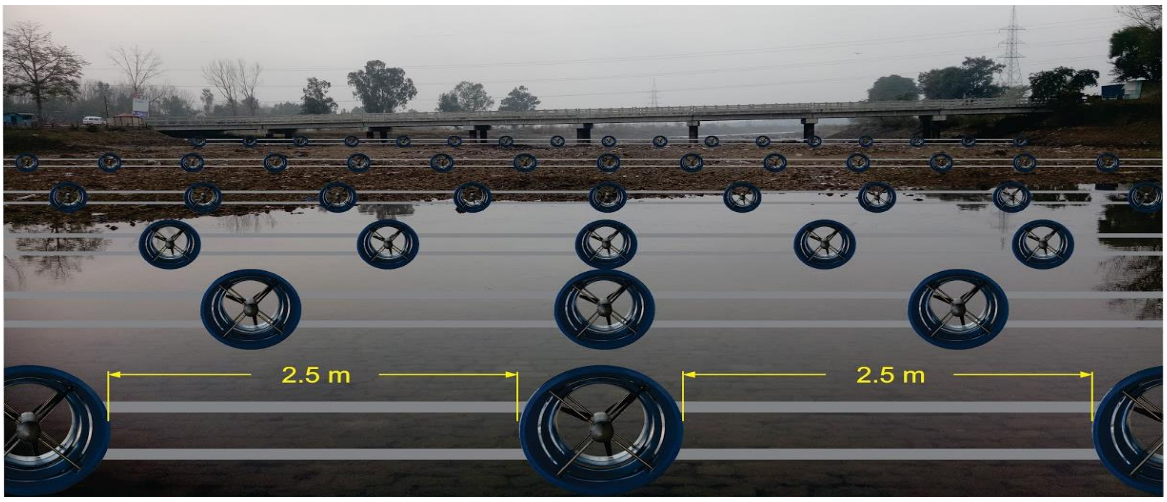


Figure 0-4: Proposed schematic arrays of the turbines that may be installed in the main canal

Hence, with the implementation of appropriate policies and commercialization of this reasonably good potential in one canal, this could be a role model for other canals in Pakistan as well as for rest of the SAARC member states to harness this untapped huge power potential to satisfy their respective energy needs.

4.2.4 Calculation of Economical resource potential

The economic potential of a project can be calculated by following considerations;

- **Projected Power from the Upper Jhelum Canal**

As per calculation the technical potential of this canal we get = **11 MW**

= 11000 x 24 KWh/day

Considering, (a planned shutdown of the canal is 30 days annually and incidental shutdowns of the canal may occur due to accidents and water scarcity in the dam and machine problems etc. may effect for 36 days annually). Hence, canal and turbines availability may be for 300 days annually.

Availability of KWhs annually = **11000** x 24 x 300 kWh/year

= 79.2 M kWh/year

As upfront tariff for Micro hydro power plants by NEPRA (Pakistan) = PKRs.12.7 / KWh

(This tariff is based on certain conditions regarding financing structure, available head and Plant

Factor etc). Reference Annexure-VII page: 55

Hence, annual revenue from the upper Jhelum canal = 79.2 M x 12.7

= PKRs. 1005.84 Million (M)

As current conversion rate of US$ …. (Rs.110 = 1US $) **Annual revenue** = **U.S $ 9.14 M**

For hydrokinetic power plants;

The average equipment cost/Turbine = U.S $ 15000

Total Turbines = 136 + 2052 + 41306 + 27648

= 71142

Cost of total turbines = U.S $ 71142 x 15000

= U.S $1067.13 Million (M)

The project cost/MW @50% of Equipment cost = US$ 1067.13 M x 0.5

Hence, installed cost of the project = US$1600.695 M

Annual O&M cost of the project (2.4% of the project cost) = U.S $ 1600.695 x 2.4/100

= U.S $ 38.41 M

Annual net profit = U.S $ (11.11 – 38.41) M

= U.S $ - 27.3 M

= PKRs. - 3003.73 M

Annual loss from this project = PKRs. 3003.73 M annually

Hence, due to low water flowing velocity in the main canal, this model turbine may not be feasible. However, this turbine can be installed under the Head Regulator Bridges with 3.6 m/s water flow velocity but not on the siphons as well as in the main canal.

However, as 11 MW of electrical potential exists in the Upper Jhelum Canal which can be harnessed by employing any other turbine type which may be more efficient at low water flow velocity like 1.12 m/sec available in the main Upper Jhelum canal.

Let we calculate the economic potential under the Head Regulator Bridges only.

Total Turbines under the Bridges = 136

Cost of total turbines = U.S $ 136 x 15000

= 2.04 Million (M)

The project cost/MW @50% of Equipment cost = US$ 2.04 M x 0.5

Hence, installed cost of the project = US$3.06 M

Annual O&M cost of the project (2.4% of the project cost) = U.S $ 3.06 x 2.4/100

= **U.S $ 0.073 M**

Total Power from 136 turbines = (P^{B}_{tech})

= **0.6 MW**

Annual revenue from 136 turbines = PKRs. 12.7 x 0. 6 x 1000 x 24 x 300

= PKRS. 54.86 M

= US$ 0.498 M

Annual net profit = U.S $ (0.498 – 0.073) M

= **U.S $ 0.425 M**

= PKRs**. 46.75 M**

Annual profit of the project = PKRs. **46.75 M annually**

= US$ 0.425 M

Cost of the Project = US$ 3.06 M

Pay Back period of the project = Cost of the project / Annual Profit

= 3.06/0.425

= 7.2 Years

= 7 Years Approximately

It gives an attractive indicator for the private investors so this project may be feasible by using the Model Turbine of 5 KW capacity made by Smart Hydro Power under the 4 Head Regulator Bridges of the Upper Jhelum Canal.

Hence, after the successful operation of the project the payback period is approximately 7 years, which is a reasonable period over the project life cycle, in this regard.

Let we make financial and economic analysis;

Net return over 25 years life= PKRs. **1334619000**

Annual return = Rs. **1334619000**/25

= PKRs. 53384760

EIRR = [Annual return/Capital cost] x 100

= (53384760/336600000) x 100

= 15.86%

This is an attractive value on the Capital investment.

Hence, private investors may be readily available to invest in this as a commercial project.

Financial and economic analysis is placed in Annexure-IX at Page: 57. The Benefit Cost Ratio is 1.59 with 15.86 % EIRR which shows the level of feasibility of the project.

NPW of Benefits @10%	NPW of Total Cost @10%	Benefit: Cost Ratio	EIRR
487368896	**306907581**	**1.59**	**15.86**

4.3 GENERIC MODEL TO CALCULATE HYDROKINETIC RESOURCE POTENTIAL OF ANY CANAL

The theoretical resource potential for any canal or river can be calculated by using the following expression or entering the respective parameters in Excel based model as presented below.

The governing equation for the theoretical resource potential (P_{th}) is given below.

$\mathbf{P_{th} = \gamma\, Q\, \Delta H}$ **………….** Eq-1

Where, γ **=** Specific weight of water (9789 NM^{-3}).

Q = Flow rate of water (Cs).

ΔH = Elevation difference of the starting and ending points of the canal or river (m).

