सत्यमेव जयते

Government of India

Ministry of Power

Central Electricity Authority

REPORT OF THE COMMITTEE TO STUDY THE CONCEPT & COMMERCIAL APPLICATIONS OF HYDRO KINETIC TURBINE DEVELOPED BY M/s MACLEC

October 2021

New Delhi

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FOREWORD

The Government of India (GoI) has set a target to add 175 GW of Renewable Energy (RE) capacity by the year 2022 and 450 GW by 2030 mainly through Solar and Wind, which are sources of highly variable and intermittent power. GoI has taken several measures to accelerate RE capacity addition by introducing various policy measures and promoting various regulatory measures for adoption of imported technology in Indian scenario, indigenous capacity building for its manufacturing, indigenous development and deployment of new technologies, etc. GoI is looking into the prospects of harnessing and developing new technologies in the country as a means to increase penetration of RE in the entire energy requirement spectrum, and which would also be in line with the world's larger goal of cleaner, greener and sustainable development.

Hence, it is the need of the hour to develop Hydro Power Sector (HPS) in the country by promoting innovative and indigenously developed technologies. An Indian Company, **M/s Maclec Technical Project Laboratory Pvt. Ltd., Delhi (MACLEC)** has offered such an innovation in the form of the indigenously developed technology of Hydro Kinetic Turbines, using kinetic energy of flowing water (i.e. practically 'zero' potential head) for generation of electrical energy unlike conventional units, which utilize potential energy of water through construction of suitable civil structures such as dam, diversion weir, barrages for creation of necessary 'Head', etc.

This new and growing class of hydropower turbines is called as Hydro Kinetic (Velocity) Turbines, generation of which is highly predictive vis-à-vis solar, and wind based generation. Considering the abundance of flowing water network in India and some specific studies done, the potential of Hydro Kinetic Turbines in India appears to be on GW scale, however, reasonable exploitable potential in MW (Demand) and MWh (Energy) can be assessed based on actual study considering the information on hydrology, Geographical Information Survey (GIS), etc. Further, by virtue of their smaller size capacity/ installation, their connectivity to off-Grid/ Grid systems would be at Distribution Voltage level, and this would also obviate the need of paying transmission system charges for such an equivalent power available locally to the end users. Hence, there is an urgent need to harness hydro power by new innovative ideas and approaches by promoting Research & Development (R&D) in the field of hydro generation.

In light of the above, a Committee headed by Member (Hydro), CEA and comprising members from CEA, MNRE, NHPC Ltd., THDCIL and IIT-Roorkee was constituted by CEA on directions of Ministry of Power, GoI to study the Concept and Commercial Applications of Hydro Kinetic Turbine developed by MACLEC. The Committee had number of deliberations and discussions amongst its members besides holding presentations by MACLEC, M/s GKinetic Energy Ltd., Ireland and M/s Imp Powers Ltd., Mumbai (an Indian partner of M/s Smart Hydro Power, Germany having exclusive rights for India). This Report has been prepared by the Committee covering various aspects of concept and commercial applications of the Hydro Kinetic Turbines based on the inputs given by the Developers/ Vendors of Hydro Kinetic Technology (HKT) and discussions held amongst the members of the Committee.

The Committee would like to place on record the motivation provided by Ministry of Power, GoI in the work of promoting innovative technologies pertaining to Hydro Power Sector. The cooperation extended by the organizations viz. MNRE, NHPC, THDC and IIT-Roorkee apart from the expert Divisions of CEA including HPA Division and F&CA Division has been of immense help to adopt a collective approach while preparing this report.

The contribution of Sh. Rakesh Kumar, Chief Engineer (HE&TD), and his team is sincerely acknowledged for insightful suggestions and in preparation of the report.

(B.K. Arya)
Member (Hydro), CEA &
Chairman of the Committee

CHAPTER 1

INTRODUCTION

1. A meeting was held on 03/08/2021 under the Chairmanship of Secretary, Ministry of Power, Government of India (GoI) regarding the Surface/ Smart Hydro Kinetic (SHK) Turbines developed by M/s Maclec Pvt. Ltd., Delhi (MACLEC) wherein the different techno-commercial aspects and potential of this innovative technology were discussed.

2. Ministry of Power vide letter No. 14-37/68/2020-H.I(255414) dated 13/08/2021 (copy enclosed at **Annexure-I**) forwarded the Record of Discussion (RoD) of the aforementioned meeting, wherein it was decided to constitute a Committee headed by Member (Hydro), CEA and consisting of members from CEA, MNRE, NHPC, THDC and IIT-Roorkee to study the concept and commercial applications of Hydro Kinetic Turbine (HKT) developed by MACLEC. Further, it was decided that since the subject matter is in the domain of Ministry of New and Renewable Energy (MNRE), it may be referred to MNRE after submission of the report of the Committee to Ministry of Power (MoP). It is observed that there is no scheme at present in MNRE to provide financial support to Small/ Mini/ Micro Hydel Projects.

3. Accordingly, CEA vide Office Memorandum No. CEA-HY-17-145/1/2018-HETD Division-Part(2) dated 24/08/2021 (copy enclosed at **Annexure–II**) constituted a Committee under the Chairmanship of Member (Hydro), CEA. The composition of the Committee is as under:

i.	Sh. B.K. Arya, Member (Hydro), CEA	-	Chairman
ii.	Sh. Sharvan Kumar, Chief Engineer (HPA), CEA	-	Member
iii.	Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA	-	Member
iv.	Sh. Gangesh Upadhyay, Scientist – ‘G’, MNRE	-	Member
v.	Sh. S.K. Shahi, Scientist – ‘D’, MNRE	-	Member
vi.	Sh. Keshav Deshmukh, ED (D&E), NHPC	-	Member
vii.	Sh. L.P. Joshi, GM (EM Design), THDCIL	-	Member
viii.	Prof. Arun Kumar, IIT- Roorkee	-	Member
ix.	Prof. R.P. Saini, IIT- Roorkee	-	Member
x.	Sh. Rakesh Kumar, Chief Engineer (HE&TD), CEA	-	Member-Convener

4. The Terms of Reference (ToR) of the Committee, inter-alia, shall be to study the Concept and Commercial Application of HKT developed by MACLEC**.**

5. Total five Meetings of the Committee were held through Video Conferencing (VC), as shown in **Table 1**, wherein detailed discussions and deliberations were held on the subject matter and presentations were also given by some of the Indian and foreign manufacturers of HKTs, viz. M/s Maclec Pvt. Ltd., Delhi (Indian), M/s GKinetic Energy Ltd. (Ireland) and M/s Imp Powers Ltd., Mumbai (Indian partner of M/s Smart Hydro Power, Germany having exclusive rights for India). A copy of presentations by M/s Maclec Pvt. Ltd., M/s GKinetic Energy Ltd. and M/s Imp Powers Ltd are enclosed at **Appendix-I & Appendix-III, Appendix-II and Appendix-IV** respectively**.** Though M/s DLZ Ltd., USA was also requested to provide inputs/ make presentation before the Committee, no response was received from them.

Table 1: List of the Meetings held by the Committee

Meeting	Dated	General Agenda	MoM enclosed at Annexure
1st	02/09/2021	General Discussion among Committee Members regarding scope and proceedings of the Committee	**Annexure III**
2nd	06/09/2021	Presentation by **M/s Maclec Pvt. Ltd.** – General Introduction	**Annexure IV**
3rd	14/09/2021	Presentation by **M/s GKinetic Energy Ltd.**(Ireland)- General Introduction and Response to Members' queries	**Annexure V**
4th	14/09/2021	Presentation by **M/s Maclec Pvt. Ltd.** – Specific discussion on Technology Readiness Level (TRL) of its product and Response to Members' queries	**Annexure VI**
5th	16/09/2021	Presentation by **M/s Imp Powers Ltd.**- General Introduction and Response to Members' queries	**Annexure VII**

6. The issues and observations of the Committee including conclusion and recommendations thereon are discussed in the ensuing Chapters, and which are based on detailed discussions amongst members and inputs provided by the manufacturers/ vendors.

CHAPTER 2

HYDRO KINETIC TURBINES-ISSUES AND OBSERVATIONS

2.0 OUTLINE

This Chapter is broadly divided into two categories as per the ToR of the Committee: the Concept behind Hydro Kinetic Turbines (HKTs) and secondly their Commercial Application. The Chapter is further organized as given below:

The Section **2.1 Concept** is sub-categorized as below:

- Concept of Hydro Kinetic Energy
- Hydro Kinetic Technology
- Availability of Standards
- Construction/ Installation/ Gestation Period/ Useful Life of Hydro Kinetic Units
- Comparison of Hydro Kinetic Turbines with Conventional ‘Head based Turbines
- Salient Points of Presentations by Indian and Foreign Manufacturers/ Vendors

The Section **2.2 Commercial Applications** is sub-categorized as below:

- Potential and Feasible Exploitable Potential
- Status of Development of HKT Technology in India and Abroad
- Cost
- Estimated Tariff of Electricity
- Framework for Pilot Installation, Scaling-Up and Energy Transaction

2.1 CONCEPTS

2.1.1 CONCEPT OF HYDRO KINETIC ENERGY

Hydro Kinetic Turbines (HKTs) extract the power from the mass of flowing fluid (water) and the amount of hydrokinetic energy depends on the velocity of the mass of fluid. Hydrokinetic energy consists of different naturally available forms of energy, i.e., wave based hydrokinetic energy, and current based hydrokinetic energy.

Theoretically, the hydrokinetic energy can be expressed as per Eq. 1;

$$P_{Theoritical} = \frac{1}{2}\rho A V^3 \quad \textbf{(1)}$$

where ρ is the density of water

A is the swept area of rotor

V is the flow velocity

It is observed from the energy equation that generated power is similar to the principles as that of Wind Turbines and is proportional to the area of the rotor and cubic proportional to the flow velocity. Therefore, larger rotor will be able to generate more power and small increment in flow velocity will substantially increase the generated power. Further, this incremental increase in power generation in case of HKTs would be much more than that of Wind Turbines and which would correspond to the ratio of water density to that of air.

Eq. 1 gives the theoretical power available in the flowing water. However, practically extracted power is much lesser than the theoretical kinetic power and depends on the type of system used to harness the kinetic energy. HKTs can extract a fraction of the kinetic energy available in the water which passes through its cross section. This fraction is known as the power coefficient (C_P). The power captured by HKTs can be expressed as given below in **Eq.2 and Eq.3**:

$$P_{Captured} = C_P P_{Theoritical} \quad \textbf{(2)}$$

or

$$P_{Captured} = C_P \frac{1}{2} \rho A V^3 \quad \textbf{(3)}$$

The power coefficient depends on a speed factor called as Tip Speed Ratio (TSR), which is defined as the ratio of the tangential velocity of the rotor to the velocity of the flow of fluid, and can be expressed as per Eq. 4;

$$\text{TSR } (\lambda) = \frac{\text{Peripheral velocity of the rotor}}{\text{Velocity of the flow of fluid}} \frac{(\omega R)}{(V)} \quad \textbf{(4)}$$

2.1.2 HYDRO KINETIC TECHNOLOGY

Hydrokinetic technologies differ from traditional Hydro Power Plants (HPPs), which rely on the elevation difference (Head) between the intake and outlet. Hydrokinetic devices can be placed directly in the stream of flowing water and the kinetic energy of the flowing water is converted to mechanical energy that drives a generator to produce electricity.

HKTs are similar to the wind turbines in design and working principle. Wind turbine captures the kinetic energy available in winds, while HKTs extract the kinetic energy of water. The only difference is in the density of the fluids, i.e., Water and Air. Water is about 820 times denser than the air, and that is why the energy produced by the water may be equal to the energy produced by the wind even at low flow velocities.

Fig. 1 represents the behavior of hydrokinetic and wind turbine power densities at different flow velocities. Hydrokinetic energy conversion technologies are modern and fast growing sector in the RE generation and gain a major attention for riverine hydrokinetic conversion. In the recent years, various new untraditional hydrokinetic energy tapping devices have been introduced, i.e., vortex induced vibration system, oscillating hydrofoil, pulse stream commercial demonstrator, screw turbine, Super wheel, PAX rotor, Volturnus, and Piezo polymer conversion.

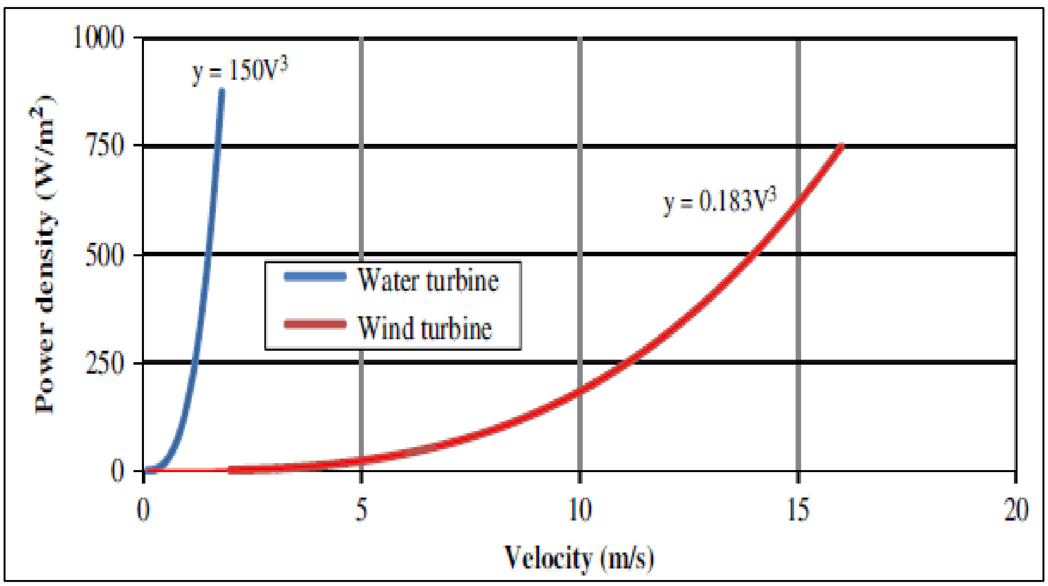

Fig. 1 Comparison of power density of hydrokinetic and wind turbine

HKTs are broadly classified in two major categories as axial flow turbines and cross-flow turbines. The classification of these turbines is based on the axis of orientation of rotor with respect to flow direction as shown in **Fig. 2.**

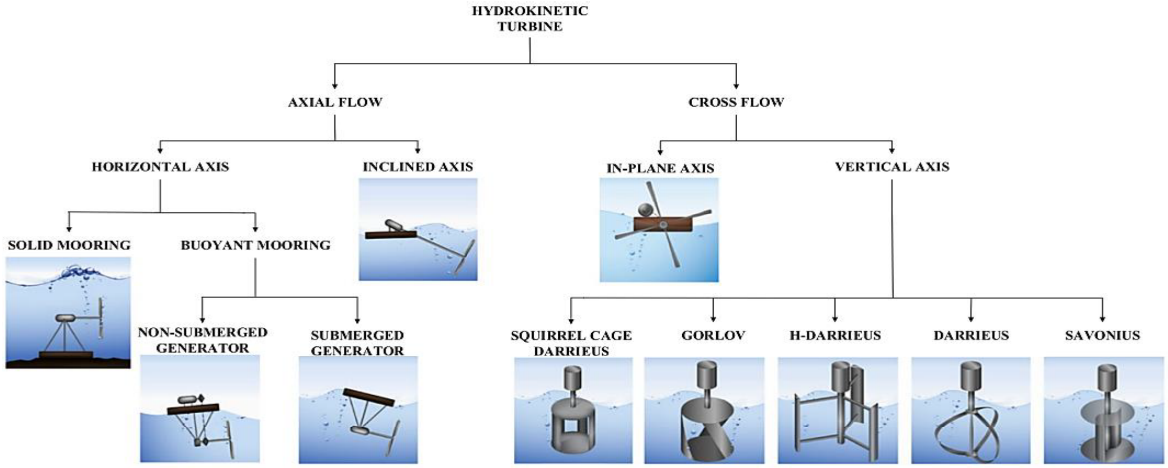

Fig 2. Types of Hydro Kinetic Turbines

The axial flow HKTs have its rotational axis horizontal/ inclined and parallel to the flow direction of water. These turbines are similar in design and working as the ship propeller and hence also known as propeller turbines. In order to achieve high efficiency, the alignment of the turbine rotor should be accurate according to the water stream. A yawing mechanism is required to align the turbine rotor with flow direction. The stream flow requirement for axial flow turbines makes it more suitable for the application like ocean, and tidal. The rotor of these turbines may have two, three or multi-blade, based on the torque requirement and flow properties. The axial flow hydrokinetic turbine is shown in **Fig. 3 (a).**

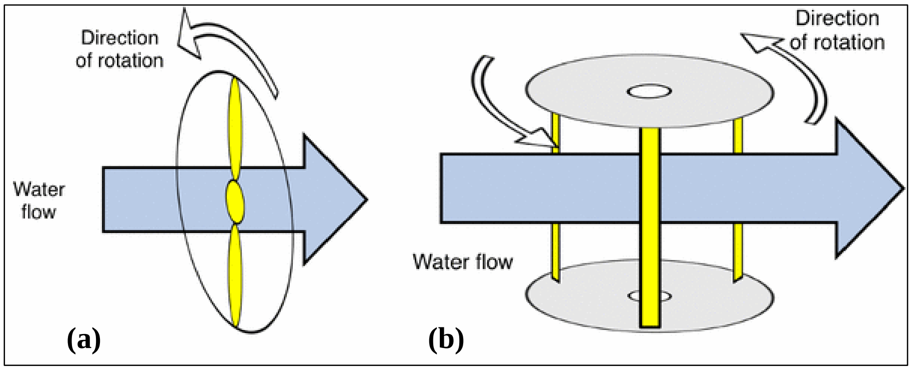

Fig. 3. (a) Axial Flow Hydrokinetic Turbine (b) Cross Flow Hydrokinetic Turbine

Cross flow HKTs have its rotational axis always orthogonal (horizontal/ vertical) to the incoming water flow. Cylindrical shape of the cross-flow turbine facilitates the efficient use of the channel depth. Cross flow turbines accept water from any direction. **Fig. 3 (b)** shows the water flow and rotational direction for this turbine. The rotor of cross flow HKTs may also have two, three or multi-blade depending on the torque requirement and flow conditions.

HKTs have relatively low power coefficient, which makes it unpopular technology in comparison to other conventional energy conversion technologies. The maximum power that a kinetic energy system (HKT) can extract is governed by Betz limit. The Betz limit for the kinetic energy conversion is about 59.3%.

The performance of the turbine can be evaluated by plotting the power coefficient versus Tip Speed Ratio (TSR). The power coefficient of the turbine never crosses the limit defined by Betz. Operating TSR range of the HKT depends on the governing force and accordingly, the operating parameters for HKT can be determined. The performance characteristics of various rotors for hydrokinetic conversion system are shown in **Fig. 4.** A general comparison of parameters related to characteristics of different HKTs are given in **Table 2.**

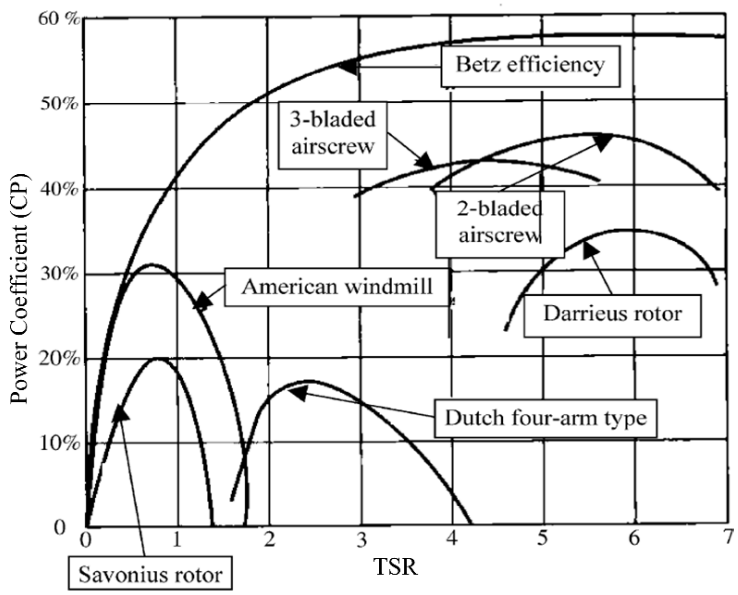

Fig. 4: Performance of typical Hydrokinetic Rotors

Table 2. Comparison of Axial v/s Cross Flow Hydrokinetic Turbines

General characteristics	**Axial flow turbine**	**Cross flow turbine**
Minimum operating current velocity	0.5 m/s	1 m/s - need higher velocity to self-start
Operating tip speed ratio (TSR)	High (TSR up to 4.5)	Low (TSR below 3)
Coefficient of power C_P	Up to 35%	Up to 30%
Debris resistant	Lower	Higher
Torque ripple	Smoother	Pulsating
Rotor simplicity	Fairly complex	Simple
Material quantity and cost	Less	More
Weight	Less	More
Mechanical power transmission	Complex	Simple

2.1.3 AVAILABILITY OF STANDARDS

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies. Following Standards as listed below are applicable for the Hydro Kinetic (water current) technologies:

1. IEC 62600-4, 2020 : Marine energy – Wave, tidal and other water current converters – Specification for establishing qualification of new technology.
2. IEC 62600-3, 2020 : Marine energy – Wave, tidal and other water current converters –Measurement of mechanical loads.
3. IEC 62600-301, 2019 : Marine energy – Wave, tidal and other water current converters –River energy resource assessment.
4. IEC 62600-300, 2019 : Marine energy – Wave, tidal and other water current converters –Electricity producing river energy converters – Power performance Assessment.
5. IEC 62600-30, 2018 : Marine energy – Wave, tidal and other water current converters –Electrical power quality requirements.