$P_{th} = \gamma\, Q\, \Delta H$ **(Theoretical Resource Potential)**

ϒ	Q	ΔH	$P_{th\ (KW)}$	Section
9789	250	11.16	27311	1st Section

9789	223.00	7.95	17354	2nd Section
Total			44666	

Similarly, the technical resource potential (**P_{tech}**) for any canal or river can be calculated by using the following expression or entering the respective parameters in Excel based model as presented below. The governing equation for this model is given below;

P_{tech} = ½[ξ pV^3(NA$_r$) n]…………… Eq-2 (**Technical resource Potential**)

Ptech (W) = ½[ξ pV3(NAr)n]										
	0.5	ξ	p	V^3	N	Ar	n	No. of Siphons	Ptech(KW)	
Under The Brigdes	0.5	0.3	998	46.656	34	0.79	1		188	(PBtech)
On The Siphons	0.5	0.3	998	1.8158	19	0.79	6	18	441	(Pstech)
Main Canal First Section	0.5	0.3	998	1.4049	19	0.79	2174		6863	$(P^M_{tech})_H$
Main Canal Second Section	0.5	0.3	998	1.4049	18	0.79	1536		4594	$(P^M_{tech})_T$
Total Power in UJ Canal									12,085	

Similarly the economic resource potential of any canal can be calculated by putting the respective values in the following EXCEL based model. The governing equation for this model is;

Economic Potential = Power Produced (Kw) * Hours/day (H)* No. of days turbine produced power (D) * Tariff (PKRs./KWH) – (2.4*Capital cost)/100

Kw	H	D	Tariff (PKRs./Kwh)	Economic Potential (MPKRs)	
11000	24	300	12.7	1006	Equation Based
600	24	300	12.7	55	Turbine Based

Chapter: 5 PLANNING FOR INSTALLATION OF A SUBMERSIBLE TURBINE

A 5KW hydrokinetic floating type submersible turbine is available with Mr. Malik Nadeem Awan, CEO Al-Awan General Trading Corporation, Sialkot and Country Head for Smart Hydro Power in Pakistan, for demonstration purpose and the specifications of this turbine has been presented in Table 2.1. Moreover, required NOC for installation at Jaggu Water Level Crossing Head works Upper Jhelum Canal has been obtained from the Department of Irrigation Punjab and presented in Annexure VIII, at Page No. 56.

Upper Jhelum Canal runs for 11 months and shutdown for one month (5th January to 5th February) annually, for maintenance purposes. Therefore, a planned schedule of activities for the

Installation of the above-mentioned turbine at Jaggu water Level Crossing in UJ Canal has been made and presented in the Table 5.1.

However, for the next phase of planning for whole canal, as per collected parameters of the Upper Jhelum canal (UJ Canal), the velocity of water and depth of canal will be communicated to the 44 submersible turbine manufacturers, developers and suppliers all over the world and they will be requested to propose/recommend their available respective model of submerged submersible turbine which best suits to the UJ canal. Hence, SEC will be facilitated with different proposals from different manufacturers and suppliers. On the basis of the technical parameters e.g. maximum power output, ease of installation, stability, useful life, financial aspects and after sales service etc., the best suitable turbine will be selected for each location of the canal, accordingly.

5.1 GENERAL PLANNING FOR 5KW SUBMERSIBLE TURBINE

a. Permission from Punjab Government.

This canal is under control of Punjab Government who has established Punjab Power Development Board (PPDB) in the Punjab Energy Department (PED) to;

(i) Facilitate the implementation of power generation projects and power distribution arrangements, in case of power sale to a private sector;

(ii) Pre-qualify the sponsors both in case of raw site projects or solicited site projects;

(iii) Evaluate the bids of pre-qualified sponsors and issue Letters of Interest and Letters of Support to the successful sponsors;

(iv) Assist the sponsor / project company in seeking necessary consents / permissions from various governmental agencies;

(v) Negotiate the implementation agreements (IAs), assist in the negotiations relating to the water use licenses (WULs), and assist the power producer, fuel supplier and provincial authorities in the negotiations, execution and administration of other agreements such as the PPA, the FSA/ GSA/CSA and the WUL;

(vi) Co-ordinate with Federal Government agencies and DISCOs / NTDC for development of the power generation projects;

(vii) Follow up and assist in the implementation and monitoring of projects; and,

(viii) Take up such other matters as may be required for the promotion of power generation projects in the province.

Punjab Irrigation department has already issued permission for the installation of above-mentioned turbine for non-commercial utility at the designated site however; Punjab Energy Department shall be contacted for allocation of site for commercial utilities as per Punjab Energy Generation Policy 2006, revised 2009. Activity Chart for the purpose is placed at Annexure-X at Page: 59.

b. The transportation of the turbine from Sialkot to the site of installation will be carried out through a professional transport company. The transportation of the turbine from the truck to the specific location will be carried out with the help of a mobile crane arranged by the EPC contractor.
c. The installation plan of the turbine will be followed as per instructions by the manufacturer of the turbine
d. For the evacuation of power from the turbine, the basic infrastructure is already available. However, the relevant distribution company i.e. Islamabad Electric Supply Company (IESCO) will be approached to carry out the required activities like approval of net metering, laying of power lines from the turbine circuit breaker/control room to the 220 KV line and installation of Net Meter etc.
e. At present net metering regulation issued by NEPRA does not allow purchasing power generated by hydropower plant. However with the changing scenario in the power sector it is presumed that this facility will soon be extended towards hydro and biomass power plants.

5.2 COST OF THE INSTALLATION OF THE TURBINE

The installation of the turbine will be carried out through some EPC contractor and following is the breakdown of the expected expenditures involved in different entities;

Transportation of the turbine & supporting structure from
Sialkot to Jaggu Head Works Jhelum = Rs.50,000

Fabrication Cost of the supporting structure of the turbine = Rs.250,000
Cost of Installation by the EPC contractor = Rs.150,000
Cost of testing and commissioning of the turbine = Rs.125,000
Cost of 72 hours reliability test by the IESCO = Rs.50,000
Cost of the Net Meter = Rs.13000
Cost of power conditioner/controller = Rs.80,000
Cost of cabling from the turbine circuit breaker to the utility circuit breaker = Rs. 40,000
Cost of cabling from the turbine circuit breaker to the 220 V Grid line = Rs. 50,000
Salary of the Electrical Supervisor for one year @ Rs. 25000/month = Rs. 300,000
Miscellaneous expenditures = Rs. 100,000
Total expected expenditures for installation of the turbine = **Rs.1208000**

5.3 PLANNING FOR PROCUREMENT

International limited tenders will be floated for the supply of hydrokinetic turbines for the whole canal, mentioning the specific parameters of the canal, required quantity and the quotations will be requested from following 44 hydrokinetic turbine manufacturers all over the world for a wide competition; (Sørnes, 2010)

- Smart Hydro Power GmbH (Germany)
- Thropton Energy Services (UK)
- Alternative Hydro Solutions Ltd (Canada)
- Energy Alliance (Russia)
- New Energy (Canada)
- Tidal Energy Pty. Ltd. (Australia)
- Lucid Energy Technologies (USA)
- Seabell Int. Co., Ltd. (Japan)
- Eclectic Energy Ltd. (UK)
- Greentech Avvenue (USA, Canada, Germany)
- kirloskar integrated technologies private limited (India)
- ACEP (Alaska)
- And so on.
- Full list of 44 manufacturers and developers presented in Annexure-IV, Page No. 50.

5.4 PLANNING FOR TRANSPORTATION

The transportation of the turbines from the dry port Islamabad to the site of installation will be carried out through some professional transport company. The transportation of the turbine from the truck to the specific location will be carried out with the help of a mobile crane by the EPC (Engineering, Procurement and Construction) contractor.

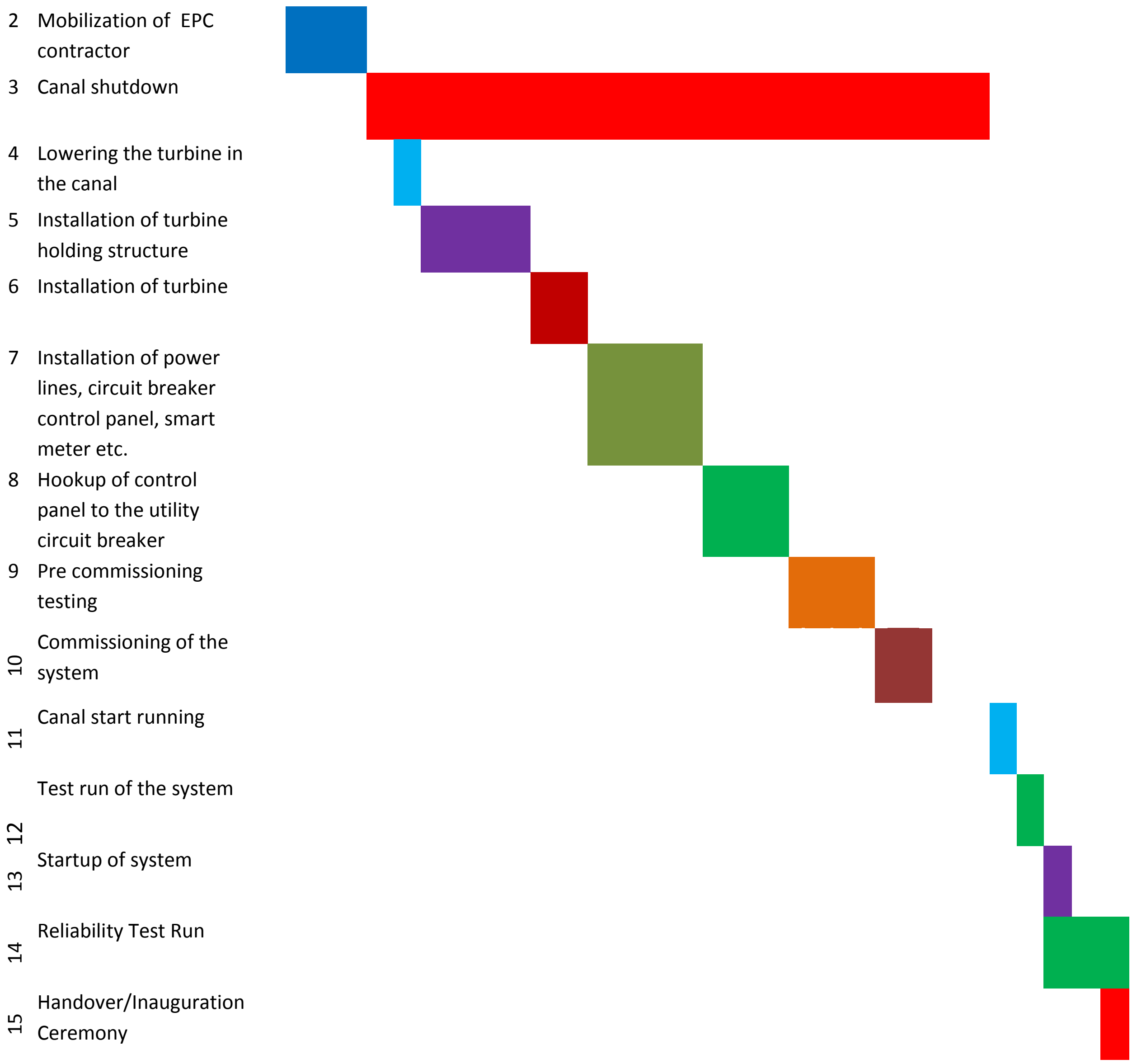
5.5 PLANNING FOR INSTALLATION AND COMMISSIONING (INCLUDINGSTANDARD RELIABILITY TEST)

The installation plan for the 5KW turbine to be provided by the manufacturer and will be followed. Commissioning of the turbine will be carried out strictly in line with the instructions provided by the turbine manufacture. After the successful installation and commissioning of the turbine, a 72 hour Standard Reliability Run Test will be carried out as per SOP made by IESCO pursuant to their standard practices.

Table 5.1: Planned schedule of activities for the Installation of a 5 KW Submersible Turbine at Jaggu Water Level Crossing in UJ Canal.

Planning for the Installation of a 5 KW Submersible Turbine at Jaggu water Level Crossing in UJ Canal (January-February, 2018)

		January																									February				
No	Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	30	31	5	6	7 7	10	15
1	Transportation of Turbine to the site																															



In case of rest of the canal, administrative procedures clarify the roles of all participants in the organization involved in such a project. Once the role of these parties is identified, a plan for the turnover of equipment/systems from the contractor to the owner should be developed. Schedules of construction, completion dates and all testing should be included with the administrative procedures. The startup organization described herein is based on the owner, engineer, and contractor having an active role in the installation, startup and commissioning activities. The responsibility of the various entities may shift slightly depending on their contractual relationship. In general, the typical role of the participants of the installation and startup organization is described below.

5.6 THE OWNER OF THE TURBINE/PROJECT

The owner is usually the operator and provides the operating and maintenance personnel that may coordinate, supervise and participate in the installation and commissioning program. In this case the owner is Mr. Malik Nadeem Awan Country Head, Smart hydro Power. The owner's representatives usually perform following activities;

They will review administrative, construction, installation, pre-operational and operational programs, and schedules etc.

They will witnesses testing activities, as necessary, in support of the commissioning program.

- They will provide coordination with offsite operating, dispatching, or interfacing agencies, as required.
- They will conditionally accept equipment and systems for operation during the pre-commissioning testing phase.
- They will accept equipment, systems and will facilitate, subsequent to successful testing of these items, and provide final acceptance of the project.
- They will operate all permanent equipment and turbine to support the start-up schedule; and make final decisions in areas of disputes relating to test activities performed during the testing program.

I. EPC Contractor

The EPC contractor typically provides engineering, procurement, construction, installations activities and test the equipment and systems under the terms and conditions of the contract. Tests performed by the contractor may be witnessed by the engineer or owner. The contractor will perform following;

- He will provide all engineering activities like selection of the turbine and associated auxiliary systems.
- He will coordinate procurement activities and transportation of all of the equipments from the dry port to the installation site.
- He will prepare layout drawings of the building, installation of equipments and associated systems.
- He will prepare Gant-Charts and schedules of all sub activities from start to completion of the project.
- He will perform commissioning, testing on owner-furnished equipment in accordance with the contract.
- He will record test data results during construction/installation and pre-commissioning testing and will distribute to the engineer, and incorporate into the system turnover package.
- He will Implement tagging and work clearances on systems and equipment under the jurisdiction of the contractor in accordance with the commissioning program tagging procedure prior to turn over to the owner.
- He will schedule completion of construction work and test activities to support the

overall commissioning program.