It is observed from IEC 62600-4, 2020 that following Technology Readiness Levels (TRLs) have been defined to assess at what stage of development/ application a particular product/ technology of HKE (Hydro Kinetic Energy) Developer is:

- TRL 1: Basic principles observed
- TRL 2: Technology concept formulated
- TRL 3: Experimental proof of concept
- TRL 4: Technology validated in lab
- TRL 5: Technology validated in relevant environment
- TRL 6: Technology demonstrated in relevant environment
- TRL 7: System prototype demonstration in operational environment
- TRL 8: System complete and qualified
- TRL 9: Actual system proven in operational environment

It can be inferred from above that a product/ technology can be considered at Technology Demonstration Stage (i.e. demonstration/ establishment of technology) when it has TRL of 6 & above, and which can be considered for commercial purpose/ scale if it has TRL of 9.

2.1.4 CONSTRUCTION/ INSTALLATION/ GESTATION PERIOD/ USEFUL LIFE OF HYDRO KINETIC UNITS

The applicability of Hydrokinetic technology in rivers, tidal and ocean currents and man-made channels enables installation at sites which do not hold possibilities for other technologies. Hydrological parameters, civil structures required for installation, gestation period and useful life of HKTs are as discussed below:

2.1.4.1 Hydrological Parameters

The installation of hydrokinetic device depends on various hydrological parameters discussed below such as, depth of water in river, velocity distribution of water, slope of bed of river, sediment properties, nearness to an existing installation, the water channel and its impact on it, etc.

- **Depth of Water in River**

  The process which determines the depth of water in river, is known as, 'Bathymetry'. It models the hydrodynamic behavior of river.

- **Velocity Distribution**

  The available energy of water at the upstream of HKT is directly proportional to the cubic of water velocity. It is very necessary to use highly accurate and precise instruments to derive the velocity profile of flowing water.

- **Bed Surface Characteristics**

  The bed surface characteristics can be assessed by measuring the size and density of sediment or silt present in river. The large size or highly dense sediment particles may affect the velocity distribution of water which may alter the performance of HKT.

2.1.4.2 Civil Structures

In order to get optimum installation, HKT can be placed in water channel at various positions, such as;

i. Bottom-Surface Mounting (BSM) – Positive Clearance Ratio
ii. Floating-Surface Mounting (FSM) – Negative Clearance Ratio
iii. Near-Surface Mounting (NSM) – Zero Clearance Ratio

In most cases, axial flow HKT is considered for bottom-surface mounting and FSM or NSM for cross-flow turbines. Some advantages associated with FSM or NSM installation are easy accessibility, no sealing required for generator, low maintenance cost, improved performance, etc. In case of BSM, some challenges are water-proof sealing requirement for generator, accessibility difficultly, high installation and maintenance cost, etc. Hence, it is concluded that FSM or NSM installation is more beneficial as compared to BSM installation. BSM, NSM and FSM installations are shown in **Figure 5**.

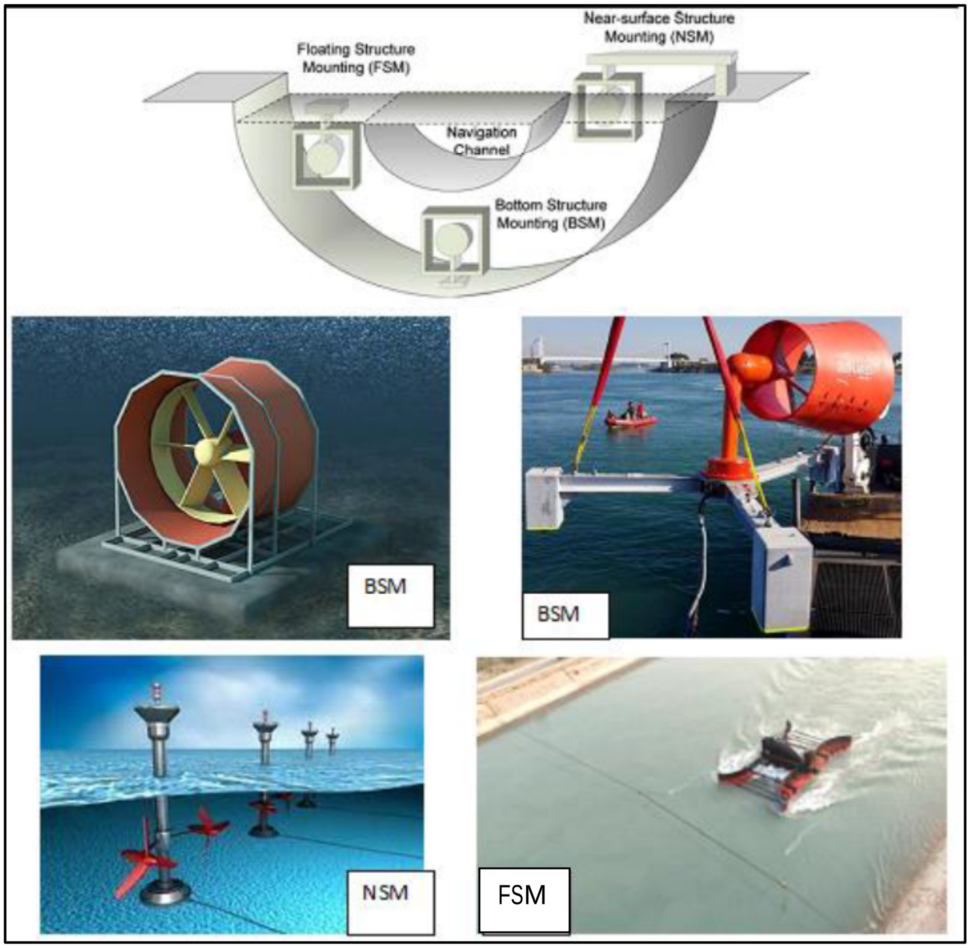

Fig.5: Different Mounting Options For Hydrokinetic Turbine In River

There are various installation methods for HKTs: installation on the riverbed or seabed, use of a vertical mast, installation beneath a floating platform, and kiting the turbine with a cable. The riverbed or seabed installation is practical when the bed is smooth. The floating platform installation is a convenient method as it offers an easy access to the turbine. However, it is limited by cold weather and floating debris. In order to prevent the contact with floating debris, a protection may be provided in front of the turbine blade or the system may be designed so as to deflect fish and debris.

2.1.4.3 Gestation Period/ Installation Time/ Useful Life

The gestation period of a project may vary from few months to about a year depending on the size of the project, whether it is Grid connected or Off-Grid, availability of nearby infrastructure such as roads for accessibility, power lines for connectivity, type of civil installation requirements, etc. The actual product is basically plug-&-play type and the entire actual installation of product(s) may range from a day to few days. Further, the useful life of product as claimed by the manufacturers may vary from 25 to 40 years depending on the operating environment and with proper O&M including periodic maintenance as recommended by the Original Equipment Manufacturer (OEM). However, the assessment of useful life and O&M costs in Indian scenario can be firmed up only after observing its performance in field (i.e. actual operating environment) for a reasonable period of time.

2.1.5 COMPARISON OF HYDRO KINETIC TURBINES WITH CONVENTIONAL 'HEAD' BASED TURBINES

The closest comparison of HKTs in terms of hydro power generation may be done with conventional Small Hydro Plants (SHPs) for evaluation of this new technology and its potential. Following **Table 3** shows a typical techno-commercial comparison between HKTs (Unit Size up to 500 kW) & Conventional Low Head Hydro Turbines (Unit Size up to 15 MW):

Table 3: Typical Comparison between HKTs (Unit Size up to 500 kW) & Conventional Low Head Hydro Turbines (Unit Size up to 15 MW)

Parameters	Hydro Kinetic Turbines	SHPs with Conventional (Low Head) Hydro Turbines
Principle of Operation	Only kinetic energy or flow of water is required to rotate the turbine and to produce electricity	A 'Head' of water by virtue of naturally available different water levels is used to convert potential energy to kinetic energy to rotate the turbine and produce electricity
Capacity	0.5 kW to 500 kW	5 kW to 15 MW
Efficiency	48% (claimed by M/s Maclec) 41% (claimed by M/s GKinetic) 40% (claimed by M/s Imp Powers)	75% to 94% for Low Heads (includes 75% to 85% for Ultra Low Heads- below 3m)

Parameters	Hydro Kinetic Turbines	SHPs with Conventional (Low Head) Hydro Turbines
TRL (Technology Readiness Level)	At demonstration stage	Well established
Cost per MW	Rs. 15 Cr- As per Proposal for NHPC prepared by M/s Maclec for 1 MW capacity comprising number of modules (having some imported content then). However, the proposal was not found technically feasible. As low as about Rs. 8 Cr – As provided by M/s Maclec to the Committee (with complete indigenization) Rs. 46.25 Cr – As per M/s GKinetic (Fully Imported) Rs. 21.4 Cr – As per M/s Imp Powers (with more than 50% domestic content)	Rs. 7.8 Cr/MW to Rs. 11 Cr/MW – (As per CERC Tariff Regulations for RE, 2020)
Area of Usage	Irrigation Canals, Perennial Rivers, Downstream of HEPs, Waste Drains, etc. having Flow i.e. 'Kinetic Head'	On Rivers, Canals etc. having natural 'Potential Head'
Completion Time	0.5 - 1 year	2 - 4 years

Apart from the aspects presented in the **Table 3** above, HKTs have added advantage of negligible requirement of civil structures, lower disturbance to the natural flow of water body and due to local connectivity at Distribution Voltage level, the requirement of having and paying for Transmission Systems & Losses for such equivalent power does not arise.

2.1.6 SALIENT POINTS OF PRESENTATIONS BY INDIAN AND FOREIGN MANUFACTURERS/ VENDORS

Apart from M/s Maclec, Delhi (the Indian firm), whose indigenously developed product in the form of Smart/ Surface Kinetic Turbines was under examination by the Committee, some other Indian and foreign HKTs vendors were also invited to showcase their technology. As a result, M/s GKinetic Energy Ltd., Ireland (Foreign Developer) and M/s Imp Powers Ltd., Mumbai (an Indian partner of Germany based M/s Smart Hydro Power, and having exclusive rights for India) gave a presentation before the Committee. Though M/s DLZ Ltd., USA was also requested to provide inputs/ make presentation before the Committee, no response was received from them. Important excerpts from their presentations are given below:

I. M/s Maclec Pvt. Ltd., Delhi (Indigenous Manufacturer)

The presentation given by **MACLEC** is enclosed at **Appendix-I** and **Appendix-III**. Salient features of their presentation are as follows:

- The operating velocity range for their turbines is 0.5m/s - 7m/s with an operating depth of minimum 0.5 m and above.
- Other parameters: operating water quality with silt (up to 30,000 ppm), floating debris (up to 200mm), sand, boulders (up to 300mm).
- The results of prototype testing showed efficiency of approximately 48%.
- The modular life of their product is around 40 years with an O&M plan comprising of regular O&M every 6 months and scheduled maintenance in every 3 years. Only electrical parts may require major technical transformation in every 10-15 years.
- Claimed Technology Readiness Level: 9 (System Complete and Operational) and Commercial Readiness Level: 8 (Actual System proven in Operation Environment)
- The Company has done testing of HKT Prototypes from 100 W to 1 kW in Ramganga River (tail race of Kalagarh Dam) in May 2015-Dec 2016. Further, they have done testing of modular performance in downstream of Chilla SHP, Uttrakhand from Feb 2018-April 2018.
- The Company has performed testing on a small scale product of 2 kW turbine on a micro irrigation Canal of 1.8 m width and depth 200 mm with velocity variation of 1.5m/s - 3m/s with no water regulator at Ramnagar, Uttarakhand.
- The guaranteed minimum generation per module would be about 3500 units/kW/Annum based on site parameters.
- The Company claimed that there would be no impact on environment and aquatic life from their product.
- The Company has assessed and identified the theoretical Hydro Kinetic potential in India, which includes main irrigation canal networks, major rivers, downstream channels of existing HPPs, etc., which comes out to be 92.2 GW.

However, no evidence for the efficiency, performance testing, velocity of the flow such as 7 m/s, guaranteed output, impact on environment, technology readiness level and potential assessment based on standard procedure were presented or shared before the Committee.

II. M/s GKinetic Energy Ltd. (Ireland)

The presentation of **M/s GKinetic Energy Ltd**., an Ireland based company, is enclosed at **Appendix-II**. Salient features of the presentation are as follows:

- The Company has completed 3 deployments of 10 kW, 25 kW and 60 kW HKTs.
- The 12 kW turbine requires minimum water channel velocity of 0.5 m/s (cut-in velocity). Their turbines hit the rated capacity at 2 m/s and are very efficient at lower speeds.
- The efficiency of their product tested in lab is 41%.
- The special design of their turbines naturally deflect fish and debris.
- Their full scale 25 kW & 60 kW devices have been designed, built, installed and

  in operational environment (TRL 6-7).
- They have achieved TRL 6-7 in 2017-2020 and are targeting TRL 8 by April 2022 and TRL 9 by fourth quarter of 2022.
- They have limited capacity for the year 2022, comprising 25 units (of 12 kW each), out of which 18 units are already allocated to different projects and remaining 7 are yet to be allocated.
- The Cost-to-Build of one complete unit of 12 kW is around € 28,475 (Rs. 24.7 lakhs as of today) and Ex-Works Sale Price This excludes installation and service charges.
- The expected design life of the parts is 7 years and the generator gear box is of standard equipment depending upon the high & low energy sites.
- Regarding the depth requirement of the machine, the product requires 1.8m for floating and 1.5m for generating power.

However, no evidence for the efficiency and impact on environment, were presented or shared before the Committee.

III. M/s Imp Powers Ltd., Mumbai (Indian Partner of M/s Smart Hydro Power, Germany having exclusive rights for India)

The presentation of **M/s Imp Powers Ltd.** is enclosed at **Appendix-IV**. Salient features of the presentation are as follows:

- The Company has installed a pilot project of 4 x 5 kW (20 kW) capacity at Neyveli Lignite Corporation India Ltd.(NLCIL), which has been successfully commissioned under R&D initiative of NLCIL. The project has been synchronized with 0.415 kV, 50 Hz NLCIL grid in the month of October, 2017. As of August 2021, 2.2 lakh units have been fed to the grid.

- Another project under execution/finalization includes a 5x5 kW (25 kW) Kakkad Hydro-kinetic project, allotted under the consultancy of Energy Management Centre, Kerala in the Tail Race of 50 MW Hydro-Electric Project of KSEB.
- Areas of application of HKTs could include: Irrigation Canals, Tail Races of all HPPs, Check Dams/ Diversion Gates, Thermal Power Plants, Sewage Treatment Plants, Cooling Channels in Industries, etc.
- As per the Company, the cost for 5x20 kW (100 kW unit) project is around Rs. 2.14 Crores. It was stated that this cost includes every aspect (cost of turbine, installation, accessories etc.) with basic anchoring. However, this cost can be reduced with the support of Government.
- Regarding estimation of Minimum Domestic Content including supply and services, the Company stated that except generators (imported from Germany) all other components are domestically manufactured and it has more than 50% domestic content.
- Their product includes free-stream and floating turbines.
- The output of turbines ranges from 250-5000 W. However, at present, they are manufacturing only a single capacity of 5 kW.
- Their models without diffusers require minimum water channel velocity of 2 m/s and 2.3 m/s for model with diffusers.
- Claimed Plant Load Factor- 70-80%
- Claimed overall efficiency - 40%
- Expected life of product should be around 25-30 years.

However, no evidence for the efficiency, performance testing, and impact on environment were presented or shared before the Committee.

2.2 COMMERCIAL APPLICATIONS

2.2.1 POTENTIAL AND FEASIBLE EXPLOITABLE POTENTIAL

As per the assessment done by MACLEC, the theoretical Hydro Kinetic Potential in India (based on hydrology data, information available from GIS, etc.), which includes main irrigation canal networks, major rivers, downstream channels of existing HPPs, etc., is 92.2 GW as presented before this Committee. Further, in their previous presentation on 10/11/2020 before Ministry of Power, they had claimed identified potential of 32.6 GW across the country. However, in a site specific study by them in the stretch covering only 32 km length of BBMB canal of length 65 km, a potential of 24 MW has been assessed for their technology/ product.

M/s GKinetic, Ireland informed that as per the report of International Renewable Energy Agency (IRENA) on 'Hydropower Technology Brief', the global technical potential of small hydropower is estimated to be 150-200 GW and only about 20% of this potential has been exploited till date. However, this potential is of small hydro power in general, and not specific to hydro kinetic energy. M/s GKinetic further informed that the non-profit Electric Power Research Institute (EPRI), USA has estimated that in the United States alone, new hydrokinetic technologies could provide an increase in generation capacity of 3,000 MW by 2025. Further, as per the EPRI report on 'Assessment and Mapping of the Riverine Hydrokinetic Resource in the Continental United States', the estimate of the theoretical resource of HKE for the continental United States totals 1,381 TWh/yr, out of which Technically Recoverable Power is 120 TWh/yr, and which translates to about 18.3 GW of exploitable potential at Load Factor of 75 %.

M/s Imp Powers, India have done feasibility study for 10-12 sites in India. However, no concrete figure could be provided by them for the potential capacity.

It can be inferred from the presentation and subsequent discussions with all the three companies having technology of HKTs that no comprehensive scientific study by a State/ Nationally accredited or recognized body has been done till date for India covering all the groupings of potential sites for Hydro Kinetic Energy like Canal, River, Tailrace of HPPs, marine current, etc. Considering the abundance of flowing water network in India and some specific studies done, it appears that the exploitable potential in India is also significant and which may be in the range of GWs. However, reasonable exploitable potential in MW (Demand) and MWh (Energy) can be assessed based on actual study considering water availability, hydraulic conditions (velocity and depth of flow), etc. required for SHK turbine. Hence, there is an urgent need for undertaking such a study to realistically determine the exploitable potential of this technology as globally acceptable Standards for carrying out such an assessment have also become available recently.