- He will provide the engineer with status of contractor-furnished equipment and systems deficiency list items and will advise the engineer when turnover for pre-commissioning testing will occur on contractor-furnished equipment and owner-furnished equipment.
- He will perform pre-commissioning testing on contractor-furnished equipment and systems in accordance with test requirements contained within the contract.

II. Project Engineer

The Project Engineer typically provides the design documents to install and test the turbine based on the manufacturer's recommendations.

- He will provide all engineering documents and information necessary for construction, completion and testing of the turbine.
- He will assist other engineers on-site to provide assistance on design and engineering problems.

5.7 PRE-COMMISSIONING TEST

Pre-commissioning test is to ensure all tests and checks necessary for each plant system to be functional before startup of commissioning testing of the overall integrated plant commences. The purpose of these procedures is to verify that each system performs in accordance with design requirements. Commissioning test procedures will be used during the final phase of the plant startup. These procedures outline tests to be performed on the major plant systems and components such as turbine-generator and controls, voltage regulator and excitation systems, relays and protection equipment, and the various modes of starting, loading, and stopping each unit. This phase will be coordinated with the vendor's representatives supplying the turbine and with the operating authority for this turbine.

Following tests will be performed in support of the commissioning program and in keeping with the schedules for preoperational and operational testing.

a) Unit alignment;
b) Rotational run-out checks;
c) Rotor diameter measurement;
d) Rotor roundness measurement;
e) Stator bore diameter measurement;
f) Stator roundness measurement;
g) Air-gap measurement;
h) Verification of temperature devices;
i) Current transformer polarity checks;
j) Stator and rotor winding resistance measurements;
k) Open circuit saturation test;
l) Short-circuit test;
m) Phase sequence test;

n) Heat run; Over-speed tests;
o) Load rejection tests;

5.8 COMMISSIONING OF THE TURBINE

The installation plan of the turbine to be provided by the manufacturer will be followed. Commissioning of the turbine will be carried out strictly in line with the instructions provided by the turbine manufacture. However, in case of unavailability of commissioning procedures for this turbine following tests will be conducted;

- Speed no load (SNL) rejection.
- 25% load acceptance and rejection.
- 50% load acceptance and rejection.
- 75% load acceptance and rejection.
- 100% load acceptance and rejection.
- Normal shutdown.

After the successful installation and commissioning of the turbine, a 72 hour Standard Reliability Run Test will be carried out as per SOP made by IESCO pursuant to their standard practices. The 72 Hours Reliability Test Acceptance Form has been placed in Annexure V, at page.53 and Generator Parametric Log Report in Annexure VI at Page 54. For this test the whole system will be operated continuously for 72 hours and all critical parameters mentioned in the Table at Annexure VI, like voltage, current, Power Factor, Power, frequency, RPM, stator winding temperature etc. will be recorded after every hour and daily signed by the EPC contractor, Manager construction and owner/client of the turbine accordingly. If due to any reason turbine go into shutdown than again 72 hours will start from zero hour to confirm reliability in continuous operation.

5.9 PLANNING FOR PERFORMANCE MONITORING AND OPERATIONAL LIFE

The Plan for the Periodic Performance Monitoring and Preventive Maintenance of the Turbine will be adopted as supplied by the manufacturer of the turbine. As the turbine will be fully submerged in the water so continuous physical performance monitoring is difficult. However, a smart meter will be installed on the power evacuation system that will convey and record the performance of the turbine in terms of output power along with data logging that can be helpful in performance monitoring and operational life of the turbine. Further, with temperature sensors installed in the stator winding and, main bearing as well as leakage sensors provided in the stator housing and cable entry, the generator can be monitored for problems before their occurrence.

Moreover, every year a planned shutdown of the canal from 5th January to 5th February is available for physical inspection and maintenance of the turbine, if required.

5.10 PLANNING FOR CONSENSUS BUILDING AMOUNG STAKEHOLDERS

As per experience and available knowledge, following are the stake holders for the installation of the proposed submersible turbine [5 KW Submersible Turbine (Smart Hydro Power)] in the UJ canal.

- SAARC Energy Centre Islamabad
- IST (Institute of Space Technology, Islamabad)
- M/s Al-Awan General Trading Corp. (Country Head, Smart Hydro Power)/Owner of the Turbine)
- Department of Irrigation, Government of the Punjab
- Punjab Energy Development Board
- IESCO (Islamabad Electric Supply Company)
- Ministry of Environment, Government of the Punjab
- Representatives of the local area

For the purpose of consensus building among all the above-mentioned stakeholders', 2-fold strategy is proposed:

- Sharing of this report with all the e above-mentioned stakeholders.
- A 1-day dissemination workshop may be arranged at the site and all the stake holders and limited local population may be invited to build the consensus.

5.11 PLANNING FOR PROVISION OF ELECTRICITY TO USERS

Located close to the selected site, there is an office building of Hydro Monitoring Station with a connected load of 3 kW. The output of the installed turbine may be consumed within this public sector office. Moreover, in the premises of Jaggu Head, there are a number of installations whose security and monitoring activities demand uninterrupted electrical power supply which can be met through the output power from this turbine for 11 months annually.

Further, for the coming projects on this site, electricity consumers all around the area, facing more than 12 hours load shedding, would be eager to utilize the electricity produced; the beneficiaries may also include small scale industrial units.

Chapter: 6 CONCLUSIONS AND RECOMMENDATIONS

This study was undertaken with the purpose of demonstration of a new technology in SAARC countries, capable of harnessing untapped huge resource with affordable funding, little efforts and short time etc. Moreover, resource assessment of the entire canal in terms of theoretical, technical and economic potential have been made which highlighted the importance of this technology to grab this much untapped energy. After going through the study, we have reached to the following conclusions and recommendations.

6.1 CONCLUSIONS

The study concluded the following important aspects:

a. The installation of 5Kw floating type submersible turbine will demonstrate the realization of the engineering concept and may become a catalyst for all of the stake holders to work collectively for the exploitation of this technology for the utilization of untapped hydrokinetic energy throughout SAARC member states.
b. The UJ canal has a theoretical potential of around **44.66 MW** which is a reasonably attractive resource to be exploited accordingly.
c. The UJ canal has a technical potential of around **11 MW** which can be tapped with proper planning and implementation of workable policies, business model and employing suitable turbines for a water flow velocity of 1.12 m/s as per in the main canal.
d. However, by employing the available Model turbine of 5 KW capacity made by Smart Hydro Power, Germany only under the 4 Head Regulator Bridges **0.6 MW** power can be harnessed.
e. The economic potential with available Model Turbine is **Rs. 46.75 M.**
f. The payback period for this project is approximately **7** years, which is a very attractive figure in comparison to hydel power projects utilizing the potential energy.
g. The completion time required for this project is very less than the time required for conventional hydel power projects.
h. The required grid connected infrastructure i.e. distribution power system being managed by IESCO is available for the evacuation of electrical power throughout the length of the canal.
i. Both sides of the UJ Canal are thickly populated providing opportunity for the local utilization (domestic, industrial and agricultural purposes) of the power produced through this intervention.

6.2 IMPACT OF POWER GENERATION FROM SUBMERSIBLE TURBINES ON SURROUNDING POPULATION

As the surrounding population of the intervention area is facing severe electrical power shortage; in summer more than 12 hours people are living without any grid power supply. In this scenario, these people will be enthusiastic to be facilitated with the power generated from the submersible turbines in the Upper Jhelum canal for their utilization.

Besides being thickly populated, both sides of the canal are surrounded by the agricultural land. Hence, uninterrupted electrical power from these turbines, for almost 11 months annually, may also be utilized for agricultural activities.

Due to the existence of canal, fish farming remains a potential resource of income; uninterruptible power supply from the pilot project may be utilized for this small scale industry (for water storage in the fish farms and cold storage process of fish). Due to the availability of agricultural raw material, small scale industrial activities may also be a candidate for utilization of the electricity produced from these turbines. In this way, economic activities may be enhanced in this area which will, in return, uplift the quality of life, educational activities and overall development of the area.

The proposed project is expected to fetch important, long term benefits such as the following:

- Alleviation of poverty by generating direct and indirect employment in the area. The project will generate indirect employment during the construction of the project activity and also permanent employment during operation of the project through provision of electricity.
- The power generation from the project activity would complement to the utility's efforts towards grid stability and will help in providing uninterrupted power for the farmers.
- The project activities will contribute to the development of infrastructure in and around the project like roads, buildings and communication systems in the rural area.
- The project activity will reduce the migration of the rural populace to urban areas, as the project activity will generate employment opportunities.
- Being a hydropower project, it will not lead to any GHG emissions. So, the project wouldn't affect the microclimate of the region since it will not entail any wastes or production of toxic gases, hence the hole initiative would be environmentally benign and will help in reducing global warming impacts.
- This project will also become a source of earning carbon credits, accordingly.

6.3 RECOMMENDATIONS FOR USE OF SUBMERSIBLE TURBINES IN THE SAARC REGION

Following are the recommendations for SAARC Energy Centre and relevant organizations of the SAARC Region:

- The countries with abundant resources of hydrokinetic energy or even having potential for micro hydel like Afghanistan, Bhutan, India, Nepal, Pakistan, Bangladesh and Sri Lanka need to explore and assess the hydrokinetic energy resource potential.
- Pilot projects of appropriate capacities may be started initially on the most feasible locations of the rivers and/or canals by the respective government organizations.
- Import duties and taxes on the equipment and spares needed for hydrokinetic turbines and associated systems may be exempted to make the pilot projects possible and feasible.
- To popularize and boost interest in the installation of hydrokinetic energy projects, government subsidies may be allocated till the full utilization of this resource potential.

6.4 UP SCALING THE PROPOSAL WITH RESPEST TO SAARC REGION

This study report have been disseminated among relevant professionals and entities of the SAARC Member States by conducting Dissemination Webinar on 8-9 Feb, 2018, so that all Member States, where applicable, may be benefitted through this study report by learning, confidence building and make utilization of this untapped resource. Moreover, it will also be available on SEC Website.

Later on, this intervention / experiment / pilot project may be up scaled for each of the SAARC Member State, where applicable, by customizing UJ Canal success story.

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ANNEXURE – I POTENTIAL RIVERS AND CANALS IN PAKISTAN

Following are the rivers and canals in Pakistan which may carry the required potential that can be harnessed through the utilization of appropriate submersible turbines;

Rivers

1. Kabul River
2. Indus River
3. Jhelum River
4. Neelum River
5. Chitral River
6. Kunhar River
7. Swat River
8. Kurram River
9. Gomal River
10. Chenab River

Canals

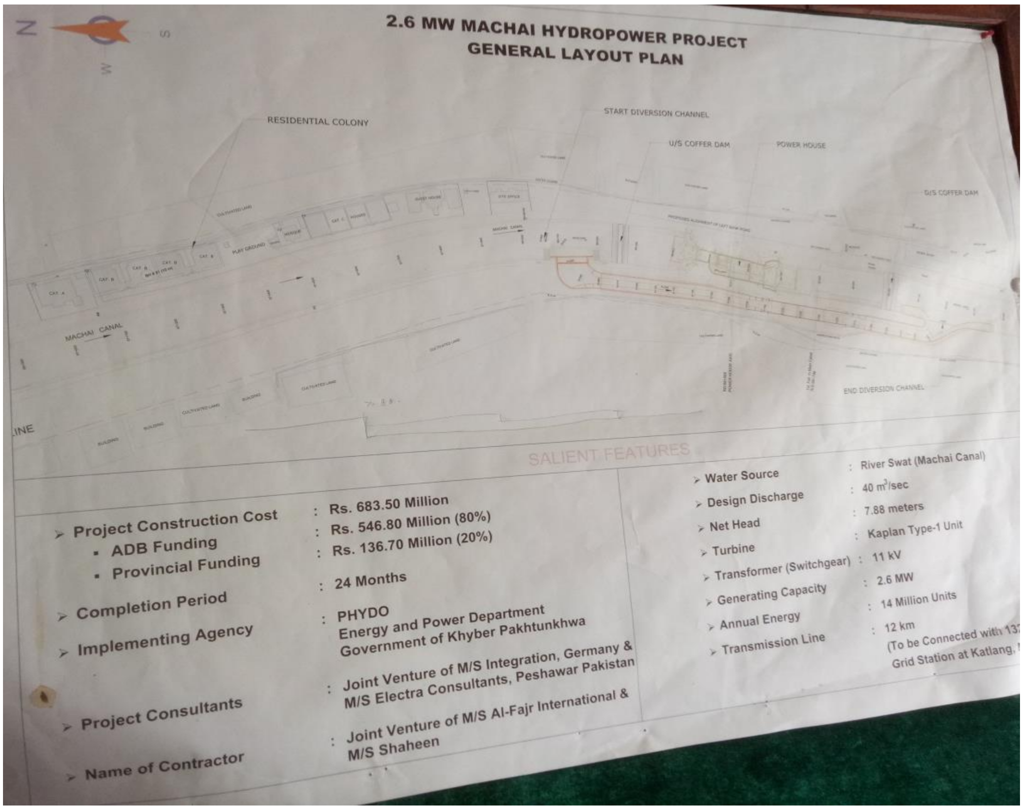
1. Ghazi Brotha Canal
2. Upper Swat Canal
3. Machai Canal
4. Upper Jhelum Canal
5. Upper Jhelum Link Canal
6. Lower Jhelum Canal
7. Warsak Right Bank Canal
8. K.R.C Canal
9. Upper Swat Canal
10. Lower Swat Canal
11. Pehur Canal
12. Thal Canal
13. Chashma Right Bank canal
14. Chashma Right Bank Lift Gravity Canal
15. Chashma Jhelum Link Canal

16. Marala Ravi Link canal
17. Upper Chenab link Canal
18. B.R.B Link Canal
19. Upper Chenab Internal Canal
20. Taunsa Panjnad Link Canal
21. Upper Pakpatan Canal
22. FoedWah Canal
23. Eastern Sadqia
24. L.B.D.C Canal
25. Lower Pakpatan
26. Mailsi Canal
27. Sidhnai-Mailsi-Bahawal Link Canal
28. Qaim Canal
29. Upper Bahawal Canal
30. Rangpur Canal
31. Lower Bahawal Canal
32. Qadirabad-Baloki Link Canal
33. L.C.C. East Gugera Canal
34. L.C.C west Jhang Canal
35. L.C.C Feeder
36. Rasool Qadirabad Link Canal
37. Trimu –Sidhnai Canal
38. Haveli Link Canal
39. Kachhi Canal
40. D.G Khan Canal
41. MuzaffarGarrh Canal
42. Panjnad Canal
43. Abbasia Canal
44. Pat Feeder Canal
45. Desert Feeder Canal