2.2.2 STATUS OF DEVELOPMENT OF HKT TECHNOLOGY IN INDIA AND ABROAD

2.2.2.1 Scenario of HKTs in India

1) In the Indian context, the electricity generation through RE system such as solar, wind and biomass system have grown to a significant capacity and has huge capacity addition targets over the next decade. On the similar lines, HKTs present themselves as an additional source of available Renewable Energy (RE) and exploitation of which on commercial scale would lead to deeper penetration of RE in the energy spectrum of the country. The present status of HKTs in India is given in **Table 4**:

Table-4: Some of the Projects carried/ being carried out in India

S. No.	Project name	Turbine type	Company	Constraints	Location
1.	Chilla Power Channel	Axial Flow (25 kW)	DLZ Corp., US	• Submerged turbine • Low debris handling capability • Require constant depth of operation.	Chilla canal, Dehradun Uttarakhand, India
2.	Neyveli Lignite Corporation Ltd.	Axial flow (4x5 kW)	M/s Smart Hydropower(German) in collaboration with M/s Imp Powers(Indian)	• High flow velocity requirement (3.1 m/s) • Intricate blade shape • High debris protection required	Neyveli Lignite Corporation India, Chennai, Tamil Nadu, India
3.	Not yet installed	Axial flow	Elemental Energy Technologies (EET), Australia + Kirloskar, India	• High depth applications (Marine Applications) • High flow velocity requirement (3-4.5 m/s)	Not available

4.	Kakkad HEP	Axial flow 5x5 kW (25 kW)	M/s Imp Powers (an Indian firm in technological collaboration with M/s Smart Hydropower, Germany)	• Project Allotted	Kerala, India

2) In India, SHK Turbine for harnessing the potential available in water stream is under technology development stage, and which may be inferred from information as below:
   a) M/s Maclec Pvt. Ltd., Delhi is the indigenous manufacturer of HKT in the country. The available unit sizes with the Company presently is up to 5 kW, though they have made claim for size up to 500 kW. As per the presentation of M/s Maclec and subsequent discussions with the Committee members, it was revealed that their Technology Readiness Level (TRL), as defined in IEC Standard 62600-4, 2020 is between 6 (Technology Demonstrated in Relevant Environment) and 7 (System Prototype Demonstration in Operational Environment), even though they have claimed it to be of Level 9 (Actual System Proven in Operational Environment).
   b) Another vendor, M/s GKinetic Ltd., based in Ireland, has totally off-shore content and their available unit sizes are from 10 kW to 60 kW. M/s GKinetic have achieved TRL 7 by the year 2020 and are targeting TRL 8 (System complete and qualified) by April 2022 and TRL 9 by fourth quarter of 2022.
   c) M/s IMP Powers, Mumbai claim to have more than 50% local content and the available unit size is only 5 kW as of today. For M/s Imp Powers, TRL appears to be around Level 8 in India, as one of their projects is already installed and running at Neyveli Lignite Corporation India Ltd. (NLCIL) since 2018. However, in their presentation, they have stated that the performance outcome data is yet to be obtained from NLCIL due to delay on account of Covid impact and they plan to obtain it shortly.

It can be observed that in Indian scenario, the HKT technology by Indian vendors is currently at Technology Demonstration stage, i.e. around TRL of 6-7. This technology can be taken up for commercial purpose only after successful field demonstration in operational environment by the developers for a reasonable period of time and after fulfilling special requirements like placement in remote areas, low velocity water channels, etc.

2.2.2.2 International Scenario of HKT

Some of the developed countries, especially with coastal areas, are utilizing HKTs to harness energy. Status of some of the projects carried out by companies in other countries is given in **Table 5**:

Table 5: Some of the Projects carried out in Countries other than India

S. No.	Project name	Turbine type	Company	Constraints	Location
1.	Duncan Dam	Cross flow	M/s Instream Energy Systems	• High depth requirement • High flow velocity requirement (4.2 m/s)	Kaslo, British Columbia
2.	Roza Canal				Yakima, Washington
3.	Tiger Project	Cross flow	M/s Hydroquest SAS	• Minimum flow velocity of 3.1 m/s • High depth requirement • Blade complexity	France and UK
4.	Sluice of Dutch icon Afsluitdijk, Wadden Sea	Axial Flow	M/s Torcado	• High Flow velocity (4.2 m/s/) and depth requirement (4 meters)	UK
5.	Pointe du Bois	Cross flow	M/s New Energy Corporation	• High depth and flow velocity requirement • Intricate blade profile	Manitoba, Canada
6.	Canadian Hydrokinetic Turbine Test Centre				Lac Du Bonnet, Manitoba
7.	Canoe Pass				British Columbia, Canada
8.	RITE Project	Axial flow	M/s Verdant, USA	• Minimum flow velocity of 2.2 m/s • High depth requirement • Blade complexity • Debris protection requirement	Canada and USA

9.	HyTide 1000	Axial Flow	M/s Voith Hydro	• High depth requirement • Severely affected by debris • High flow velocity requirement	Jindo, Korea
10.	Seeneoh	Cross Flow 25 kW	M/s GKinetic, Ireland	--	River Garonne in Bordeaux, France
11.	Kirkwall harbour	Cross Flow 60 kW	M/s GKinetic, Ireland	--	Orkney Islands, Scotland

It may be observed here that HKE Internationally as a Technology with various leading vendors may be nearing completion/ completed Technology Demonstration Stage. The USA, Canada and few countries in Europe are working extensively on developing HKT but with the focus on Marine water, and on few locations of rivers having almost constant flow with a depth of 10 – 40 m. For such applications, the unit capacity is being developed for few 100 kWs.

2.2.3 COST

As on date, no guideline/ regulation is available in India for the estimation of cost for hydro kinetic energy technology based SHK turbine-generator module. Moreover, the credential for commercial operation of such technology is yet to be established. In light of this, the cost data given below is based on inputs provided by the vendors and which indicates that it is sensitive to unit/ project capacity, domestic content, type of civil installation, etc.

2.2.3.1 Installation Cost for HKTs given by Vendors:

1) **Class-I Local Supplier (Minimum Local Content more than 50% as per PPP-MII Order)**

- The total installation cost for SHK Turbines earlier quoted by MACLEC for pilot project at Tanakpur power canal of M/s NHPC for 1 MW and at BBMB site for 210 kW installation was **Rs. 14.95 Crores/ MW** and Rs. **18.50 Crores/ MW** respectively, whereas data submitted by them before the Committee is as low as about **Rs. 8 Crores for a 1 MW** installation comprising no. of modules. However, the cost for smaller capacity installations may be of the order of **Rs. 16 Crores/ MW**. In response to Committee observation on the change in the cost data, MACLEC clarified that it is due to complete indigenization of the product.

- For M/s Imp Powers (Indian Partner of M/s Smart Hydro Power, Germany having exclusive rights for India), the cost for 100 kW project is around Rs. 2.14 Crores, which comes out to be Rs. **21.4 Crores/MW**.
- The cost of M/s Imp Powers appears to be higher vis-à-vis MACLEC due to its import content.

2) Class-II Local Supplier (Minimum Local Content greater than 20% as per PPP-MII Order)

- No information is available in this category.

3) Foreign Supplier

- For M/s GKinetic, the Cost-to-Build one complete unit of 12 kW is around € 28,475 (Rs. 24.7 lakhs as of today) and Ex-Works Sale Price is € 64,000 (Rs. 55.5 lakhs as of today). This is about **Rs**. **46.25 Crores/MW**. Further, this excludes installation and commissioning charges. This appears to be higher compared to both of the above Class-I vendors as it is a fully off-shore product.

As per CERC Tariff Regulations for RE, 2020, the normative capital cost of Small Hydro Power Projects varies from Rs. 7.8 Cr/MW to Rs. 11 Cr/MW.

Since the claim for an indigenous HKT product price is cheaper and amounts to as low as about Rs. 8 Crores/MW for a 1 MW installation, the domestic manufacturers may present a better alternative cost-wise in future after reaching to the TRL level of 9 with few successful, well monitored and efficient pilot projects installation. This will also be in line with the 'Make in India' initiative of Government of India. Also, if these technologies are manufactured and scaled up along with sufficient Government support, the overall cost may be further brought down. However, the products/ technologies whether indigenous or imported need to be sufficiently tested for a reasonable period in Indian operating scenario before their commercial exploitation.

2.2.4 ESTIMATED TARIFF OF ELECTRICITY

The tariff estimate for electricity on HKTs is based on the Central Electricity Regulatory Commission (CERC) Tariff Regulations for RE, 2020 by considering the norms as provided for 'Small Hydro' therein. The sensitivity analysis of tariff for Capacity Utilization Factor

(CUF), Capital Cost (CC) as claimed by MACLEC, useful life and CERC norms considered therein has been discussed at Para 2.2.4.1 and tabulated at **Tables 6 and 7**.

It may be observed here that the assumptions made in tariff estimation are subject to change upon establishment of technology based on the actual cost incurred and successful performance outcomes of technology demonstration projects in field. For assessing the outcome, the performance of these projects need to be monitored, evaluated and reported over a reasonable period of time.

2.2.4.1 Calculation of Capital Cost (CC) on First Year Tariff (FYT) and Levellised Tariff (LT) for HKTs:

Assumptions:

Debt-Equity Ratio of 70:30

IDC: 3.5% of hard cost

Loan Repayment Period: 15yrs

Discount rate: 10%

Effective Tax rate: 25.17%

As per CERC Regulations for 'Small Hydro':

Auxiliary Consumption: 1%

Interest on Working Capital: 10.5%

O&M expenses for the first year: Rs 0.42 Cr/MW

O&M escalation rate: 3.84% per annum

Depreciation: 4.67% for first 15 years and remaining spread equally during the useful life of the project (assumed 40 years)

Return on Equity (ROE): 14%

Interest rate: 9%

<u>**Case I**</u>: **Tariff Sensitivity Analysis for Project Life: 25 years, Capacity Utilization Factor (CUF) varying from 50% to 75%, Capital Cost (CC) varying from Rs. 8 Cr to Rs. 16 Cr.**

Table 6: Tariff for Project life of 25 years

Project Life (Years)	CUF	CC (Rs. Crores)	FYT (Rs./Unit)	LT (Rs./Unit)
25	50%	8	4.17	3.90
25	50%	10	4.96	4.53
25	50%	12	5.75	5.17

Project Life (Years)	CUF	CC (Rs. Crores)	FYT (Rs./Unit)	LT (Rs./Unit)
25	50%	14	6.54	5.80
25	50%	16	7.34	6.43
25	55%	8	3.79	3.54
25	55%	10	4.51	4.12
25	55%	12	5.23	4.70
25	55%	14	5.95	5.27
25	55%	16	6.67	5.85
25	60%	8	3.47	3.25
25	60%	10	4.13	3.78
25	60%	12	4.79	4.30
25	60%	14	5.45	4.83
25	60%	16	6.11	5.36
25	65%	8	3.21	3.00
25	65%	10	3.82	3.49
25	65%	12	4.42	3.97
25	65%	14	5.03	4.46
25	65%	16	5.64	4.95
25	70%	8	2.98	2.78
25	70%	10	3.54	3.24
25	70%	12	4.11	3.69
25	70%	14	4.67	4.14
25	70%	16	5.24	4.59
25	75%	8	2.78	2.60
25	75%	10	3.31	3.02
25	75%	12	3.83	3.44
25	75%	14	4.36	3.87
25	75%	16	4.89	4.29

Case II: Tariff Sensitivity Analysis for Project Life: 40 years, Capacity Utilization Factor (CUF) varying from 50% to 75%, Capital Cost (CC) varying from Rs. 8 Cr to Rs. 16 Cr.

Table 7: Tariff for Project life of 40 years

Project Life (Years)	CUF	CC (Rs. Crores)	FYT (Rs./Unit)	LT (Rs./Unit)
40	50%	8	4.17	3.90
40	50%	10	4.96	4.50
40	50%	12	5.75	5.10
40	50%	14	6.54	5.70
40	50%	16	7.34	6.31

Project Life (Years)	CUF	CC (Rs. Crores)	FYT (Rs./Unit)	LT (Rs./Unit)
40	55%	8	3.79	3.55
40	55%	10	4.51	4.09
40	55%	12	5.23	4.64
40	55%	14	5.95	5.19
40	55%	16	6.67	5.73
40	60%	8	3.47	3.25
40	60%	10	4.13	3.75
40	60%	12	4.79	4.25
40	60%	14	5.45	4.75
40	60%	16	6.11	5.26
40	65%	8	3.21	3.00
40	65%	10	3.82	3.46
40	65%	12	4.42	3.93
40	65%	14	5.03	4.39
40	65%	16	5.64	4.85
40	70%	8	2.98	2.79
40	70%	10	3.54	3.22
40	70%	12	4.11	3.65
40	70%	14	4.67	4.07
40	70%	16	5.24	4.50
40	75%	8	2.78	2.60
40	75%	10	3.31	3.00
40	75%	12	3.83	3.40
40	75%	14	4.36	3.80
40	75%	16	4.89	4.20

2.2.4.2 Observation

From the above **Tables 6 and 7**, it can be observed that **Levellised Tariff (LT)** varies from **Rs. 2.60 to Rs. 6.43** and **First Year Tariff (FYT)** varies from **Rs. 2.78 to Rs. 7.34** for CUF varying from 75% to 50%, CC varying from Rs. 8 Cr to Rs. 16 Cr as claimed by M/s Maclec, and useful life varying from 40yrs to 25yrs. It can be further observed that as CUF increases, FYT and LT decreases and as Capital Cost increases, FYT and LT increases, keeping all other factors constant. However, the FYT and LT is subject to change/ confirmation based on the performance outcome of the products (HKTs/ HKEs) undergoing/ to be undertaken in Indian scenario. The tariff would be increasingly higher for lower CUF and technologies/ products having increasingly imported content.

2.2.5 FRAMEWORK FOR PILOT INSTALLATION, SCALING-UP AND ENERGY TRANSACTION

SHK Turbine based on hydro kinetic energy technology for harnessing the potential available in water stream is under developmental stage and yet to mature. As per the presentation of MACLEC and subsequent discussions of the Committee members, it was revealed that the Technology Readiness Level (TRL) of MACLEC as defined in IEC Standard 62600-4 (2020) is between 6 - 7, M/s GKinetic have achieved 7 and targeting 8 by April 2022, and that of M/s Imp Powers is around 8. In order to adopt such kind of emerging technology on a large scale (unit size as well as deployment), sufficient data shall be required to ascertain the successful performance of SHK Turbine-Generator (TG) modules/ units in terms of electricity generation, handling of trash and sediment, impact on environment and structural continuity particularly in Indian Scenario. As such, at this stage, pilot installation of SHK TG can be planned by Vendors as Technology Demonstration Projects for ascertaining its performance in Indian Power System. The deployment of such TG modules for commercial applications/ scale can be done only after ascertaining the satisfactory performance of the pilot installations.

Further, MACLEC is the only indigenous developer of HKT in the country whereas on the other hand, M/s IMP Powers claim to have more than 50% domestic content. Further, M/s GKinetic has totally off-shore content. The available unit sizes of MACLEC, M/s GKinetic and M/s Imp Powers are 0.5 kW to 500 kW, 10 kW to 60 kW and 5 kW respectively. There are few other leading foreign developers of this technology. Hence, as per the PPP- MII (Public Procurement (Preference to Make in India)) policy order, both MACLEC & M/s IMP Powers are eligible as "Class-I Local Supplier" (i.e. having minimum domestic content of 50%).

During the deliberation among the Committee members, it was decided that the following main points be considered before delving into the details of pilot installation and project implementation of HKTs:

i) Approach for awarding Technology Demonstration Projects may be different from that of a Commercial project.

ii) Awarding technology demonstration project for promoting indigenous development of technology may have different approach and in this regard, Government guidelines regarding Start-Ups and MSMEs need to be complied with.

Accordingly, the approach in this matter is proposed to cover the following aspects:

1. Selection of site and technology for HKT pilot project implementation:

The ideal site for implementation of pilot project shall be selected based on availability of continuous discharge with minimum velocity of 0.5m/s and minimum depth of 1 meter having stable slope condition suitable for anchoring.

a. Site Selection and Potential

i. Categorization of sites should be done for potential assessment i.e. Canal, River, Water channels of Thermal Power Plants, Tailrace of HPPs, etc. Detailed site information such as flow distribution, flow velocity and depth must be collected/ compiled to study the impact of turbine installation on site characteristic.

ii. Assessment of recoverable resources should be made.

iii. Wake recovery distance is crucial for array or farm application which should be considered by upstream and downstream to determine affected distance.

iv. Theoretical models for the potential assessment should be developed by considering different aspects of site conditions and its effects on head loss/performance on generation during installation at channels of existing HPPs.

v. There is a need to prepare the standards for the different levels of resource assessments.

b. Technology Selection

i. Different technologies are to be thoroughly investigated considering following conditions to find the feasible solutions.

- Site conditions.
- Effect of debris management and sediment
- Different installation parameters i.e. clearance ratio, direction of rotation, blockage ratio and vortex formation.
- Utilization (off-gird and on-grid).

ii. Scientific studies on the following aspects should be carried out before the selection of hydrokinetic generating unit along with control system;

- Reliability,
- Ease of transport at the site,
- Ease of installation and maintenance,
- Ease of connectivity,

- Ease of power evacuation and,
- Life cycle cost assessment.

iii. The testing of turbine in laboratory and field is essential before final deployment of this technology at site as per available Standards.

iv. Generating unit along with control system should be designed by considering the variations in the site conditions to obtain the acceptable quality of power.

v. Commercial production of HKT should be standardized. However, this may not be applicable at the time of pilot project.

c. Research & Development

i. Studies for performance enhancement of different HKT rotors based on the system parameters should be carried out.

ii. Validation of the performance of such turbines with field data should be done.

iii. Other issues related to the structural strength of the complete system such as shape of the rotor and material of construction should be analyzed.

iv. Effect of installations of different HKTs on the potential site should be carried out such as

- Effects on head loss/ performance on generation during installation at channels of existing HPPs.
- Wake recovery distance for farm applications.
- Effects on the water level in upstream and downstream side of turbine installation.
- Effects on the natural habitat.

v. Lab scale models should be studied to develop prototypes for field testing.

vi. R&D should be carried out on complete unit of prototype (turbine, generator, controllers etc.).

vii. Guidelines for resource assessment, site selection and technology selection need to be developed.

2. Invitation of Expression of Interest (EoI)

To explore the market for available technologies, EOIs may be invited from prospective OEMs (Original Equipment Manufacturers), Innovators and technologists having indigenous capability to develop HKE projects as per the following scope of work:

(a) Assessment of potential, preparation of DPR and techno-economic feasibility of HKE potential available at the proposed location for tapping Hydrokinetic Energy.

(b) Pilot project implementation with minimum feasible capacity.

(c) The basic site data covering average/maximum/minimum discharges, average depth, average width and geological conditions shall be mentioned in EOI.

3. Eligibility Criterion for Evaluation of EOIs

It appears that the pilot installation will be in kW range (as per the data presented by vendors) and cost of such project would not be more than limit stipulated in Order no. 12/17/2019-PPD of Ministry of Finance, Department Of Expenditure, Govt. of India pertaining to Global Tender Enquiry.

Based on various presentations, it is implicitly clear that the technology is still at its nascent stage. Therefore, in order to ascertain the performance of the turbine and before it is scaled up to commercial application, it is proposed that pilot projects under different site conditions and unit sizes may be installed for the demonstration purpose by CPSUs near their plants along with monitoring and evaluating their performance. EOIs may be invited by respective PSUs on domestic basis for pilot project. After the technology is proven viable, one may go for open tender enquiry to have more competition.

Following criteria may be laid down for the evaluation of EOI subject to compliance of the Government guidelines applicable for start-ups and Micro, Small & Medium Enterprises (MSMEs):

I. The agency shall be in the business of providing technological services in India for the similar work for period of at least two or more years from the cut-off date.

II. The agency shall be a private/ public limited company with proven track record in consultancy/ implementation/ research in the field of micro/ mini/ small hydropower or other power & infrastructure projects. The agency may include a company in a JV with HKT manufacturer to fulfil this criteria.

III. Net Worth Criteria to assess financial status.

IV. The agency shall have suitable facility in India for assembly of equipment and spare parts involved in the scheme.

4. Selection of Prospective Bidder and Implementation of Scheme

i) A committee may be constituted by the buyer for "Innovative Technology Selection".

ii) Based on the criteria laid down in the EOI, the eligible parties may be scrutinized by the committee and their offers shall be evaluated for:

- Minimum capacity for pilot installation with number of modules and equipment for completeness of pilot project in all respects.
- Their products have been tested by independent institutions for their performance.
- Preference will be given to the technology that offers a module which brings highest deployable capacity (i.e. comprising multiple modules) at the water channel cross-section of selected site.
- The Quality and Cost Based Selection (QCBS) concept may also be adopted for selection of eligible bidder say, with the technical weightage of 75% and financial weightage of 25%.
- Finalization of Business model: Business models, as shown in following **Table 8**, can be considered.

Table 8: Different Options of Business Models

Business Models	**Modes**	**Impact**
Collaboration	➢EPC + AMC (With generation Guarantee)	• Active engagement of OEM • Generation Guarantee • Ownership with project developer
	➢Partnership in mutual agreed terms of engagement	• Cost Sharing between OEM and PD • Direct involvement of OEM • Liability sharing between OEM & PD • Low-cost tariff can be achieved
BOO – Built , Operate & Own	➢Selling Electricity to Government/project owner	• Work in sync with project owner without active involvement • Higher generation tariff due to external partners

- Utilization of generated energy and mode of connectivity: The energy generated from the developed pilot project can be utilized for meeting the auxiliary consumption requirement of hydro power plant in two modes of connectivity:
    a. Grid connectivity: In this mode of connectivity, output of the HKT energy system will be connected to auxiliary supply system either at Medium Voltage (MV) or Low Level (LV) of supply.
    b. Standalone mode: Under this mode, some part of auxiliary load which is non-critical in nature shall be isolated from main system and connected with the HKT energy system.