46. Begharri Feeder Canal
47. Gharri Feeder Canal
48. Rainee Thar Canal
49. Nara Canal
50. Khairpur East Canal
51. Khairpur West Canal
52. Rohrri Canal
53. North West Canal
54. Rice Canal
55. Dadu Canal

Annexure- II PICTURES OF MACHAI CANAL AND ITS POWER PROJECTS

Annexure- II Fig: 0-1: The potential location of Machai canal available for submersible turbine project



Annexure- II Fig: 10-2: Details of the 2.6 MW Machai Hydropower Project, built and owned by PHYDO (KPK)

Annexure- II Fig: 1-3: Front View of the 2.6 MW Machai Hydropower Project

Annexure- II Fig: 1-4: Turbine room of the 2.6 MW Machai Hydropower Project

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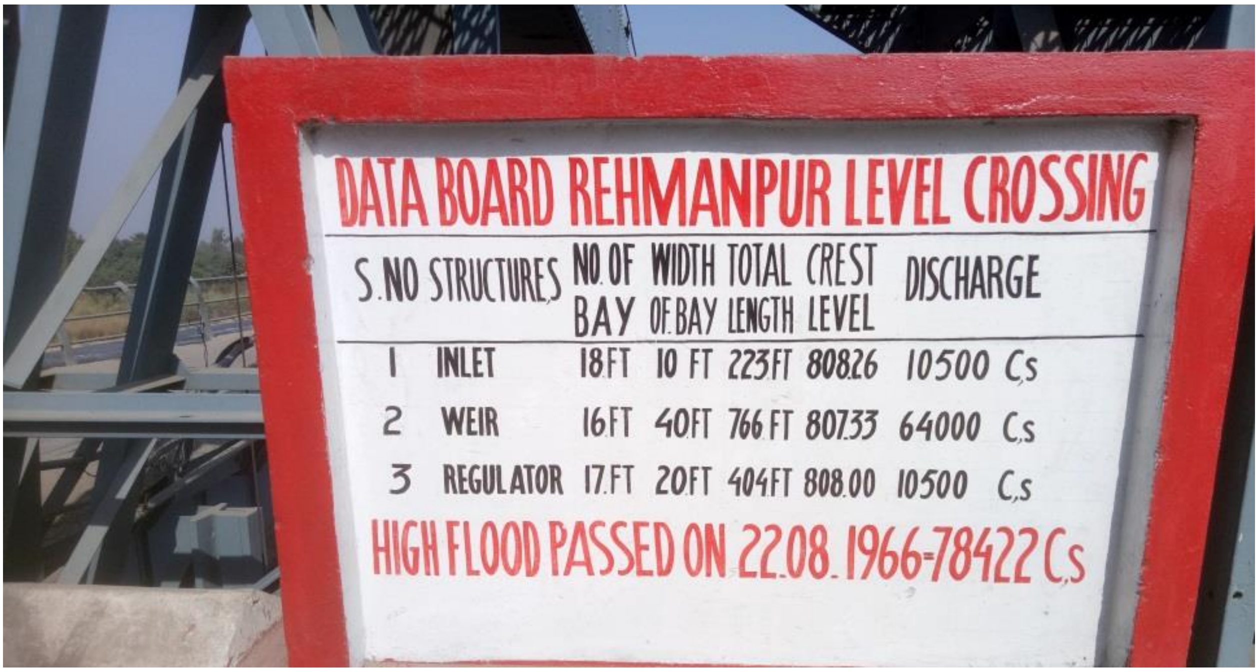
Annexure- II Fig: 0-5: Rear view of the 2.6 MW Machai Hydropower Project

Annexure- II Fig: 1-6: Another 2 MW hydropower project under construction on Machai canal

Annexure –III PICTURES OF UPPER JHELUM CANAL BEFORE AND AFTER ANNUAL SHUTDOWN



Annexure –III Fig: 1-1: Data of Rehmanpur water level crossing at Upper Jhelum canal (18 Km from GT road Jhelum).

Annexure –III Fig: 0-2: Exact location for the installation, 2nd option at the exit of 2nd channel under the bridge.

Annexure –III Fig: 0-3: Exact location for the installation, 2nd option at the entrance of 2nd channel under the bridge.

Annexure –III Fig: 0-4: Front view of the bridge showing 17 channels of the canal.

Annexure –III Fig: 0-5: Downstream of the upper Jhelum canal at Jaggu water level crossing.

Annexure –III Fig: 0-6: A siphon near Juggu Head Works, a proposed location for the installation of turbines.

Annexure –III Fig: 0-7: Channel No.7 under Jaggu head works bridge, after annual shut down, which is a final selection for installation of turbine.

Annexure –III Fig: 0-8: Downstream of the upper Jhelum canal at Jaggu water level crossing after annual shutdown.

Annexure – IV MANUFACTURERS, DEVELOPERS AND SUPPLIERS OF HYDROKINETIC TURBINES

The following list includes developers who have, at a minimum, built an in-stream prototype hydrokinetic turbine.

Manufacturer	Location	Device Name	Website
Tidal Sails	Norway	Tidal Sail	www.tidalsails.com
Tidal Stream	United Kingdom	Tidal Stream Device	www.tidalstream.co.uk
UEK	Annapolis, Maryland	Underwater Electric Kite	www.uekus.com
Verdant Power	Arlington, VA	Kinetic Hydro Power System	www.verdantpower.com
Vortex Hydro Energy	Ypsilanti, MI	Vivaci	www.vortexhydroenergy.com
Woodshed Technologies	Australia	Tidal DelayTM	www.woodshedtechnologies.com.au
BioPower	Australia	bioStreamTM	www.biopowersystems.com
Blue Energy	Canada	Davis Turbine	www.bluenergy.com
Bourne Energy	Malibu, CA	Riverstar	www.bourneenergy.com
Clean Current	Canada	Clean Current Turbine	www.cleancurrent.com
Current to Current	Burlington MA	Submersible Power Generator	www.currenttocurrent.com
Free Flow Power	Manchester, MA		www.free-flow-power.com
Hammerfest Strom	Norway	Hammerfest Strom Turbine	www.tidevannsenergi.com
Hydro Green Energy	Houston, TX	HydroGreen Turbine	www.hgenergy.com
Lucid Energy	Goshen, IN	Lucid Energy Turbine	www.lucidenergy.com