- Technical specifications, BOQ, detailed scope of work, special terms and conditions shall be finalized after comprehensive analysis and examination of offers of shortlisted parties received from EOI. The assessment of performance shall be one year reckoned from the date of commissioning of project.

5. Implementation of pilot project

Implementation of pilot project in accordance with technical specifications, adopted business model and scope of works shall be done through open tender enquiry.

6. Assessment of performance

The performance of the demonstration project shall be evaluated based on the parameters given in **Table 9**:

Table 9: Parameters for evaluating Performance of Demonstration Projects

Sr. No.	**Parameters to be monitored**	**Unit of assessment**	**'Values'**	
			Claimed by Developer	**Actual**
1.	Gross Energy Generated	kWh		
2.	Annual Plant Load Factor	%		
3.	Outages: i) Planned ii) Forced and Failure of components	Numbers/ Duration/ Criticality		
4.	Cost of Maintenance	In Rs.		
5.	Revenue Generated	In Rs.		
6.	Tariff (Rs./Unit)	In Rs./Unit		
8.	Reliability assessment of Units under all-weather condition and disturbance in the system			
9.	Safety Aspects assessment under all-weather condition			
10.	Impact on performance of original scheme related to water stream (irrigation canal, power channel, drain/sewage channel, cooling water intake channel in thermal power plants, etc.)			

The Capacity of the demonstration project may be scaled up further based on the performance.

CHAPTER 3

CONCLUSIONS & RECOMMENDATIONS

3.1 CONCEPT

1) Concept of Hydro Kinetic Energy (HKE) and Hydro Kinetic Technology (HKT)

The HKTs extracts the energy of flowing water i.e. practically zero 'Head' of water, thereby leading to deeper RE penetration in country by exploitation of such technology.

Further, the probable locations based on site specific studies for HKT installation could be canals, major perennial rivers, rivulets, upstream/ downstream channels of existing/ upcoming conventional HPPs, cooling water channel of thermal power plants, urban waste water/ sewage canals, tidal rivers and oceans (tidal current runs in many rivers when they enter into sea), etc. The approach for selection of site and technology shall be based on Para. 2.2.5 - 1.

Benefits of the Technology:

i. Renewable and 100% green technology i.e. environment friendly. No reliance on fossil fuels and no carbon emissions.
ii. Predictable energy from free flowing water unlike solar and wind, which are largely variable and intermittent in nature.
iii. Offers base load power generation.
iv. Minimal disturbance to natural flow of river.
v. Negligible T & D losses and no transmission charges due to generation near load centers and connectivity at Distribution Voltage level.
vi. Portable and easy installation, which is possible even in running water. Further, HKT machines are mobile and flexible.
vii. No land use requirement, no major civil construction requirement.

Overall, the Hydro Kinetic Technology may prove to be a green and clean renewable energy solution to the people on grid and off-grid (i.e. in remote areas). It is also a reliable and cost efficient source of electricity. Moreover, it can contribute significantly to RE portfolio of country. The proper support of R&D for this niche area of RE may be a mega boost for economic competitiveness with both conventional and advanced fossil fuel-based electricity sources.

2) Availability of Standards

The International Electro-technical Commission (IEC) standards for the Hydro Kinetic technologies have been developed under IEC 62600 series and are listed in Chapter 2-Para 2.1.3.

These Standards cover various related aspects such as river energy resource assessment, specification for establishing qualification of new technology, measurement of mechanical loads, power performance assessment of river energy converters and electrical power quality requirements, etc.

3) Construction/ Installation/ Gestation Period/ Useful Life of Hydro Kinetic Turbines

The unit/ project capacity of HKTs and installation of hydrokinetic device depends on various hydrological parameters such as depth of water, velocity distribution of water, slope of bed of river, sediment properties, etc. Further, in order to prevent the contact with floating debris, a protection is required in front of the turbine blade or the system may be designed so as to deflect fish and debris.

As far as the gestation period of a HKE project is concerned, it may vary from few months to about a year depending on the project size, whether it is Grid connected or Off-Grid, availability of nearby infrastructure such as roads for accessibility, power lines for connectivity, type of civil installation requirements, etc. However, the entire actual installation of product(s) may range from a day to few days as the product itself is basically a plug and play kind of device.

Further, the useful life of product, as claimed by the manufacturers, may vary from 25 to 40 years depending on the operating environment and with periodic maintenance as recommended by Original Equipment Manufacturer (OEM).

However, the assessment of useful life and O&M costs in Indian scenario can be firmed up only after observing its performance in field (i.e. actual operating environment) for a reasonable period.

4) **Comparison of Hydro Kinetic Turbines (HKTs) with Conventional 'Head' based Turbines**

Upon comparison between HKTs (Unit Size up to 500 kW) and Conventional Low Head Hydro Turbines (Unit Size up to 15 MW), it is observed that HKTs can be put into operation by extracting energy of flowing water even where there is no natural 'Head' available and have advantage of minimal requirement of civil structures thereby having lower time of completion and lower disturbance to the natural flow of water body. However, the unit size of HKT in India may be generally limited to less than 50 kW due to limited water depth and flow velocity at different sites. By virtue of HKT's connectivity at Distribution Voltage level, they have lower Transmission and Distribution (T&D) losses and no requirement of paying transmission charges/ losses by DISCOMs for equivalent power drawn from the Grid to meet the electricity demand. The technology of conventional 'Head' based turbines is well established whereas the technology for HKTs in India is under technology demonstration stage and internationally, HKTs may be nearing completion/ completed technology demonstration stage.

3.2 COMMERCIAL APPLICATIONS

1) **Potential**

There is no scientific study done till date in India by a State/ Nationally accredited or recognized body covering all groupings of Hydro Kinetic Energy like Canal, River, Tailrace of HPPs, marine current, etc. For example, the non-profit organization Electric Power Research Institute (EPRI), USA has estimated that in the United States, new hydrokinetic technologies could provide an increase in generation capacity of 3,000 MW by 2025. Further, as per their report on 'Assessment and Mapping of the Riverine Hydrokinetic Resource in the Continental United States', the estimate of Technically Recoverable Power of Hydro Kinetic Energy for the continental United States is 120 TWh/yr, translating to about 18.3 GW of exploitable potential at Load Factor of 75 %.

Considering the abundance of flowing water network in India and some specific studies done, the potential of HKTs in India appears to be on GW scale, however, reasonable exploitable potential in MW (Demand) and MWh (Energy) can be assessed based on actual study considering water availability, hydraulic conditions (velocity and depth of flow), etc. required for SHK turbine. **As the globally acceptable Standards for assessing potential have recently become available under IEC, the undertaking of**

such a study could be considered by GoI by awarding the work to a competent agency/ institution and outcome of which could be considered for inclusion in RE potential of India under 'Small Hydro'.

Further, the site-specific project potential needs to be based on the Detailed Project Report (DPR) and which may be prepared covering all techno-economic issues based on site-specific project parameters. The approach for selection of site and technology shall be based on Para. 2.2.5 – 1.

Apart from the above, other user conflicts such as drinking water, irrigation, navigation, recreational activities (boating, fishing) should also be considered during planning phase. **Further, the allotment process of HKTs/ HKE technology should be similar to small hydropower with a single window clearance.**

2) Status of Development of HKT Technology in India and Abroad

The technology of HKTs is already under various stages of establishment in India and other parts of the world and not a new innovation. However, the major challenge remains that this technology is still under development stage and not a proven technology yet. **Performance of these turbines need to be observed in field trials for a reasonable period of time and after successful results of such pilot project(s), further course of action for implementation of SHK technology for commercial purpose and on commercial/ large scale may be undertaken.**

3) Cost

The total installation cost of SHK Turbines given by **MACLEC** (Indian firm- Class-I Local Supplier having minimum local content of 50%) as submitted before the Committee is as low as **Rs. 8 Crores for a 1 MW installation** comprising number of modules of an indigenous product. For **M/s Imp Powers** (Indian Partner of M/s Smart Hydro Power, Germany having exclusive rights for India- Class-I Local Supplier), the cost is **Rs. 21.4 Crores/MW**. For **M/s GKinetic** (Foreign firm), the cost is **Rs. 46.25 Crores/MW** excluding installation and commissioning charges.

As the claim for an indigenous HKT product price is cheaper and as low as about Rs. 8 Crores/MW for a 1 MW installation, it can be inferred that the domestic manufacturers present a better alternative cost-wise after reaching to the TRL of 9 with successful outcome of installation of few pilot projects that are efficient and well monitored. This will also be in line with the 'Make in India' initiative of GoI.

The cost of installation of SHK turbines also depends on the unit size, total installed capacity of a project, extent of indigenization, site parameters, etc. and may further change depending on the sectoral growth. Also, if these technologies are manufactured and scaled up along with sufficient Government support, the overall cost may be further brought down.

4) **Estimated Tariff of Electricity**

Based on norms under CERC Tariff Regulations for RE, 2020 under 'Small Hydro', the **Levellised Tariff (LT) for HKT product of M/s Maclec varies from Rs. 2.60 to Rs. 6.43 per unit whereas First Year Tariff (FYT) varies from Rs. 2.78 to Rs. 7.34 per unit for Capacity Utilization Factor (CUF) varying from 75% to 50%, Capital Cost (CC) varying from Rs. 8 Cr to Rs. 16 Cr and useful life varying from 40 yrs to 25 yrs**. It can be further observed that as CUF increases, FYT and LT decreases and as CC increases, FYT and LT increases, keeping all other factors constant. The sensitivity analysis of estimated tariff with respect to CUF, CC and useful life is detailed/ tabulated at Chapter 2 - Para 2.2.4.1. However, this may also vary depending on the actual cost and CUF of the unit, life of equipment/ project and O&M cost, and which could be firmed up at a higher confidence level only after its performance observance in actual operating environment over a reasonable period during the technology demonstration stage.

5) **Framework for Pilot Installation, Scaling-Up and Energy Transaction**

The approach for awarding Technology Demonstration Projects may be different than that for awarding a Commercial project. Further, awarding the technology demonstration project for promoting indigenous development of technology may have a different approach and in this regard, Government guidelines regarding Start-Ups and MSMEs need to be complied with. The details in this regard including different business models have been discussed under Chapter 2 – Para 2.2.5.

The ideal site for implementation of pilot project shall be selected based on the availability of continuous discharge with certain minimum velocity, depth, stable slope condition suitable for anchoring, etc. To explore the market for available technologies, Expression of Interests (EOIs) may be invited from prospective OEMs, Innovators, and technologists having indigenous capability to develop HKE projects.

In this regard, GoI may consider advising Power Generating Utilities under its administrative control to take up such technology demonstration projects for suitable capacities at different locations under varying operating environment to promote R&D activities in the country, for development of indigenous technology and for establishment of technology to help in deeper penetration of RE in the energy spectrum of the country.

Further, there is an impending need of government policies pertaining to financial assistance and tariff structure especially for hydrokinetic technologies development. The assistance sought from Government by MACLEC (an Indian firm) and M/s Imp Powers (the other Indian firm in technological collaboration with M/s Smart Hydro Power, Germany, and having over 50% domestic content) in this aspect is covered under their respective presentations to Committee and which are at **Appendix-I & IV**. Also, the regulated framework for permissions for implementation of Hydro Kinetic Energy technologies in India would need to be prepared. However, this may be required upon successful outcome of Technology Demonstration in Indian scenario and for further embarking on its implementation for commercial purpose/ scale.

22/10/21 (Sh. Keshav Deshmukh) ED (D&E), NHPC	21.10.21 (Sh. L.P.Joshi) GM (EM-Design), THDCIL
(Sh. Gangesh Upadhyay) Scientist 'G', MNRE	(Sh. Sanjay Kumar Shahi) Scientist 'D', MNRE
(Prof. Arun Kumar) IIT Roorkee	(Prof. R. P. Saini) IIT Roorkee
(Sh. Ajay Talegaonkar) Chief Engineer (F&CA), CEA	(Sh. Sharvan Kumar) Chief Engineer (HPA), CEA
22/10/2021 (Sh. Rakesh Kumar) Chief Engineer (HE&TD), CEA & Member Convener of the Committee	(Sh. B.K Arya) Member (Hydro), CEA & Chairman of the Committee

ANNEXURES/APPENDICES

TO THE REPORT

ANNEXURE-I

MoP letter dated 13/08/2021 containing Record of Discussions (RoD) chaired by Secretary (Power), GoI dated 03/08/2021 wherein it was directed to constitute the Committee under the chair of Member (Hydro), CEA to study the Concept and Commercial applications of Hydro Kinetic Turbines developed by M/s Maclec Pvt. Ltd.

F.No.14-37/68/2020-H.I(255414)
Government of India
Ministry of Power

Shram Shakti Bhawan, Rafi Marg
New Delhi, dated the 13th August, 2021

To

i. **The Member (Hydro), CEA.**
ii. **The CMDs of NTPC, NHPC, THDCIL, SJVNL & NEEPCO.**
iii. **Shri Sanjay Kumar Shahi, Scientist 'D', MNRE.**

Sub:- Hydro Kinetic Turbines developed by M/s MACLEC - forwarding of record of discussions dated: 03/08/2021 - reg.

Sir,

The undersigned is directed to forward herewith a copy of the record of discussions held on 03/08/2021 under the Chairmanship of Secretary (Power) on the above subject.

2. It has been decided in the meeting, that a committee, consisting of representatives from CEA, NHPC, THDCIL, MNRE and IIT-Roorkee may be formed to study the concept, its commercial applications and submit a report at the earliest. The committee may be headed by Member (Hydro), CEA.

Encl: As above,

Ashok Kr.

(Ashok Kumar)
Director (Hydel-I)
Telefax: 23717753
Email: kumar.ashok2021@nic.in

Copy for information to:-
PPS to Secretary (Power)/PPS to AS(Hydro)/ PPS to JS(Hydro)/ PS to Director(H.I & H.II)

Record of discussions of meeting held on 03/08/2021 regarding Hydro Kinetic Turbine developed by M/s Maclec

List of participants is annexed.

2. Initiating the discussion, JS(H) appraised that a note was received in October-2020 on the proposal enclosing the above reference. The matter was examined in detail and the comments of IIT- Roorkee, Government of Uttarakhand and CPSUs were sought. Thereafter, a comprehensive proposal was submitted for kind consideration and approval of Hon'ble Minister of Power.

3. Hon'ble Minister of Power had observed that ' *How has the cost of the New Technology Generator been determined? The actual cost needs to be examined.'*

5. JS(H) informed to the participants that CEA was requested to determine the actual cost of the technology. CEA had examined the matter in consultation with NHPC and MNRE and has arrived at Rs.15 Crores per MW.

6. CEA was requested to make the presentation. CEA while making the presentation informed that :-

i. M/s Maclec is an Indian Company initiated in 2013. The company has received 3 patents and has in-house fabrication facility of 1 MW/month with full fledged Hydro Kinetic Testing Facility in collaboration with IIT-Roorkee.
ii. M/s Maclec has been awarded projects by various State Governments ranging from 5KW to 100KW, these projects are mostly in PFR/DPR stage.
iii. Ms/ Maclec had furnished that the identified potential of Small Hydro Kintic Turbine as 32.6 GW at 71 sites in the country.
iv. For operation of this turbine, M/s Maclec had stated that the minimum velocity required for operation is about 0.5 m/sec, and the minimum depth is 0.4m. The unit size of the turbine is 500W to 500kW. Plant life is >35 years. Tariff for of-grid is Rs.3 to Rs.6/unit and for Grid-connected it is Rs.2.5 to Rs.6.5 per unit. The cost per MW shall be Rs.7 Cr to Ra.10 Cr.

7. After the presentation/discussions, the following emerged:-

i. The explored potential of SHPs as determined by M/s Maclec is 32.6 GW (at 71 sites) need to be examined as this is on the extremely higher side.

ii. Since the projects completed by M/s Maclec are only demonstration projects and not actual projects, the price discovery is a challenge. The cost per MW as determined by M/s Maclec which is Rs.7 to Rs.10 core cannot be relied upon as the turbine manufactured is a proprietary item.

iii. A committee may be formed consisting of members from CEA, NHPC, THDCIL, MNRE and IIT-Roorkee to study the concept, its commercial applications and submit a report.

iv. Secretary (Power) stated that since the subject matter is in the domain of MNRE, the subject may be transferred to MNRE after the report of the Committee constituted at (iii) above.

Annexe

List of participants

MINISTRY OF POWER

1.	Shri Alok Kumar, Secretary (Power) ……………..in Chair
2.	Shri S.K.G Rahate, Addl. Secretary (Hydro)
3.	Shri Tanmay Kumar, Joint Secretary (Hydro)
4.	Shri Ashok Kumar, Director (H-I)
5.	Shri R.P Pradhan, Director (H-II)
CEA	
6	Shri B.K Arya, Member (Hydro)
7	Shri Rakesh Kumar, Chief Engineer
8	Shri Sharvan Kumar, Chief Engineer
9	Shri Ritesh Tiwari, Dy. Director
MNRE	
10	Shri Sanjay Kumar Shahi
11	Shri Gangesh
NTPC	
12	Shri Gurdeep Singh, CMD
13	Shri U.K Bhattacharya, Director
NHPC	
14	Abhay Kumar Singh, CMD
15	Shri Keshav Deshmukh
16	Shri V.K Sinha

NEEPCO	
17.	Shri V.K Singh, CMD
18.	Shri H.K Deka, Director (Technical)
19.	Shri Ranen Sharma
SJVNL	
20	Shri N.L Sharma, CMD
THDCIL	
21.	R.K. Vishnoi, Director(Technical)
22.	Shri L.P Joshi
Others	
23.	Shri Santosh Kumar Verma
24.	Shri Raj Gupta
25.	Shri Sitish Barchi
26.	Shri Sudarshan Chakravorty
27.	Shri Vikram Dhaka
28.	Shri Vinay

ANNEXURE-II

CEA O.M. dated 24/08/2021 vide which the Committee under the chair of Member (Hydro), CEA was constituted to study the Concept and Commercial applications of Hydro Kinetic Turbines developed by M/s Maclec Pvt. Ltd. Delhi.

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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www.cea.nic.in

No.: 10/3/HETD/2021/ Date: .08.2021

OFFICE MEMORANDUM

Subject: Constitution of Committee to study the concept & commercial applications of Hydro Kinetic Turbine developed by M/s MACLEC - reg.

A meeting was held under the chairmanship of Secretary (Power) with representatives of CEA, MNRE & CPSUs under Ministry of Power through Video Conferencing on 03.08.2021 to deliberate on the technical as well as commercial aspects of Hydro Kinetic Turbine developed by M/s MACLEC. A copy of Record of Discussion (RoD), received vide MoP letter dated 13.08.2021, is enclosed for reference, wherein, it has been decided to constitute a Committee headed by Member (Hydro) and consisting of members from CEA, MNRE, NHPC, THDC and IIT-Roorkee to study the concept & commercial applications Hydro Kinetic Turbine developed by M/s MACLEC. The composition of the Committee would be as under:

1.	Member (Hydro), CEA	-	Chairman
2.	Chief Engineer (F&CA), CEA	-	Member
3.	Chief Engineer (HPA), CEA	-	Member
4.	A Representative of MNRE	-	Member
5.	A Representative of NHPC*	-	Member
6.	A Representative of THDC*	-	Member
7.	A Representative of IIT-R	-	Member
8.	Chief Engineer (HETD), CEA	-	Member Convener

Scope of the Committee, inter-alia, shall be to study the operational concept, cost of generation and commercial applications etc. of Hydro Kinetic Turbines and shall submit its report within 45 days to Ministry of Power. The Committee may co-opt any other member, if required.

This issues with the approval of Competent Authority.