Lunar Energy Ltd	United Kingdom	RTT	www.lunarenergy.co.uk
Marine Current Turbines Ltd	United Kingdom	Seaflow SeaGen	www.marineturbines.com
Natural Currents	Highland, NY	Natural Current Vertical Axis Turbine	www.naturalcurrents.com
Neptune Renewables	United Kingdom		www.neptunerenewableenergy.com
Oceana	Washington DC		www.oceanaenergy.com
Ocean Flow Energy	United Kingdom	EvapodTM	www.oceanflowenergy.com
Open Hydro	Ireland	Open Center Turbine (OCT)	www.openhydro.com
Ocean Renewable Power	Fall River, MA	OCGenTM	www.oceanrenewablepower.com
Pulse Generation	United Kingdom	Pulse Generation	www.pulsegeneration.co.uk
Ponte di Archimeda	Italy	Enemar	www.pontediarchimede.com
Seapower Int'l AB	Sweden	EXIM TM	www.seapower.se
Sea Snail	United Kingdom	Sea Snail	www.rgu.ac.uk
Scots Renewables	United Kingdom	SRTT	www.scotrenewables.com
SMD Hydrovision	United Kingdom	TidEl	www.smd.co.uk
Startkraft	Norway	Statkraqft	www.statkraft.com
Swan Turbines	United Kingdom	Swan Turbine	www.swanturbines.co.uk
Tidal Generation Limited	United Kingdom	Tidal Generation Turbine	www.tidalgeneration.co.uk
Tidal Hydraulic	United Kingdom	Tidal Hydraulic Generator	www.dev.onlinemarketinguk.net/THG/
Lucid Energy	USA		

Technologies			
Smart Hydro Power GmbH	Germany	Smart Hydro Power	info@smart-hydro.de
Thropton Energy Services	U.K		
Alternative Hydro Solutions Ltd	Canada		
Energy Alliance	Russia		
New Energy	Canada		
Seabell Int. Co., Ltd.	Japan	+81-3-3237-9634	info_overseas@japanasiagroup.jp
Eclectic Energy Ltd.	UK		http://www.eco-web.com/cat/9.5.html
Greentech Avvenue	USA Canada Germany	+1 310.990.7680 +1 778.960.5472 +49 175.656.9795	mike.rimoin@greentechavenue.com axel.schaefer@greentechavenue.com udo.tschipke@greentechavenue.com
kirloskar integrated technologies private limited	India	+91 20 25457940 + 91 20 25457939	www.kitlgreen.com tidal.kitl@kirloskar.com
ACEP	Alaska	001 (907) 474-5402	ACEP.info@alaska.edu http://acep.uaf.edu/about/contact.aspx

Annexure –V 72 HOURS RELIABILITY TEST ACCEPTANCE FORM

ACCEPTANCE TEST

Project	Plant Design, Procurement and Construction Of 5 KW Submersible Turbine at Jaggu Head works Upper Jhelum Canal	Date: 15th February, 2 018
Description	72 hours / Continuous operation for Nominal output operation	Reference:

Consultant Remarks:

Annexure- VI

5 KW Submersible Turbine Generator Parametric Log Report for 72 hours Reliability Test run

Date: 10-02-18	Phase to Phase Voltage (V)			Phase to Phase Current A)			PF	KW (P)	FREQ (HRTZ)	KVar	RPM	Stator winding Temperature (^{o}C)						General Temperature (^{o}C)		Turbine BRG Temperature (^{o}C)		Grid Voltage (V)		
Time	RY	YB	BR	R	Y	B						1	2	3	4	5	6	1	2	1	2	RY	YB	BR
0:00																								
1:00																								
2:00																								
3:00																								
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21:00

22:00

23:00

24:00

EPC Contractor	**MC**	**Client**
Sign:	Sign:	Sign:
Name:	Name:	Name:
Designation:	Designation:	Designation:

Annexure –VII REFERENCE TARFF ON BOOT BASIS

Government of Pakistan
Ministry of Water & Power
****

Islamabad, the March 28, 2016

NOTIFICATION

S.R.O. 260(I)/2016.- In pursuance of sub-section (4) of section 31 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (XL of 1997), the Federal Government is pleased to notify the National Electric Power Regulatory Authority's approved tariff upfront tariff for small Hydro Power Generation Projects, namely:

REFERENCE TARIFF ON BOOT BASIS

	With 100% foreign debt		With 100% local debt	
	Years 1 to10 (Rs. /kWh)	Years 11 to 30 (Rs. /kWh)	Years 1 to10 (Rs. /kWh)	Years 11 to 30 (Rs. /kWh)
Energy Charge				
Variable O & M				
- Local	0.1299	0.1299	0.1299	0.1299
- Foreign	0.1299	0.1299	0.1299	0.1299
Capacity Charge				
Fixed O & M				
- Local	0.6233	0.6233	0.6233	0.6233
- Foreign	0.1558	0.1558	0.1558	0.1558
Insurance	0.7841	0.7841	0.7841	0.7841
Return on equity	4.8511	4.9464	5.1886	5.2904
Debt servicing	6.7417	-	9.1786	-
Total tariff	13.4158	6.7694	16.1901	7.1134

Levelised tariff		
- Rs. /kWh	11.1016	13.0297
- US cents/kwh.	10.8892	12.7804

Annexure -VIII NOC FROM THE DEPARTMENT OF IRRIGATION PUNJAB

OFFICE OF THE
CHIEF ENGINEER, IRRIGATION
SARGODHA ZONE SARGODHA
Phone No. 048-9230445, Fax No. 048-9230414

R & I BRANCH
NO 141
DT 9/01/17

To

The Superintending Engineer,
Upper Jhelum Canal Circle,
Jhelum.

No. 248 /W-I/01/2017. Dated 5 /01/2017.

Subject: - **AS A PILOT PROJECT THE INSTALLATION OF AVAILABLE FLOATING TYPE 5 KW SUBMERSIBLE HYDEL TURBINE IN UPPER JHELUM CANAL AS WELL AS IN OTHER SUTIABLE CANALS.**

Reference: - This office endorsement No. 231/WI/01/2017 dated 05/01/2017.

Since this is a new idea, we could not foresee the future consequences i.e where affirm body is lying obstructing the flow, reducing the velocity, deposition of site etc.

This office agree to give the go ahead to the concerned Department with certain conditions like:-

1. Energy should not be commercialized as this will be a Pilot Project as an experiment.
2. Regime of canal should not be disturbed.
3. There should be no hindrance in flow of canal water and velocity should not decrease.
4. There should not be chance of silt deposition in the canal bed.

You are requested to please examine the matter and submit detailed report considering the above and any other point.

Executive Engineer (OP,
Irrigation Sargodha Zone.

C.C

Secretary, Govt. of the Punjab, Irrigation Department Lahore with reference to Administrative Department letter No. SO(OP)(Irri)Misc/16 dated 02/01/2017 for information & necessary action please.