Encl: as above

(Reeetesh Tiwari)
Dy. Director

To,

(As per List attached)

To (As per List):

1. Secretary (MNRE), Block no. 14, CGO Complex, Lodhi road, New Delhi – with a request to nominate a representative (Director and above) of MNRE to the above Committee
2. Chairman & Managing Director, NHPC Ltd, NHPC Office Complex, Sector-33, Faridabad – 121003 - with a request to nominate a representative of NHPC (not below the rank of ED/GM) to the above Committee
3. Chairman & Managing Director, THDC Ltd, Rishikesh, Uttarakhand - with a request to nominate a representative of THDC (not below the rank of ED/GM) to the above Committee
4. Head of Department, Hydro & Renewable Energy, IIT-R, Roorkee - with a request to nominate a representative of IIT-R to the above Committee
5. Chief Engineer (F&CA), CEA
6. Chief Engineer (HPA), CEA
7. Chief Engineer (HE&TD)

Copy for information to:

1. Joint Secretary (Hydro), MoP
2. SA to Chairperson, CEA
3. SA to Member (Hydro), CEA
4. SA to Member (E&C), CEA

ANNEXURE-III

Minutes of 1st Meeting of the Committee held on 02/09/21

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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वेबसाइट/Website:
www.cea.nic.in

No. 10/3/HETD/2021/ Date: .09.2021

Subject: Minutes of 1st Meeting of the Committee constituted to Study the Conceptual and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 02.09.21 – reg.

Please find enclosed herewith the minutes of 1st meeting of the Committee constituted to study the conceptual and commercial application of Small/Surface Hydro Kinetic Turbine developed by M/s Maclec held through VC on 02.09.21 placed at **Annex-I**.

Encl: as above

(Reeetesh Tiwari)
Dy. Director

To:

1. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
2. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
3. Prof. Arun Kumar, IIT Roorkee
4. Prof. R. P. Saini, IIT Roorkee
5. Sh. Gangesh Upadhyay, Scientist G, MNRE
6. Sh. Sanjay Kumar Shahi Scientist D, MNRE
7. Sh. Keshav Deshmukh, ED (D&E), NHPC
8. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
9. SA to Member (Hydro), CEA

Annex-I

Minutes of 1st Meeting of Committee constituted to Study the Conceptual and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 02.09.21

List of Participants:

1. Sh. B.K. Arya, Member (Hydro), CEA
2. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
3. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
4. Prof. Arun Kumar, IIT Roorkee
5. Prof. R. P. Saini, IIT Roorkee
6. Sh. Gangesh Upadhyay, Scientist G, MNRE
7. Sh. Sanjay Kumar Shahi Scientist D, MNRE
8. Sh. Keshav Deshmukh, ED (D&E), NHPC
9. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
10. Sh. Rakesh Kumar, Chief Engineer (HE&TD) CEA

The 1st meeting of the Committee, constituted under the chair of Member (Hydro), CEA vide CEA Office Order dated 24.08.2021 subsequent to MoP letter dated 13.08.2021 to study the concept and commercial application of Hydro Kinetic Turbine developed by M/s Maclec, was convened by Sh. Rakesh Kumar, CE (HETD), CEA on 02.09.2021 through Video Conferencing. The meeting started with opening remarks by Sh. B.K. Arya, Member (Hydro), CEA.

Member (Hydro), CEA appreciated the innovative idea of installing SHK turbines in small canals for generating electricity. However, he emphasized to verify the technical & commercial viability and cost of electricity generated through this technology.

CE (HE&TD) gave a presentation throwing light on background of the events and informed about the sequence of events that led to formation of this committee. In Nov' 2020, M/s Maclec gave a presentation on the Surface Hydro Kinetic Turbine technology developed indigenously by them. In July'21, discussion were again held among CEA and representatives of different Hydro PSUs in presence of JS (Hydro), MoP to examine the usefulness of such technology. Finally, Secretary Power in a subsequent meeting on 03.08.21 decided to constitute a committee to look into different aspects of this technology. CEA issued order for constitution of committee along with Terms of Reference (ToR) on 24.08.21 with stipulation to submit report within 45 days by 08.10.21.

CE (HE&TD) in his presentation further briefed about the profile of M/s Maclec, their area of operation and specialization. It was informed that the company specializes in floating type hydro kinetic turbines whereas other companies in the field are working on submerged type. Some technical features, its components and other associated parts of Surface type Hydro Kinetic (SHK) turbine developed by M/s Maclec were also presented. It was informed that these turbines can operate at a water velocity as low as 0.5m/s, are environment friendly and have life of about 35 years as claimed by M/s Maclec. Salient outcomes of study conducted by the company for Tanakpur project of NHPC & BBMB project were presented along with their financial parameters & cost of generation.

It was further informed that India has about 92GW potential of Hydrokinetic energy as claimed by M/s Maclec. However, CE (HE&TD) stated that this figure needs to be cross checked by conducting further more studies. He further brought committee's attention to the high capital cost and comparatively lower tariffs as claimed by M/s Maclec to be checked up and verified. He mentioned that the economy of the scale shall bring the cost down.

Sh. Gangesh Upadhyaya, Scientist G, MNRE expressed his views that it needs to be verified whether the technology is well demonstrated and established globally. The claims made by the company, about efficiency of their machine, plant load factor and durability or life expectancy, needs to be established on field. He opined that projects of only few KW range have been studied hence technology is not well demonstrated yet. He, further, suggested that the claims of M/s Maclec must be verified by third party. Then only potential assessment at country level should be done. He enquired about the cost parity done by the company between conventional low head hydro plant and SHK turbines and limitation of SHK turbines below their designed water velocity.

Sh. Keshav Deshmukh, ED (Design & Engineering), NHPC opined that all the power channels are so designed to minimize the head losses of hydro plants. Installing SHK turbine on the power channel may increase the head losses resulting in generation loss from existing hydro plants. Further, SHK turbines have efficiency only up to 40%. He stated that these turbines may not be suitable for power channels except for irrigation channels or other water streams.

Prof. R.K. Saini, IIT Roorkee explained that many Hydro Kinetic Turbine developer world over have claimed about the technology readiness of their systems, howerver, installation of such turbines is challenging and site specific studies needs to be conducted. There are two types of such turbines - cross flow & axial flow. Further, submerged and surface turbines are two other categories based on their installation. He informed that M/s Maclec & IIT Roorkee have worked on a R&D project on HKT sponsored by UJVN, of which he is also a member and work is still ongoing. CFD analysis has been done for mechanical output and validated for small model of 20 watt only. This capacity can be scaled up only up to 5KW to 15KW for a water velocity of 2m/s. Ideal efficiency of such turbines is 39.2%. He also emphasized that assessment of potential should take care of all the restraining factors like wake recovery distance, water level rise, impact on conventional plants etc.

A case study of irrigation canal in USA was quoted. The study states potential of HKT includes water supply disruption, affecting head/discharge condition in irrigation canal. HKT also results in flooding when turbine is deployed and operation increases water level, reduction in power generation in nearby hydro plant and unfavorable erosion deposition in later years. Eastern Yamuna HE assessment concluded the wake recovery distance was quoted as 216m for water.

Prof. Arun Kumar, IIT Roorkee explained that all the aspects related to mechanical, electrical performance, control & integration issues should be tested and verified for such turbines. Other issues like water level rises, impact on existing plants may be analyzed before it is put to commercial use. HKT should not be installed very close to either intake or TRT outlet. Scientific approach based study of potential and performance assessment needs to be done. He informed that IEC 62600 is already published which covers four major domains - resource assessment, performance assessment, technology assessment/ electrical power quality assessment. He, further, opined that the SHK turbine of M/s Maclec may have technology readiness level of about 5 or 6 on a scale of 1 to 9. So it may not be commercially deployed right now. He also mentioned that most of the Indian rivers are not perennial in nature and have abundant water in monsoon but are dry in summers. He also threw some light on global status of this technology and mentioned that most of the projects to tap hydrokinetic energy could not see the light of the day beyond pilot phase.

However, some kind of hand holding is required for the technology to encourage the entrepreneurs and start-ups to promote Make-in-India initiative of GoI. Some funding support should also come from industries for indigenous development this new technology. Therefore, Committee should recommend on making funds available, testing of the technology, demonstration of projects in field and their performance test.

Sh. S. K. Shahi, Scientist D, MNRE also had similar opinion that the potential is debatable, cost & tariff structure needs further verification. In such scenarios, these turbines should not be commercially deployed. However, he sought opinion of the committee on the kind of support to be provided to make it viable.

Sh. Ajay Talegonkar, CE (F&CA), CEA also mentioned that hand holding a new technology is necessary. However, there is only one Indian vendor in the market and there should be fair competition in new technology to make advancements. He stated that VGF was also given to solar & wind technology and also planned for hydrogen energy. However, viability of SHK turbines needs to be established first, potential needs to be correctly established then only VGF support can be extended. Testing different HK technologies establishing financial model, validating data are the things to be done beforehand. He opined to invite oversees players for presentation for better understanding and comparative analysis of technology.

Sh. L. P. Joshi, GM (Design), THDCIL also had similar view that if Technology readiness level is only 5 or 6 then there is no use of deploying such technology at large scale. He emphasized upon analyzing the performance of upcoming projects of M/s Maclec to decide on commercial applicability. He suggested that Hydro PSUs can deploy small scale demonstration projects downstream of TRT to witness the performance. He further suggested that global EOI may be a cumbersome & tedious process and we should go for indigenous vendors to promote Atma-Nirbhar Bharat scheme. He also talked about possibilities of different business models to make it viable and stated that risk sharing approach was considered as the best.

The Committee deliberated upon the structure of report and domains to be covered on conceptual and commercial aspects and time lines of different activities for submission of report to MoP.

It was unanimously decided to invite M/s Maclec for presentation to clarify on different aspects deliberated above.

Meeting ended with a vote of thanks to all participants.

ANNEXURE-IV

Minutes of 2nd Meeting of the Committee held on 06/09/21

Special Invitee: M/s Maclec Pvt. Ltd., Delhi

Azadi Ka Amrit Mahotsav

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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No. 10/3/HETD/2021/ Date: .09.2021

Subject: Minutes of 2nd Meeting of the Committee constituted to Study the Conceptual and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 06.09.21 – reg.

Please find enclosed herewith the minutes of 2nd meeting of the Committee constituted to study the conceptual and commercial application of Small/Surface Hydro Kinetic Turbine developed by M/s Maclec held through VC on 06.09.21 placed at **Annex-I**.

Encl: as above

(Reetesh Tiwari)
Dy. Director

To:

1. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
2. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
3. Prof. Arun Kumar, IIT Roorkee
4. Prof. R. P. Saini, IIT Roorkee
5. Sh. Gangesh Upadhyay, Scientist G, MNRE
6. Sh. Sanjay Kumar Shahi Scientist D, MNRE
7. Sh. Keshav Deshmukh, ED (D&E), NHPC
8. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
9. SA to Member (Hydro), CEA

Annex-I

Minutes of 2nd Meeting of Committee constituted to Study the Conceptual and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 06.09.21

List of Participants:

1. Sh. B.K. Arya, Member (Hydro), CEA
2. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
3. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
4. Prof. Arun Kumar, IIT Roorkee,
5. Prof. R. P. Saini, IIT Roorkee
6. Sh. Gangesh Upadhyay, Scientist G, MNRE
7. Sh. Sanjay Kumar Shahi Scientist D, MNRE
8. Sh. Keshav Deshmukh, ED (D&E), NHPC
9. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
10. Sh. Rakesh Kumar, Chief Engineer (HE&TD) CEA

The 2nd meeting of Committee, constituted to study the concepts and commercial application of Hydro Kinetic Turbine developed by M/s Maclec, was convened by Sh. Rakesh Kumar, Chief Engineer (HETD), CEA on 06/09/2021 through Video Conferencing. CE (HETD) welcomed all the participants and invited M/s Maclec for their presentation.

Sh. Balram Bhardwaj, on behalf of M/s Maclec, briefed about his company profile and gave the presentation on SHK turbines. He further illustrated about Surface Hydro Kinetic Turbine technology, its design aspects, cost comparison with other existing technologies, readiness level and commercial applicability of their product. The assessment of estimated cost of generation and its validation methodology adopted by M/s Maclec were also explained.

The committee then deliberated on different aspects of the product and technology. Issues about cost of generation, integration with grid, reduction in head for conventional plant if installed in power channels of existing plants etc. were discussed. The committee also sought clarification about the assumptions made on different aspects of assessment of cost of generation viz. operational life of project, RoE, funding arrangement, PLF as well as assessment of available potential of HK energy in the country. Availability of other players in country to have fair competition in the field was also discussed.

All the committee members were of the view that M/s Maclec should come up with the results of some demonstration projects already installed & operational for validation of their claims on different performance aspects of the product and technology.

In response, M/s Maclec informed that they have done continuous research & testing and have few projects to be soon installed. However, they sought some time to compile such data available to them and present to the committee.

It was decided that the next meeting shall be convened shortly wherein M/s Maclec could clarify on aforementioned queries and share the data with committee for verification.

The meeting ended with a vote of thanks to all the participants.

ANNEXURE-V

Minutes of 3rd Meeting of the Committee held on 14/09/2021 F/N

Special Invitee: M/s GKinetic Energy Ltd., Ireland

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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No. 10/3/HETD/2021/ Date: .09.2021

Subject: Minutes of 3rd Meeting of the Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 14.09.2021– reg.

Please find enclosed herewith the minutes of 3rd meeting of the Committee constituted to study the conceptual and commercial application of Small/Surface Hydro Kinetic Turbine held through VC on 14.09.21 placed at **Annex-I,** wherein M/s GKinetic Energy Ltd gave presentation on Kinetic Turbines.

Encl: as above

(Reeetesh Tiwari)
Dy. Director

To:

1. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
2. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
3. Prof. Arun Kumar, IIT Roorkee
4. Prof. R. P. Saini, IIT Roorkee
5. Sh. Gangesh Upadhyay, Scientist G, MNRE
6. Sh. Sanjay Kumar Shahi Scientist D, MNRE
7. Sh. Keshav Deshmukh, ED (D&E), NHPC
8. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
9. SA to Member (Hydro), CEA

Annex-I

Minutes of 3rd Meeting of Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 14.09.2021

Special Invitee: M/s G-Kinetic Energy Ltd

List of Participants:

1. Sh. B.K. Arya, Member (Hydro), CEA
2. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
3. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
4. Prof. Arun Kumar, IIT Roorkee
5. Prof. R. P. Saini, IIT Roorkee
6. Sh. Gangesh Upadhyay, Scientist G, MNRE
7. Sh. Sanjay Kumar Shahi Scientist D, MNRE
8. Sh. Keshav Deshmukh, ED (D&E), NHPC
9. Sh. L. P. Joshi, GM (EM-Design), THDCIL
10. Sh. Rakesh Kumar, Chief Engineer (HE&TD) CEA
11. Sh. Vincent McCormack, CEO, G-Kinetic Energy Ltd
12. Ms. Roisin McCormack, COO, G-Kinetic Energy Ltd

The 3rd meeting of Committee constituted to study the concept and commercial application of Hydro Kinetic Turbine was convened by Sh. Rakesh Kumar, CE (HETD), CEA under the chairmanship of Member (Hydro), CEA on 14.09.2021 at 11:30 am through Video Conferencing, wherein M/s G-Kinetic Energy Ltd, an Irish Company, was invited to discuss their product in the form of Hydro Kinetic Turbine. The meeting started with brief introduction of Mr. Vincent McCormack, CEO and Ms. Roisin McCormack, COO of the company G-Kinetic Energy Ltd. It was further informed that Mr. Vincent McCormack is on the IEC Industry Advisory Adhoc Group.

At the outset, the Chair welcomed all the committee members and representatives of G-Kinetic Energy Ltd. He gave a short introduction about the committee, their interests in knowing more about the technology, its development status worldwide and to assess its viability for deeper penetration of RE in the country. He then invited representatives from G-Kinetic to start the presentation.

In her opening remarks, Ms Roisin stated that their company was founded in 2014, with a mission & vision to unlock 100% clean, predictable energy from free flowing water. The company is based in County Limerick, Ireland and is undertaking two large pilot projects, one comprising 18 units of 12kW to be deployed and the other 7 units are to be allocated. Their product profile is a floating platform that can be moored like a boat, standardized & simple which can be deployed in to the flowing water for instantaneous generation of power.

The device comprises of a central pillar and two vertical axis turbines. The key differentiator of the device is the central obstacle (bluff body) which accelerates water in to the turbines on both sides and is very effective as validated in the CFD models / real scale operational deployment. Its efficiency tested in the lab is 41%. Due to outwards design of the turbines, fish and debris are naturally deflected and thrown out. The turbine is capable of 30kW but the unit is designed for 12kW at a flow velocity of 2m/s with a cut in speed of 0.5m/s and cut off speed of 3.3m/s requiring a minimum draft of 1.8m. G-Kinetic demonstrated that these turbines can be deployed floating in canals or attached to existing infrastructure, etc. and solar panels can be added on the top. When compared with their competitors like Smart Hydro, ORPC, Emry & Hydroquest, their technological advantages are low flow velocity requirements i.e. 2m/s, natural debris deflection, mobility of the machine, access from the surface, etc.

Regarding Technological Readiness Level (TRL), NUI, Galway has validated the core concepts. The technology was validated in a lab IFERMER Test Tank at Boulogne-Sur-Mer, France like flow velocities, mechanical power generated, rotational speeds, drag forces and efficiency of 40%, etc. The technology validation in relevant environment at Limerick Dock for controlled tow tests (10 months) at different inflow and rotational speeds (TRL-5). The full scale 25kW & 60kW devices have been designed, built, installed and tested by their manufacturer 'DesignPro Ltd' for System Prototype demonstration in operational environment (TRL 6-7).

Presently, G-Kinetic is at TRL-8 and planning 3 units by April 2022 in Limerick Islands and looking for final gaps to be addressed to develop Annual Energy Prediction (AEP) software to evaluate deployment sites, energy output from continuous operation over the project period. By the end of next year, G-Kinetic hopes to be fully commercialized with 25 units of 12kW. It is selling the completed 'CEFA12 unit' for €64,000 which does not include installation/commissioning charges. G-Kinetic explained that they are highly interested in irrigation canals.

<u>Queries & Replies:</u>

1. To the committee's query regarding global potential of 200 GW, expected useful life and tariff, Ms Roisin replied that it is based on IRENA report wherein country specific studies were made. The expected design life of the parts is 7 years and the generator gear box is of standard equipments depending upon the high & low energy sites.

2. Regarding the depth requirement of the machine, the GKinetic representative said that they require 1.8m for floating and 1.5m for generating power. The turbines are self starting with PMG generators which are capable of conditioning the power and the machine can be connected to grid with inverter system.

3. The Committee members informed the invitees about the variation of seasonal flows in central India rivers, which have very low discharges with a water depth generally below 2m and where high discharges occur only during monsoon. Further, the Himalayan rivers are very steep having velocities more than 3.3m/s (i.e cut off velocity) carrying high silt & boulders.

   Ms/s GKinetic replied that this product may not be suitable for steep rivers and hydro dams are better options. Their product is suitable for places with flat gradients having big volumes of water, where conditions are good for generating de-centralised power.

4. Regarding the case of power canals with existing hydraulic installations, it was enquired whether G-Kinetic turbines could cause head loss in power canal.

   No specific reply received.

5. Regarding the case of irrigational canals where there is no issue of head loss, the seasonal nature of canals, running only for 4-5 months, it was enquired whether this system will be commercially viable.

   M/s G-Kinetic said that they have several queries from thermal plants which may be having controlled 24x7 flows coming from running waters from cooling towers in the canals.

6. Another query was raised regarding effect of heavy silt on these turbines and expected unit charge rates of about Rs15-20 with 50% load factor making this technology unviable in India.

   M/s G-Kinetic said that European policies is to increase carbon tax for making people realise that fossil fuels are not viable in the future and they don't know the

Indian market in detail for which they may require study to make the product viable in India. Further heavy silt may cause increased wear which require frequent changing of bushes.

As a closing remark, CE (HE&TD) mentioned that the report we intend will give an insight to the policy makers as well as awareness among utilities where the technology development can be further exploited and an exercise may be taken to explore the potential.

Meeting ended with a vote of thanks to all participants.

ANNEXURE-VI

Minutes of 4th Meeting of the Committee held on 14/09/2021 A/N

Special Invitee: M/s Maclec Pvt. Ltd., Delhi

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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No. 10/3/HETD/2021/ Date: .09.2021

Subject: Minutes of 4th Meeting of the Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 14.09.2021 – reg.

Please find enclosed herewith the minutes of 4th meeting of the Committee constituted to study the conceptual and commercial application of Small/Surface Hydro Kinetic Turbine developed by M/s Maclec held through VC on 14.09.21 placed at **Annex-I**.