D/Goraya/05.01.2017/with reference UJC restoration

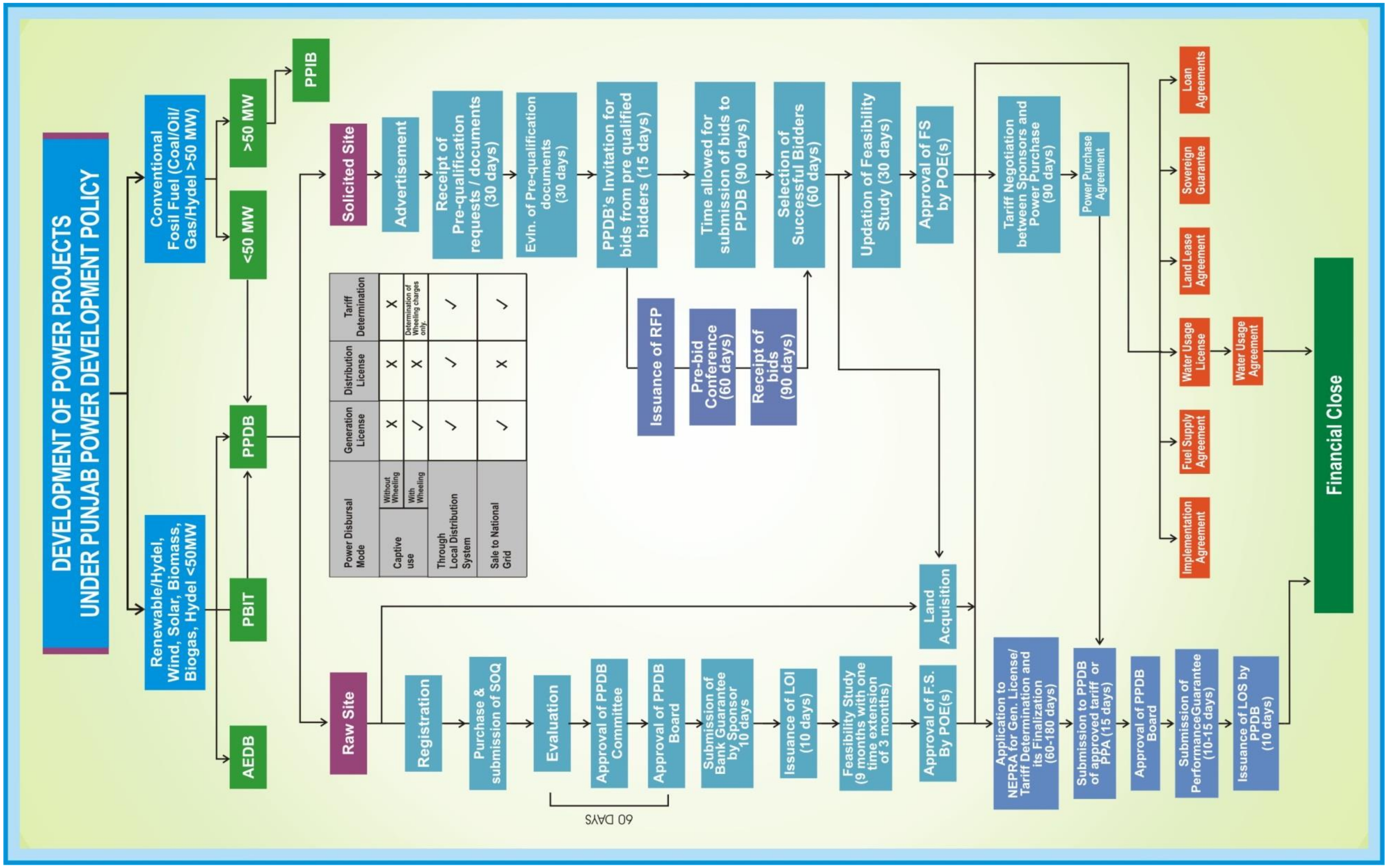
ANNEXURE – IX ECONOMIC ANALYSIS OF THE RESOURCE ASSESSMENT OF UPPER JHELUM CANAL

No of Years	Yield	WAPDA Tariff	Annual Benefits (In Rs.)	Capital Cost of the Project (In Rs.)	O & M Costs (In Rs.)	Total Costs (In Rs.)	Net Benefit (In Rs.)	Total Income
(N)	KWH	Rs.	B	C	D	E	B-E	
0			-	336,600,000	-	336,600,000	(336,600,000)	(336,600,000.00)
1	4320000	12.70	54,864,000		103,680	103,680	54,760,320	(281,839,680)
2	4320000	12.70	54,864,000		103,680	103,680	54,760,320	(227,079,360)
3	4320000	12.70	54,864,000		103,680	103,680	54,760,320	(172,319,040)
4	4320000	12.70	54,864,000		104,717	104,717	54,759,283	(117,559,757)
5	4320000	12.70	54,864,000		105,764	105,764	54,758,236	(62,801,521)
6	4320000	12.70	54,864,000		106,822	106,822	54,757,178	(8,044,342)
7	4320000	12.70	54,864,000		107,890	107,890	54,756,110	**46,711,768**
8	4320000	12.70	54,864,000		108,969	108,969	54,755,031	**101,466,799**
9	4320000	12.70	54,864,000		110,058	110,058	54,753,942	156,220,741
10	4320000	12.70	54,864,000		111,159	111,159	54,752,841	210,973,582
11	4320000	12.70	54,864,000		112,271	112,271	54,751,729	265,725,311
12	4320000	12.70	54,864,000		113,393	113,393	54,750,607	320,475,918
13	4320000	12.70	54,864,000		114,527	114,527	54,749,473	375,225,391
14	4320000	12.70	54,864,000		115,672	115,672	54,748,328	429,973,718
15	4320000	12.70	54,864,000		116,829	116,829	54,747,171	484,720,889
16	4320000	12.70	54,864,000		117,998	117,998	54,746,002	539,466,891
17	4320000	12.70	54,864,000		119,177	119,177	54,744,823	594,211,714
18	4320000	12.70	54,864,000		120,369	120,369	54,743,631	648,955,345
19	4320000	12.70	54,864,000		121,573	121,573	54,742,427	703,697,772
20	4320000	12.70	54,864,000		122,789	122,789	54,741,211	758,438,983
21	4320000	12.70	54,864,000		124,017	124,017	54,739,983	813,178,966
22	4320000	12.70	54,864,000		125,257	125,257	54,738,743	867,917,710
23	4320000	12.70	54,864,000		126,509	126,509	54,737,491	922,655,200
24	4320000	12.70	54,864,000		127,774	127,774	54,736,226	977,391,426
25	4320000	12.70	54,864,000		129,052	129,052	54,734,948	1,032,126,374
	108,000,000.00		**1,371,600,000**		**2,873,626.17**		**1,259,205,734**	

NPW of Benefits @10%	NPW of Total Cost @10%	Benefit: Cost Ratio	EIRR
487368896	**306907581**	**1.59**	**15.86**

EIRR: Economic Internal Rate of Return**, NPW:** NET Present Worth/Value

Annexure: X ACTIVITY CHART FOR DEVELOPMENT OF POWER PROJECTS UNDER PUNJAB POWER DEVELOPMENT POLICY



Annexure- XI **HISTORY OF DAILY DISCHARGE REPORT OF UPPER JHELUM CANAL (FEBRUARY –MARCH 2017)**

2	Designed Discharge 9030 Cs		
3	**Date**	**Head Gauge**	**Head Discharge**
3575	15-Feb-17	4.6	7504
3576	16-Feb-17	4.6	7504
3577	18-Feb-17	4.6	7504
3578	19-Feb-17	4.6	7504
3579	20-Feb-17	4.6	7504
3580	21-Feb-17	4.2	6489
3581	22-Feb-17	4.2	6489
3582	23-Feb-17	4.2	6489
3583	24-Feb-17	4.2	6489
3584	25-Feb-17	4.2	6489
3585	26-Feb-17	4.2	6489
3586	27-Feb-17	4.2	6489
3587	28-Feb-17	4.2	6489
3588	1-Mar-17	4.41	7015
3589	2-Mar-17	4.41	7015
3590	3-Mar-17	4.41	7015
3591	4-Mar-17	4.41	7015
3592	5-Mar-17	3.57	5012
3593	6-Mar-17	3.57	5012
3594	7-Mar-17	4.41	7015
3595	8-Mar-17	4.41	7015
3596	9-Mar-17	4.41	7015

Sheet1 Sheet2