Encl: as above

(Reetesh Tiwari)
Dy. Director

To:

1. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
2. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
3. Prof. Arun Kumar, IIT Roorkee
4. Prof. R. P. Saini, IIT Roorkee
5. Sh. Gangesh Upadhyay, Scientist G, MNRE
6. Sh. Sanjay Kumar Shahi Scientist D, MNRE
7. Sh. Keshav Deshmukh, ED (D&E), NHPC
8. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
9. SA to Member (Hydro), CEA

Annex-I

Minutes of 4th Meeting of Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 14.09.2021

List of Participants:

1. Sh. B.K. Arya, Member (Hydro), CEA
2. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
3. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
4. Prof. Arun Kumar, IIT Roorkee
5. Prof. R. P. Saini, IIT Roorkee
6. Sh. Gangesh Upadhyay, Scientist G, MNRE
7. Sh. Sanjay Kumar Shahi Scientist D, MNRE
8. Sh. Keshav Deshmukh, ED (D&E), NHPC
9. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
10. Sh. Rakesh Kumar, Chief Engineer (HE&TD) CEA
11. Sh. Balram Bharadwaj, M/s Maclec

The 4th meeting of Committee constituted to study the concept and commercial application of Hydro Kinetic Turbine developed by M/s Maclec was convened by Sh. Rakesh Kumar, CE (HETD), CEA under the chairmanship of Member (Hydro), CEA on 14.09.2021 at 03:30 PM through Video Conferencing, wherein several queries were discussed regarding Hydro Kinetic Turbines being offered by M/s Maclec.

At the outset, Sh. Rakesh Kumar, CE (HE&TD), CEA welcomed all the committee members and representatives of M/s Maclec. He invited Sh. Balram Bharadwaj from M/s Maclec to present his PPT related to the queries specifically on establishment of technology capability, testing methodology and standards in continuation to their previous presentation wherein other areas have already been covered.

Sh. Balram gave a brief of the topics to be covered in the presentation i.e. design capability, turbine testing procedure, test duration & results, Indian/International standards used, conformance to the available operational regulations in terms of grid connectivity, etc.

1) Regarding Design capability, he informed that M/s Maclec have carried out CFD analysis to check the scalability, impact of debris, wake recovery, etc. using methodology given by HRED, IIT Roorkee which also complies with the IEC62600-300:2020 (Past 300: Electricity producing river energy converters – Power performance assessment) during 2014-2019.

   According to M/s Maclec, the existing Hydro Kinetic technologies are complex as well as imported which cannot be customized with several limitations of site parameters, high capital cost, O&M cost and low efficiency. As such, M/s Maclec has come up with a new hypothesis of partial submergence of multi rotor cross flow turbine which can enhance efficiency & customizability to harness inexhaustible untapped potential at lowest possible cost to develop indigenously. Its idea validation started with the help of IITR and subsequently field tests were conducted on prototype between Aug’2014 – Feb’2015 for improvisation of the design and design validation was done using tools like Solidworks & Ansys. Performance validation was done by the tools provided by HRED, IITR and parameters by CHTTC, Canada & AHERC, US. Hence after 2015, Maclec got an algorithm to scale up the device.

Through prototype testing at multiple locations for design validation of turbine blade profile, floating & anchoring arrangement, gearbox, generator, power stabilization, etc. they came up with the validation of turbine technology, using methods given by HRED, IITR which are now qualifying IEC TS 62600-300:2020. Maclec presented the photographs & clips of prototype testing at Ramganga river, lab tests at HRED, IITR & Maclec lab, Delhi, Field test at Ramganga river and Gurgaon canal. Further the results of prototype testing showed efficiency achieved of about 48% demonstrated in Velocity vs Power coefficient (Cp) curve and Tip speed ratio (TSR).

M/s Maclec started site identification, available maximum & minimum velocity range, depth range for suitability of SHK turbine through CFD analysis using 'Velocity v/s Cp' results to understand the site parameters and performance. Detailed Design & Engineering and technology development has been done by M/s Maclec itself for practical product development during 2018-2019. M/s Maclec is trying for indigenization of system to develop complete product including turbine blades, gearbox & generator etc. they informed that final product testing has started in 2020 onwards with fixed type turbine of 2kW.

M/s Maclec mentioned that the turbine design can be scaled up & customization can be done as per site parameters. The modular life of the turbine claimed is up to 40 years with an O&M plan comprising of regular O&M every 6 months and scheduled maintenance in every 3 years. As stated, only electrical parts may require major technical transformation in every 10-15 years. M/s Maclec informed that one of the patent of the technology has been already been awarded to them.

M/s Maclec informed that the guaranteed minimum generation per module would be about 3500 units/kW/Annum based on site parameters. Regarding ambient characteristics of SHK turbine, M/s Maclec claimed the operation velocity range is 0.5m/s-7m/s, operating minimum depth is 0.5m, operating water quality with silt (upto 30,000 ppm), floating debris (upto 200mm), sand, boulders (upto 300mm) and there should be no impact on environment, fish & aquatic life.

With regard to the operational regulations in terms of grid connectivity, Maclec claimed that many of the electrical components they are using are conforming to the latest electricity grid code of CERC.

Queries & Replies:

1. The committee enquired regarding product testing during 2020 (lock down period) , test parameters and results, operating conditions / parameters for the products tested for conformance to connectivity standard , IEEE /IEC standards in particular for:

    a. Convertor performance electrical output in respect of harmonics/voltage /DC current threshold limits.

    b. Generator output in respect reactive power regulation , output frequency variation

Ms Maclec replied that it has performed testing on a small scale product of 2KW turbine on a micro irrigation Canal of 1.8 m width and depth 200mm with velocity variation of 1.5m/s to 3m/s with no water regulator. It observed that the output from this single turbine was 320V to 590V DC, harmonics were less than 3% and the manufacturer claimed to conform to connectivity standards. The manufacturer stated that inter RPM regulator was developed, to maintain output parameters by reducing the generation and rpm of turbine in case of sudden increase in velocity of incoming water.

2. The committee required clarification in respect of true reflection of plant schedule maintenance frequency during O&M stage and requirement of major technical transformation on the projected O&M cost (%3 of capex per annum) in the tariff petition.

   Ms Maclec replied that it has taken into account these factors and plan to keep 2% of capex per annum in the bank and required amount will be utilised in six month and balance amount would be utilised for major overhaul. O&M cost is dependent on site parameters and flow velocity.

3. The committee required clarification regarding life of various installed components , in particular for turbine ;whether it is exactly 40 years or it is extendable upto 40 years of turbine whereas other components adopted from wind and solar technology such as inverters, convertors etc have much less life. Hence, not only O&M cost, but capital invested would be required for such components. Information in respect of additional capex amount and frequency to infuse capex need to be deliberated to extend the life to 40 years. The committee informed that in large hydro, capital overhauling is done on the recommendation of manufacturer in about 5-10 years depending on operating condition and maintenance of the utility. This expenditure is not considered in calculation of levelised tariff and it is part of cost plus tariff regime. It also stated that clarity on this aspect is essential during the competitive bidding process.

   Ms Maclec replied that since the SHK turbines are being installed in open environment, so regular and scheduled O&M activity as mentioned would be required depending on site parameters (velocity fluctuations). Turbines installed in 0.5 to 1.5m/s would require schedule O&M in 5 years and in case of flash floods or high velocity upto 4 to 5m /s it may be in 2 years. Capital requirement is dependent on site parameters.

   In respect life of other components (inverters, convertors), M/s Maclec replied that it has taken into account capital cost requirement after the life span of 10 years such components in consultation with manufacturers of respective equipment and their submitted performance parameters under 2% Capex cost per annum. Further it also said that the life span is extended upto 40 years with recommended O&M activity. It also mentioned that since generation/ PLF is higher, it is possible to cover O&M activity.

4. To the committee’s query regarding testing plan of 100kW turbine, M/s Maclec replied that it is dependent on the approval from the concerned authorities. The committee stated that it can give recommendation only for the tested product. M/s Maclec mentioned that the product is scalable in nature and the test performed on 2KW is also demonstrating the capability of utilising maximum potential of that canal without disturbing the water discharge capability of canal and optimum wake recovery distance and efficient conversion of mechanical energy utilising existing electronics

technology. He stated that the test was used to demonstrate the scalability of the technology.

5. The committee stated that in mini and micro hydro plants installed in canals, several projects had become unviable as the water available in the canal is as per irrigation requirement/ scheduling and that the same may happen for SHK turbines which are to be installed in Canals, so it would be better if larger capacity turbines are commercially deployed and installed after demonstration and testing.

   In response to this, M/s Maclec mentioned that these turbines need to installed in canal where water availability is for at least 6 months and cost of plant is recovered if PLF is at least 45%. M/s Maclec referred to its TFR for SHK turbine installation in the downstream of Koyna HEP wherein they have considered water availability for one machine discharge to assess the potential & energy generation. They back calculated the capex v/s power generation and opex v/s power generation, to finalise the tariff. He also stated that single large capacity turbine can be given but array of turbine of 20-50kW capacity is also possible but would require time and investment.

6. Regarding early query of TRL & CRL, M/s Maclec claimed that SHK turbine is having a Technology Readiness Level (TRL) at 9 and the Commercial Readiness Level (CRL) at 8. As a clarification of TRL, M/s Maclec mentioned that in 2020, Horizon 2020 European Union funding for Research & Innovation, Climate-KIC and Swedish Energy Agency has assessed SHK turbine at TRL-8 (System Complete and Qualified). EIA has been done by International organizations like Mission Innovation under Net-zero compatible innovations initiative selected the SHK turbine and assessed the avoided emissions framework –Level 1 beta assessment in which they identified that 100+ Mt CO_2e/year reduction by 2030 if implemented as on 2020.

7. The committee enquired about the followings:

   a) The Hydraulic calculations/studies carried out showing the effect on the existing hydropower installations in terms of discharging capacity, afflux, head losses, etc. with/without installation of SHK turbines.

   b) Himalayan rivers are having steep gradients carrying boulders, silt and debris problems with high velocity wherein the large installations are swept away during floods and the central India rivers are mostly having flat gradient where the non-monsoon flow depth would be less which would be required for irrigation purpose, and the scope of SHK turbine would be limited in irrigation canals where there are no hydroelectric installations.

   M/s Maclec replied that this matter can be taken up separately and they will work on that and try to give more details for a detailed theoretical discussion.

As a closing remark, CE (HE&TD) thanked representative of M/s Maclec for sharing the details of testing output & standards used which were not covered in their earlier presentation and other committee members for attending the meeting.

Meeting ended with a vote of thanks to all participants.

ANNEXURE-VII

Minutes of 5th Meeting of the Committee held on 16/09/2021

Special Invitee: M/s Imp Powers Ltd., Mumbai (an Indian Partner of M/s Smart Hydro Power, Germany having exclusive rights for India)

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केंद्रीय विद्युत प्राधिकरण/Central Electricity Authority
जल विद्युत अभियांत्रिकी व प्रौद्योगिकी विकास प्रभाग
Hydro Engg. & Technology Dev. Division
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No. 10/3/HETD/2021/ Date: .09.2021

Subject: Minutes of 5th Meeting of Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 16.09.2021– reg.

Please find enclosed herewith the minutes of 5th meeting of the Committee constituted to study the conceptual and commercial application of Small/Surface Hydro Kinetic Turbine held through VC on 16.09.21 placed at **Annex-I,** wherein M/s Imp Powers Ltd. gave the presentation on Hydro Kinetic Turbines.

Encl: as above

(Reetesh Tiwari)
Dy. Director

To:

1. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
2. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
3. Prof. Arun Kumar, IIT Roorkee
4. Prof. R. P. Saini, IIT Roorkee
5. Sh. Gangesh Upadhyay, Scientist G, MNRE
6. Sh. Sanjay Kumar Shahi Scientist D, MNRE
7. Sh. Keshav Deshmukh, ED (D&E), NHPC
8. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
9. SA to Member (Hydro), CEA

Annex-I

MoM of 5th Meeting of Committee constituted to Study the Concept and Commercial Application of Hydro Kinetic Turbine developed by M/s Maclec held through VC on 16.09.2021

Special Invitee: M/s Imp Powers Ltd

List of Participants:

1. Sh. B.K. Arya, Member (Hydro), CEA
2. Sh. Ajay Talegaonkar, Chief Engineer (F&CA), CEA
3. Sh. Sharvan Kumar, Chief Engineer (HPA), CEA
4. Prof. Arun Kumar, IIT Roorkee
5. Prof. R. P. Saini, IIT Roorkee
6. Sh. Gangesh Upadhyay, Scientist G, MNRE
7. Sh. Sanjay Kumar Shahi Scientist D, MNRE
8. Sh. Keshav Deshmukh, ED (D&E), NHPC
9. Sh. L.P.Joshi, GM (EM-Desing), THDCIL
10. Sh. Rakesh Kumar, Chief Engineer (HE&TD) CEA
11. Sh. Aditya R Dhoot, M/s Imp Powers Ltd
12. Sh. Akshay Gadi, M/s Imp Powers Ltd

The 5th meeting of Committee constituted to study the concept and commercial application of Hydro Kinetic Turbine was convened by Sh. Rakesh Kumar, CE (HETD), CEA under the chairmanship of Member (Hydro), CEA on 16.09.2021 at 11:30 am through Video Conferencing, wherein M/s Imp Powers Ltd, an Indian Company, was invited to discuss their product in the form of Hydro Kinetic Turbine, which was manufactured in collaboration with M/s Smart Hydro Power (SHP), a German Company. The meeting started with brief introduction of Sh. Aditya R Dhoot and Sh. Akshay Gadi, representing M/s IMP Powers.

At the outset, the chair welcomed all the committee members and representatives of IMP Powers. He gave a short introduction about the committee, their interests in knowing more about the technology, its development status in India and worldwide. He then invited representatives from IMP Powers to start the presentation regarding the queries put forth to them on behalf of the committee.

Sh. Aditya R Dhoot in his opening remarks said that their company IMP Powers is 61 year old. It manufactures Power and distribution transformers. IMP in 2018 entered into exclusive licensing agreement with Smart Hydro Power (SHP), Germany for manufacturing Smart Kinetic Turbines for setting Micro Hydro Projects in India. He informed about the already commissioned 20 kW (4X5kW) Hydro Kinetic turbine project at Neyveli Lignite Corporation site.

Sh Gadi from IMP Powers started the presentation by describing the basics and methodology of Hydro Kinetic Turbines. He explained that Hydro Kinetic Turbines are zero head turbines as it harnesses energy from flowing water and it has negligible T&D losses. Its installation is portable and easy. He further explained about various models i.e robust structure fit for lower depths, with diffusers that helps to achieve max output at 2.8 m/sec, Single float model for deep rivers/canals (single anchoring points) and dual float method for lesser depths (dual anchoring points).

Regarding specifications of free stream turbines (simple model placed on bed) it was informed the output is 250-5000W @ velocity 1.1-3.1 m/sec , unit is 1.1m cube dimension wise, Rotor speed is 90-230 rpm ,weight is 300 kg, rotor blades =3 of 1000mm ϴ. For floating model (with diffuser), the output is 250-5000W @ velocity 1.1-2.8 m/sec , dimensions are length-3130mm, width 1600mm , Height -2010mm, Rotor speed is 90-230 rpm ,weight is 380 kg, rotor blades =3 of 1000mm ϴ.

Hydrokinetic turbine was compared with other renewable resources under land requirements, generation variation and PLF categories. It was mentioned that Hydrokinetic Turbines requires very less space as compared to Solar or Wind Power. Hydro kinetic turbines are base load supply modules as compared to Solar which has Peak load supply and there is huge fluctuations in wind in case of Wind turbines. The Plant Load Factors for Hydrokinetic turbines is 70-80 % as compared to Solar (20 % max) and Wind (40%-50%).

Further, Sh. Dhoot described the Site requirements (depth, width and velocity) for installation of Hydrokinetic turbines (with and without diffusers). He explained that among the above the most important requirement is velocity requirement i.e 2.8 m/s -3 m/ sec for 1000mm sweep diameter turbine without diffuser and 2.5 m/s -2.8 m/ sec for 1000mm sweep diameter turbine with diffuser. For sweep diameter of 1500 mm turbines the velocity requirements are 2 m/s -2.4 m/ sec without diffuser and 2.3 m/ for turbine with diffuser.

Sh Dhoot explained that at sites where velocity requirements may not be fulfilled there is a possibility of increasing the velocities by introducing constrictions in the canals. According to him, TRC of various hydro power projects generally fulfils the velocity requirements.

Sh. Dhoot explained the areas of application i.e Thermal Power Plants, Check dams/ diversion gates, Tailraces of all HPPs, Cooling Channels in Industries, Sewage treatment plants, fast moving irrigation canals.

Sh. Dhoot gave a brief on their already installed Project of 20 kW (4X5 kW) at Neyveli Lignite Corporation of India Ltd under R&D activities of NLCIL. The project has been synchronized with 0.415 kV, 50 Hz NLCIL grid in the month of Oct 2017. 2.2 lakh units have been fed to the grid till Aug 2021 with this project. Sh. Dhoot explained the challenges he faced in respect of anchoring these units due to high velocities and the challenge of not hampering the existing power generation.

Further, Sh. Dhoot explained the development activities by IMP Powers. He explained the concept of Hydrokinetic Turbine energy generation with energy equation and Power Curve. He informed that studies for the implementation of array models, wake recoveries and constriction models are being carried out.

Sh. Dhoot said that they need recognition of this technology under make in India Scheme. He further stated that to reduce the payback time, support from the Government will be required. He then listed out the Projects under execution/finalization with IMP Powers which included, KSEB (5X5 kW) Kakkad hydro Kinetic Project at tailrace of a 50 MW HEP of KSEB , NLC India (3x5 KW) , PEECA (Africa)- 1000 kW irrigation canal and 20 kW floating HK project in Taiwan.

At the end of presentation, Sh. Dhoot gave a brief about their conventional SHPs installed at Kargil area in Leh/Ladakh.

Queries & Replies:

1. To the committee's query regarding Maximum Unit Size, Sh. Dhoot replied that right now maximum 5 kW unit has been installed.

2. To the committee's query about estimation of the Potential available in India for this technology, he replied that he has surveyed about 10-12 sites till now. He stated that since it is a new technology, support of Government will be required.

3. To the committee's query about commercial aspects about estimation of Minimum Domestic Content including supply and services, he replied that except generators (which they import from Germany) all things are domestically manufactured. He said that more than 50 % is the domestic content.

4. To the committee's query about life of the project, Sh. Dhoot replied that since it is a new technology they have not estimated the life of the Project. He further stated that he believe that the life should be around 25-30 years as this is very simple technology.

5. To the committee's query about pricing strategy, Sh. Dhoot replied that as per calculation carried out by them cost for 100 kW project is around 2.20 crores. He reiterated that this cost can be reduced with the support of Government. It was confirmed that this cost includes every aspects (cost of turbine, installation, accessories etc) with basic anchoring.

6. To the committee's query about efficiency of the turbine, Sh. Gadi explained that in power generation formula overall efficiency (including coefficient Cp) has been taken as around 40%.

7. To the committee's query about performance feedback/certificate for the existing project at NLC, Sh. Dhoot replied that at present he has no information about it and he will check for it.

8. To the committee's query about the quality of water in NLC Project, Sh. Gadi replied that initially they have observed corrosion in turbine blades, and to rectify this they have provided the coatings to the turbine blades. The water was not treated.

9. To the committee's query about the wake recovery, Sh. Gadi replied that for low velocities it is around 20 m and for higher velocities it is around 30 m as per their calculations. As this is a new technology they don't have sufficient data for this.

10. To the committee's query about connection to the grid and whether the cost for grid connection (synchronisation) is included in the project cost and whether any PPA has been signed by them, M/s IMP powers replied that the implemented project (NLC-Tamil Nadu) is grid connected and it's upcoming project (in Kerela) would be connected to LT grid via 3Ø inverter system and as such capable to supply auxiliary power. In reference to PPA, it is replied that they don't own the projects and they only supply the machines. Concerned utilities may have used it for auxiliary power/ sold it. For Projects with KSEB, they have no information and they have to check.

11. To the committee's query about what is the need of customizing these turbines, it is replied by M/s IMP Powers that the method of anchoring can be customized and to fulfil the requirement of velocity, constrictions can be made in the canals/rivers.

12. To the committee’s query about what compliances are required to install these turbines, Sh. Dhoot explained that till now no such requirements have been experienced by them.

13. Committee members stated that the committee may need to look for the certification (if available) for the quoted 40 % efficiency of the turbines. To this Sh. Gadi replied that he will check for the certificate for efficiency and inform the committee.

14. To the committee’s query about naming the sites having velocities greater than 2.5 m/sec, Sh. Dhoot replied that he has experienced such velocities in the TRC of SHPs at Kargil area, in Canals of Thermal Power Plants, Sewage treatment plants. Committee member explained that Tail Race of conventional hydropower plants are not designed for very high velocities and they are generally below 2 m/sec. Also, Return canals of thermal power plants are generally designed for low velocities (less than 2 m/sec). These turbines are good where we have continuous flow with less trash and silt and velocities are high. Committee members suggested that developers need to modify these turbines to work on low velocities.

15. Sh. Dhoot requested the committee to provide the space to install the pilot turbine to obtain the efficiency of the turbine. To this, Committee replied that this type of studies can be done in CWPRS or Defence laboratories.

As a closing remark, the chair mentioned that there are certain starting points and take off from this meeting which we can further work upon in due course of time.

Meeting ended with a vote of thanks to all participants.

APPENDIX - I

Presentation by **M/s Maclec Pvt. Ltd., Delhi** (an Indian Developer) held on 06/09/2021 on their completely indigenous developed technology/ product of SHK Turbine

SHK TURBINE

TECHNOLOGY DEVELOPMENT JOURNEY
2013-2021

BY

MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.

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PRESENTATION OUTLINE

1.	DESIGN CAPABILITY:
	(A) Initiation of Idea
	(B) Idea validation
	(C) Prototype Testing
	(D) Determination of Ideal Site Parameters
	(E) Detailed Design Engineering & Technology Development
2.	TURBINE TESTING PROCEDURE, TEST DURATION AND RESULTS
	(I) Product Development & Standardization
	(II) Product testing and Result Validation
3.	THE INDIAN/INTERNATIONAL STANDARDS USED
4.	CONFORMANCE TO THE AVAILABLE OPERATIONAL REGULATIONS IN TERMS OF GRID CONNECTIVITY
5.	TECHNOLOGY DEMONSTRATION AS DESIRED BY THE COMMITTEE MEMBERS

1. DESIGN CAPABILITY

A. INITIATION OF IDEA (2013)

Motivation Behind- Develop Indigenous Technology to harness inexhaustible – untapped Hydrokinetic Potential of India at lowest possible cost and with no harm to environment

SHORTCOMMINGS IDENTIFIED IN EXISTING HYDROKINETIC TURBINES –
A. REQUIRED SIE ARAMETERS ARE LIMITING THE SCOPE OF HYDROKINETICS (VELOCITY > 2.5M/SEC, DEPTH > 2M, WIDTH > 3 M)
B. CAPITAL COST & O&M COST IS TOO HIGH
C. EFFECIENCY IS TOO LOW
D. NO INDIGENOUS TECHNOLOGY IS AVAILABLE
E. EXISTING TECHNOLOGIES ARE COMPLEX, IMPORTED AND CANNOT BE CUSTOMIZED AS PER SITE PARAMETERS.

INITIATION OF IDEA & HYPOTHESIS
A. PARTIAL SUBMERGENCE OF MULTI ROTOR CROSS FLOW TURBINE CAN INHANCE THE EFFECIENCY & CUSTOMIZABILITY OF HYDROKINETIC TURBINE

FIRST FIELD TEST	MARCH - 2013
SITE	UPPER GANGA CANAL (MURADNAGAR)
TURBINE PARAMETERS	PARTIALLY SUBMERGED MULTI ROTOR CROSS FLOW
TEST PARAMETERS	VELOCITY V/S ELECTRICAL OUTPUT
TEST DURATION	72 HOURS PERFORMANCE TESTING IN 18 DAYS
TEST OUTCOME	INITIATION OF IDEA

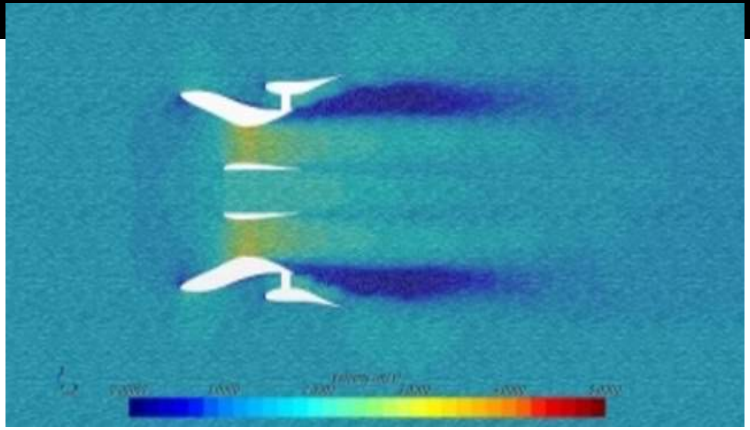
B. IDEA VALIDATION

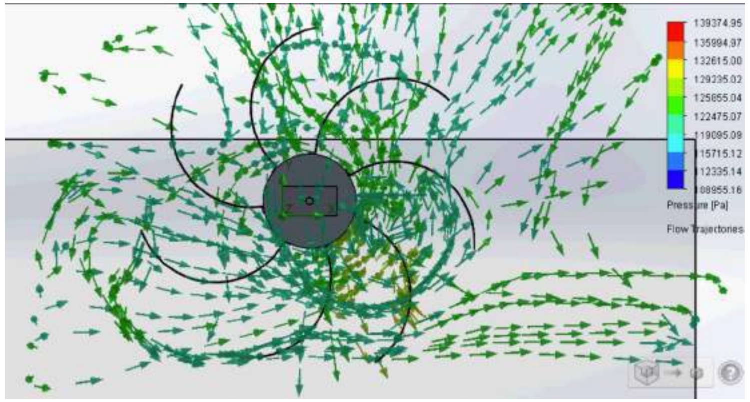
(I) DESIGN VALIDATION

TOOL - SOLIDWORKS & ANSYS

PROCESS – DESIGN IMPROVISION IN BLADE PROFILE, MODULAR STRUCTURE

DURATION – MAY 2013 - SEP 2014





(II) PERFORMANCE TESTING

TOOL – CNC SHEET METAL FABRICATION

PROCESS –FIELD TESTING OF PROTOTYPE IN DIFFERENT SITE PARAMETERS

DURATION – AUG 2014 – FEB. 2015

OUTCOME – IMPROVISATION IN DESIGN

(III) PERFORMANCE VALIDATION

TOOL – HYDROKINETIC CALCULATIONS (HRED- IITR, CHTTC CANADA, AHERC US)

PROCESS – VALIDATION OF TEST RESULTS USING CFD & HYDROKINETIC CALCULATIONS

DURATION – OCT 2014 – MAY. 2015

OUTCOME – MODEL MATHEMATICAL CALCULATIONS FOR PROTOTYPING

C. PROTOTYPE TESTING

TEST PARAMETERS

VELOCITY V/S MECHANICAL POWER

MECHANICAL POWER TRANSMISSION

ELECTRICITY OUTPUT

INITIAL DESIGNS VALIDATION OF

=> TURBINE BLADE PROFILE,
=> FLOATING ARRANGEMENT,
=> ANCHORING ARRANGEMENT,
=> GEARBOX,
=> GENERATOR,
=> POWER STABILIZATION CIRCUITRY,
=> INITIAL POWER TRANSMISSION SYSTEM

PERFORMANCE OF MATERIAL USED

PARAMETERS -
(i). Power (W)
(ii). Velocity of fluid (V)
(iii). Rotational speed (ω)
(iv). Pressure change across blades (ΔP)
(v). Gravitational acceleration (g)
(vi). Density of fluid (ρ)
(vii). Viscosity of fluid (μ) and
(viii). Characteristic length of Blade(wetted depth)

SITES	DURATION	SCHEDULE	OUTCOME
RAMGANGA RIVER TAIL RACE OF KALAGARH DAM	MAY 2015 – DEC 2016	TESTING OF PROTOTYPES SIZING 100 W TO 1 KW	PERFORMANCE VALIDATION OF TURBINE, GEARBOX, GENERATOR, POWER SYSTEMS
HYDROKINETIC TEST CANAL, HRED IITR	JUNE 2017 – DEC 2017	TESTING OF DIFFERENT MODULES UNDER CONTROLLED CONDITION	DATA VALIDATION FOR SCALE UP R&D
DOWNSTREAM OF CHILLA SHP	FEB 2018 TO APRIL 2018	TESTING OF MODULAR PERFORMANCE	DATA VALIDATION FOR SCALE UP
HYDROKINETIC TEST CANAL, MACLEC DELHI	JUNE 2018 TO SEP 2018	TESTING OF IMPROVSED BLADE PROFILE	VALIDATION OF SCALE-UP TURBINE MODULE DESIGN

PROTOTYPE TESTING @ RAMGANGA RIVER
TAIL RACE CANAL OF KALAGARH DAM

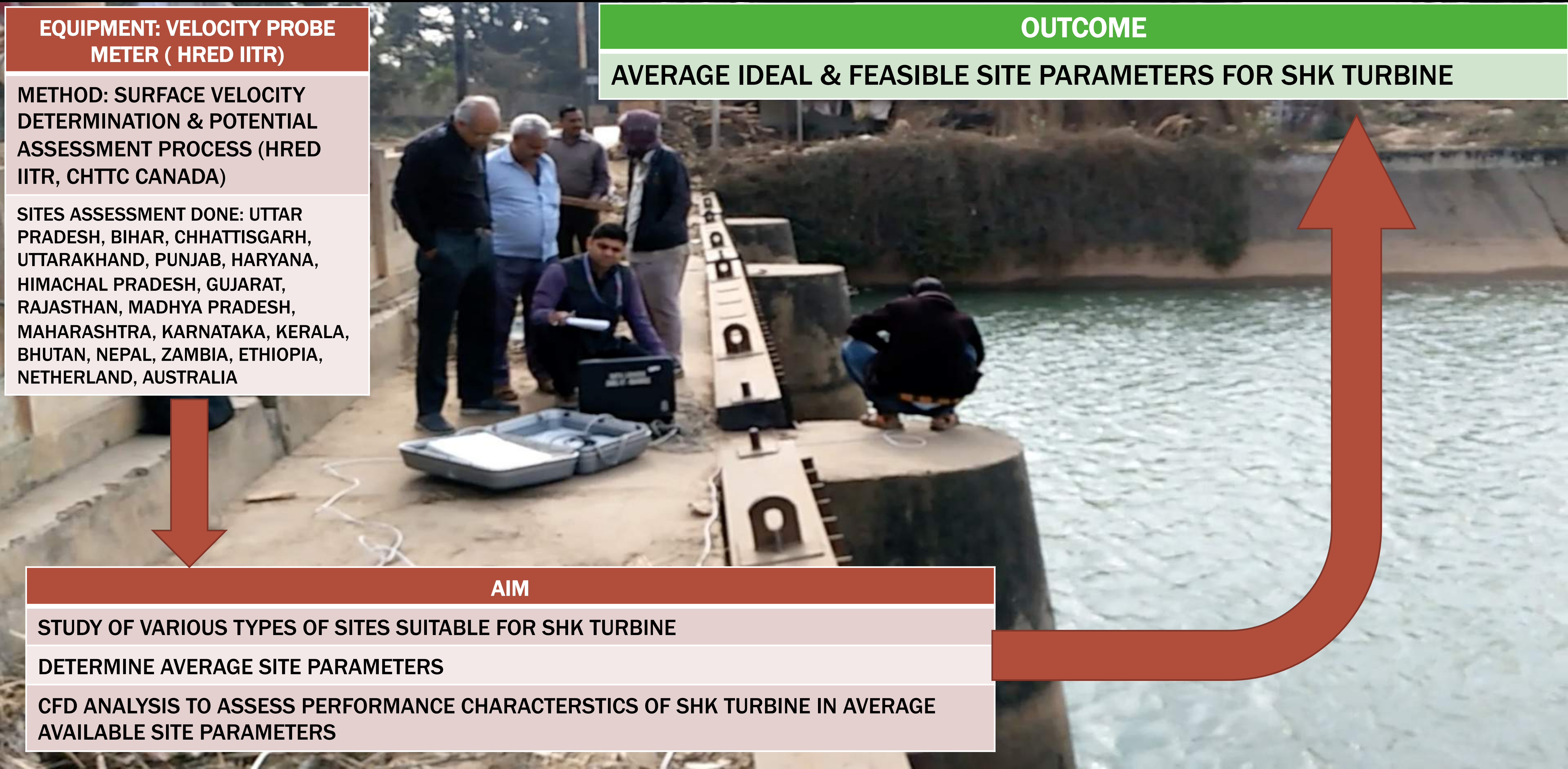
LAB TESTING @ HRED IITR

LAB TESTING @ MACLEC LAB DELHI

FIELD TEST @ RAMGANGA RIVER

FIELD TEST @ GURGAON CANAL

D. DETERMINATION OF IDEAL SITE PARAMETERS



EQUIPMENT: VELOCITY PROBE METER (HRED IITR)

METHOD: SURFACE VELOCITY DETERMINATION & POTENTIAL ASSESSMENT PROCESS (HRED IITR, CHTTC CANADA)

SITES ASSESSMENT DONE: UTTAR PRADESH, BIHAR, CHHATTISGARH, UTTARAKHAND, PUNJAB, HARYANA, HIMACHAL PRADESH, GUJARAT, RAJASTHAN, MADHYA PRADESH, MAHARASHTRA, KARNATAKA, KERALA, BHUTAN, NEPAL, ZAMBIA, ETHIOPIA, NETHERLAND, AUSTRALIA

AIM

- STUDY OF VARIOUS TYPES OF SITES SUITABLE FOR SHK TURBINE
- DETERMINE AVERAGE SITE PARAMETERS
- CFD ANALYSIS TO ASSESS PERFORMANCE CHARACTERSTICS OF SHK TURBINE IN AVERAGE AVAILABLE SITE PARAMETERS

OUTCOME

AVERAGE IDEAL & FEASIBLE SITE PARAMETERS FOR SHK TURBINE

COMMON SITE PARAMETERS AVAILABLE AT MOST SITES

SITES	CANALS, RIVERS, HILLY STREAMS, ETC.
VELOCITY RANGE	0.5 – 2 M/SEC
DEPTH RANGE	0.15 – 10 M
WIDTH	1 – 35 M
WATER QUALITY	SILT, FLOATING DEBRIS, ETC.

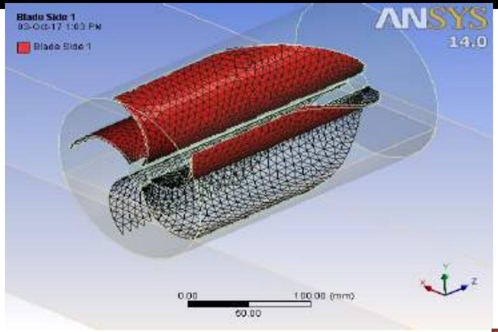
AFTER SERIES OF FIELD TRIALS, LAB TESTS, CFD VALIDATION, IMPROVISED PROTOTYPE TEST, PERFORMANCE MONITORING FROM 2013 TO 2018 WE FINALIZED –

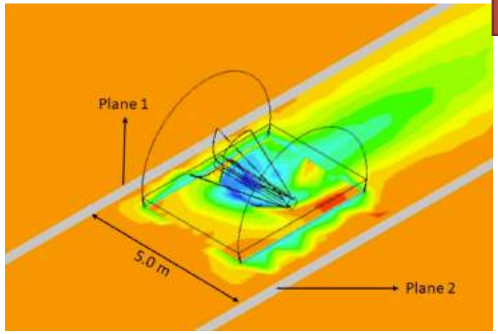
(I) COMMON SITE PARAMETERS
(II) BLADE PROFILE
(III) OUTPUT VOLTAGE RANGE
(IV) POWER OUTPUT VARIATION WRT SITE PARAMETERS

FROM OCT 2018 ONWARDS WE STARTED PRODUCT DEVELOPMENT

E. DETAILED DESIGN ENGINEERING & TECHNOLOGY DEVELOPMENT

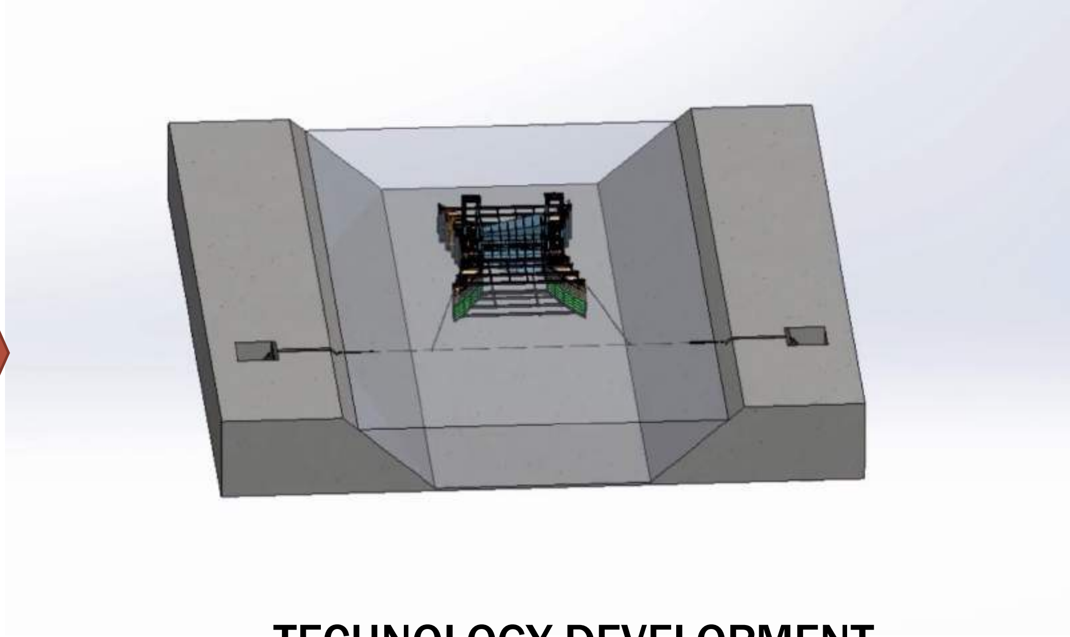
DETAILED DESIGN ENGINEERING TOOLS - SOLIDWORKS, ANSYS, CATIA
METHODOLOGY – DESIGNING OF FINAL MODULE AS PER THE PERFORMANCE DATA , CFD, LAB TESTS, FIELD TRIALS, PROTOTYPE TEST, SCALE-UP TEST





CFD VALIDATION

DESIGNING & TESTING OF INDIGENOUS
POWER ELECTRONICS



TECHNOLOGY DEVELOPMENT

2. TURBINE TESTING PROCEDURE, TEST DURATION AND RESULTS

TURBINE TEST PROCEDURE	TES DURATION	RESULT	STANDARDS USED
IDEA VALIDATION VIA FIELD TRIALS & METHAMATICAL MODELLING	2013 TO 2015	PERFORMANCE TESTING FOR IMPROVISATION	HRED IITR, CHTTC CANADA, PUBLICATIONS
PROTOTYPE TESTING	2015 – 2018	DESIGN & TESTING OF COMPLETE SHK TURBINE ASSEMBLY	HRED IITR, CHTTC CANADA, PUBLICATIONS
DETAILED DESIGN ENGINEERING	2018 – 2019	DESIGN OF FINAL ASSEMBLY (TURBINE-GEARBOX-GENERATOR-POWER CONDITIONING SYSTEM)	HRED IITR, CHTTC CANADA, PUBLICATIONS, CERC GUIDELINES, STATE ERC GUIDELINES

TEST, TRIALS, VALIDATION, UPGRADE, FIELD TRIALS

2013 - 2019

I. PRODUCT DEVELOPMENT & STANDARDIZATION

- CNC FABRICATION
- MATERIAL SELECTION
- QAP DEVELOPMENT
- MFG PROCESS DEVELOPMENT

INDIGENOUS MFG PROCESS

100% IN HOUSE R&D

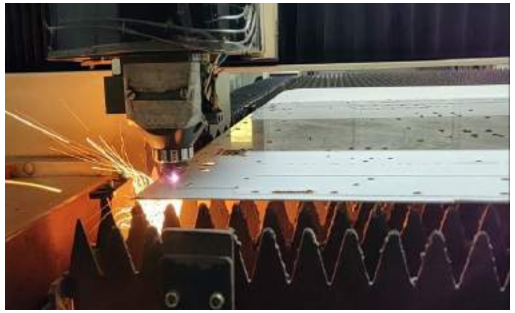
- INDIGENOUS DESIGN OF GEARBOX & GENERATOR
- PERFORMANCE TESTING
- EFFICIENCY TESTING

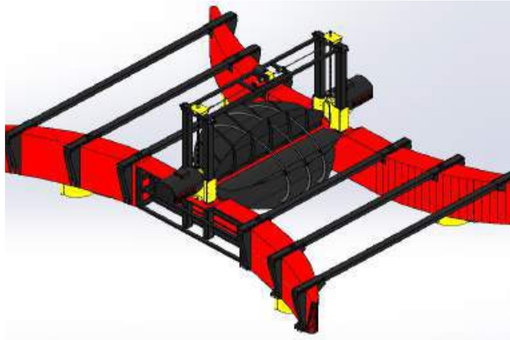
- SELECTION OF EXISTING POWER CONDITIONING SYSTEMS & CUSTOMIZATION
- PERFORMANCE VALIDATION

INDIGINIZATION OF COMPLETE PRODUCT

INDIGINIZATION OF COMPLETE PRODUCT

- FIELD TESTING OF ENTIRE ASSEMBLY IN (I) FLOATING (II) FIXED TYPE SHK TURBINE





II. PRODUCT TESTING & RESULT VALIDATION

TESTING OF MODULAR EFFECENCY & REPLICABILITY DONE – IN HOUSE LAB & FIELD TRIAL

TESTING OF MECHANICAL PERFORMANCE & ANCHORING STRUCTURE DONE AT PUGC

FINAL PRODUCT TESTING
2020 ONWARDS
POWER CONVERSION TEST DONE
POWER CONDITIONIG CIRCUIT TESTING DONE
POWER TRANSMISSION & GRID FEED IN SYSTEM TEST DONE
STATUS – COMMISSIONING IN PROCESS

II. PRODUCT TESTING & RESULT VALIDATION

TESTING OF MODULAR EFFECENCY & REPLICABILITY DONE –
IN HOUSE LAB & FIELD TRIAL

TESTING OF MECHANICAL PERFORMANCE & ANCHORING STRUCTURE DONE
AT PUGC

FINAL PRODUCT TESTING
2020 ONWARDS
POWER CONVERSION TEST DONE
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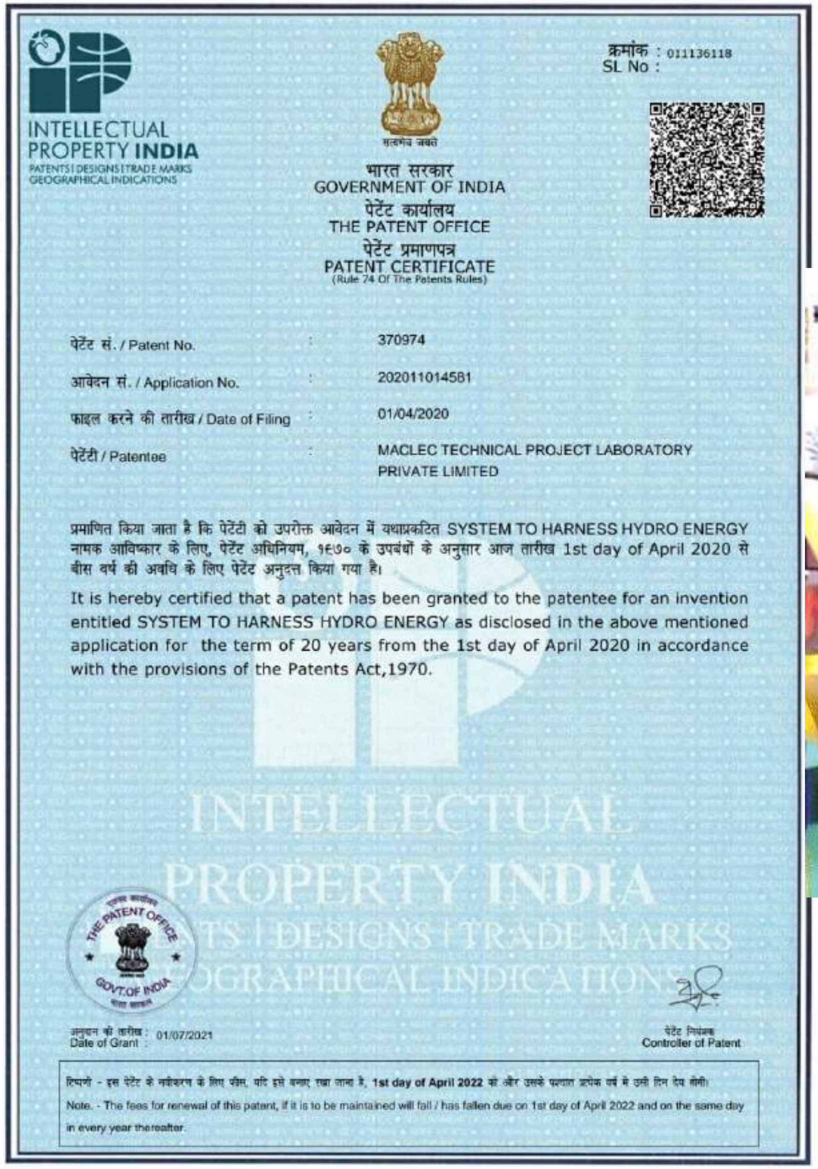
POWER TRANSMISSION & GRID FEED IN SYSTEM TEST DONE
STATUS – COMMISSIONING IN PROCESS

PATENTED TECHNOLOGIES



INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

क्रमांक : 011136118
SL No :

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE
पेटेंट प्रमाणपत्र
PATENT CERTIFICATE
(Rule 74 Of The Patents Rules)

पेटेंट सं. / Patent No.	:	370974
आवेदन सं. / Application No.	:	202011014581
फाइल करने की तारीख / Date of Filing	:	01/04/2020
पेटेंटी / Patentee	:	MACLEC TECHNICAL PROJECT LABORATORY PRIVATE LIMITED

प्रमाणित किया जाता है कि पेटेंटी को उपरोक्त आवेदन में यथाप्रकटित SYSTEM TO HARNESS HYDRO ENERGY नामक आविष्कार के लिए, पेटेंट अधिनियम, १९७० के उपबंधों के अनुसार आज तारीख 1st day of April 2020 से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled SYSTEM TO HARNESS HYDRO ENERGY as disclosed in the above mentioned application for the term of 20 years from the 1st day of April 2020 in accordance with the provisions of the Patents Act,1970.

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

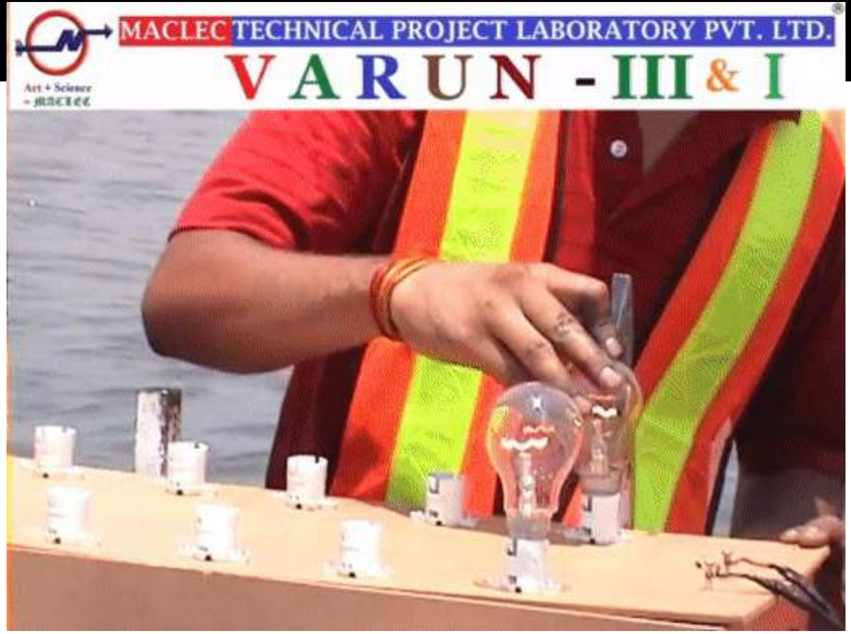
THE PATENT OFFICE
GOVT.OF INDIA

अनुदान की तारीख : 01/07/2021
Date of Grant :

पेटेंट नियंत्रक
Controller of Patent

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, **1st day of April 2022** को और उसके पश्चात प्रत्येक वर्ष में उसी दिन देय होगी।
Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 1st day of April 2022 and on the same day in every year thereafter.

SURFACE HYDROKINETIC TURBINE



A Floating Hydro Power Generation System

CONFIDENTIAL

3. THE INDIAN/INTERNATIONAL STANDARDS USED

MECHANICAL STANDARDS OF SHK TURBINE	
Length x Width x Height x Swept Area (L x W x H x S) mm	As per technology and Module design
Anchoring cable thickness (A) – mm	As per Drag force x 2
Mooring cable thickness (A) – mm	As per Drag force x 2
Overall Gross Weight of Module (kg)	As per technology and Module design
Minimum Generation of per Module (Units)/arrangement	3500 Units/KW/Annum
Preferred Hydrokinetic Turbine Technology type	Cross Flow, Radial Flux, Floating type Hydrokinetic Turbine Technology
Generator Type	PMG,/Excitation type Field Generator with 95% efficiency, operating temp. range 0 – 95 degree centigrade
Gearbox	Oil emersed, IP 65, with 97 % efficiency, operating temp. range 0 – 95 degree centigrade
Turbine Blades	Hydrofoil blade profile with minimum 40% cp
Floating arrangement	Capable to float with entire turbine assembly with automated submergence level managing capability
Power Evacuation Arrangement Junction Box (Protection degree/ Material)	IP 67 rated / Weatherproof PPO enclosure with
Connector	MC4 compatible or MC4, IP67 rated
Cable	4sqmm cross section
Fire safety class	C
Safety application class	A
Safety class	II

Ambient Characteristics of SHK Turbine	
Temperature coefficient of Current (I_{sc}), α (% / ºC)	0.0681
Temperature coefficient of Voltage (V_{oc}), β (% / ºC)	-0.2941
Temperature coefficient of Power (P_m), γ (% / ºC)	-0.3845
NOCT (ºC)	46 ± 2
Operating temperature range (ºC)	-10 to 85
Operating Velocity range (meter/second)	0.5 – 7 m/sec
Operating minimum water depth	0.5 meters
Operating water quality	Silt (up to 30000 ppm), floating debris (up to 200 mm), sand, boulders (up to 300 mm)
Environment Impact	Should be no environment impact, no impact on fish and aquatic wildlife

Technical Specifications of Power System of SHK Turbine

Sl.No	Items	Range
1.	Substation Output Rating	60 KVA – 600 KVA
2.	MPPT Voltage Range	90V to 900V
3.	AC Output with 50Hz frequency	415V/11 kV/33kV/132 kV 3 phase AC
4.	Integrated MPPT Input Regulator	As per design KVA
5.	Minimum Efficiency above 30% input power	Above 90%
6.	Accuracy of AC voltage control	+ / - 1%
7.	Accuracy of frequency control	+ / - 0.5%
8.	Grid frequency Synchronization range	+ / - 3 Hz
9.	Maximum Input DC Voltage	Based on make, should follow standard
10.	Ambient temperature considered	50 degree C
11.	Humidity	95% Non-condensing
12.	Protection of Enclosure	IP – 65 (Minimum) for outdoor
13.	Grid Frequency Tolerance range	+ / - 3%
14.	Grid Voltage tolerance	- 20% & + 15%
15.	No-load losses	Less than 1% of rated power
16.	THD	<3%
17.	Type of Loads	all types of loads, resistive, inductive, complex and non-linear
18.	Cooling	Fan Forced
19.	Protections	Output peak overload, short circuit, phase imbalance, over voltage, under voltage of the grid, Surge protections (input and output SPD)
20.	Control type	Voltage source, microprocessor assisted output regulation
21.	Certificatios	IEC 600068-1,2,14 and 30 or equivalent – Environment IEC 61000-3-15 EMC IEC 61683-Efficiency requirements as Specified above
22.	SURGE PROTECTION	as per IEC 60364-5-53 & NFEN 50539-11
23.	LAYING OF CABLES	XLPE insulated unarmored / armored with copper / aluminum conductor conforming to IS 7098/part 1/1988
24.	Other standards	VDE 0126- 1-1, IEC 60255.5 / IEC 60255.27 / IEC 621 , IEC 62109-1, IEC 62109- , Efficiency Measurements as per IEC 61683 / IS 61683 and Environmental Testing as per IEC 60068-2 (1, 2, 14, 30) /Equivalent BIS Std .

4. CONFORMANCE TO THE AVAILABLE OPERATIONAL REGULATIONS IN TERMS OF GRID CONNECTIVITY

Conformation
1. All Power Electronics of SHK Turbine is selected from available and presently running technologies related to Solar, Wind, Micro Hydro and Biogas based power stations
2. Only minute customization has been done to make them compatible for SHK Turbine power evacuation and grid feed-in
3. All power electronics are confirming Latest **Indian Electricity Grid Code by Central Electricity Regulatory Commission**
4. Standard SHK Plant Monitoring & Control System for Individual Module as well as entire plant has been developed indigenously and patented by MTPL.

5. TECHNOLOGY DEMONSTRATION AS DESIRED BY THE COMMITTEE MEMBERS

Our Technology is ready to customize and install in any site,
Therefore, we request you to provide any site
for technology demonstration.

Thank You

MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.
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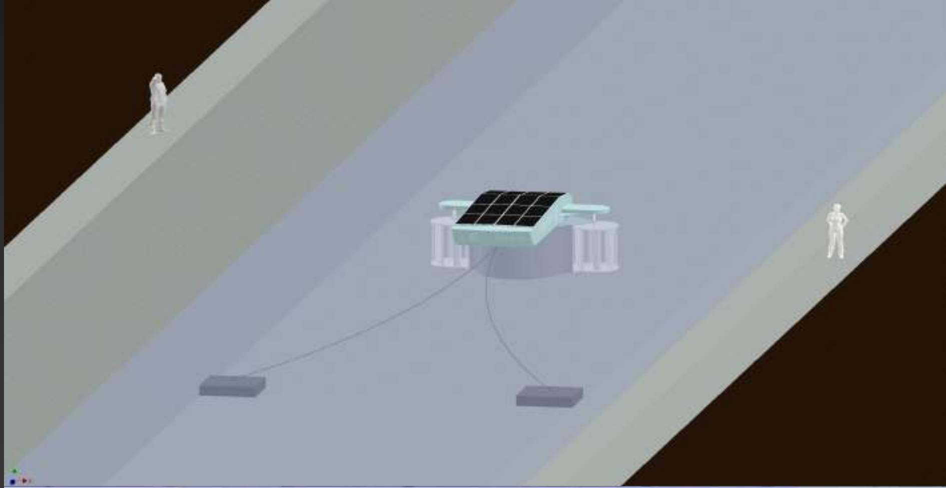
APPENDIX - II

Presentation by **M/s GKinetic Energy**, **Ireland** (Foreign Developer) held on 14/09/2021 on their technology/ product having fully imported content

GKINETICENERGYLTD

100% Clean, Predictable Energy from Free-Flowing Water

Presentation to Government of India
14th September 2021



Company Profile

"GKinetic Energy is a leading developer of innovative turbines that work with nature to generate clean, predictable energy from free-flowing water"

- Founded in 2014
- Based in County Limerick, Ireland
- 3 deployments of technology completed: **10 kW, 25 kW & 60 kW**
- Extensive IP Portfolio
- Commercial project rollout planned for 2021-2022
- 7 employees

The Team

Experienced in deep tech, leadership & hydrokinetic solutions for the energy transition.

Vincent McCormack
CEO & Founder

____

IP Owner & Inventor
Experienced Leader
Project Developer & Manager
CEO @ P&J Builders

Roisin McCormack
COO & Co-Founder

____

Led €2.7m H2020 project
Enterprise Ireland HDip
Employee #2 @Soundwave
(acquired by Spotify)

Bart Bonsall
Financial Advisor

____

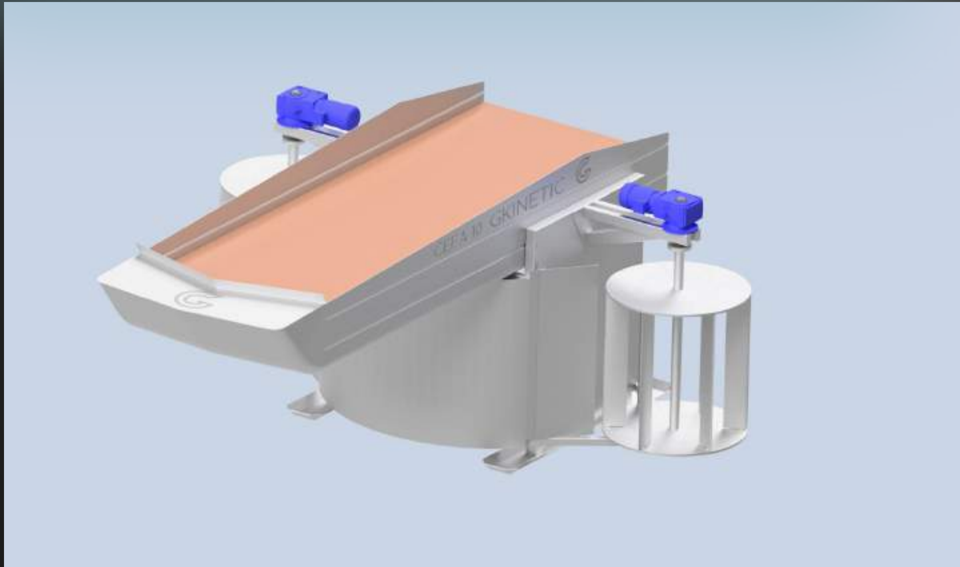
CEO at Chorus
2 successful exits
Finance & Strategy Executive
Specialises in Energy Transition

Partners:

Ocean Energy Europe
Interreg North-West Europe Marine Energy Alliance
seai Sustainable Energy Authority of Ireland
MaREI
Blue Invest
+CityxChange
MaRINET2
CASE

Product Profile

A floating platform that can be moored like a boat and instantly generate clean, predictable power.



100% Clean, Predictable Energy from free flowing water.

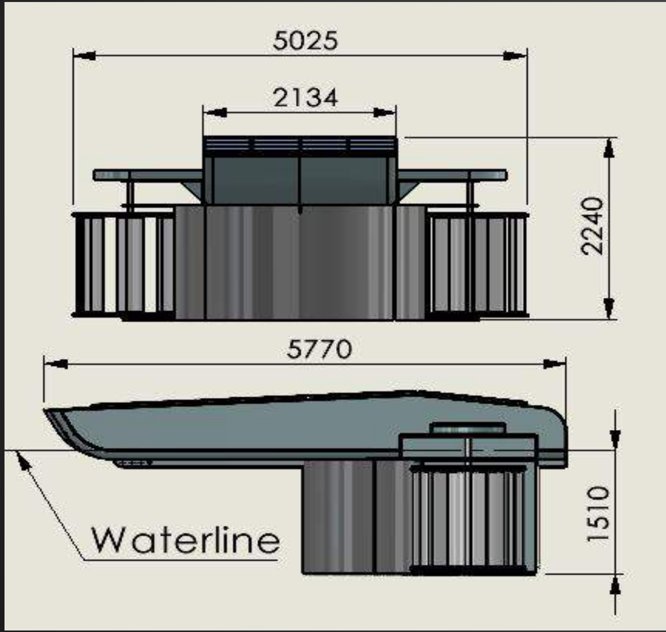
Accelerates the flow of water to generate more energy.

Plug & Play turbine: can be towed to site and moored like a boat.

Environmentally friendly and diverts debris away from the turbines.

Optional floating solar add on.

CEFA 12 - Technical Specifications



Type	Vertical Axis
Min Draft [m]	1.8
Rated Power [kW]	12
Rated Speed [m/s]	2
Power at 3m/s [kW]	30 kW
Cut-in speed [m/s]	0.5
Cut-out [m/s]	3.3
Weight [tonnes]	1.9
Diameter [m]	1.2
Blade Length [m]	1.2
Rotor swept Area/turbine [m^2]	1.44
Rotor Swept Area total [m^2]	2.88
Power/Swept Area [m^2]	3.47
Efficiency (turbine area)	88%
Weight of barge only [tonnes]	0.61

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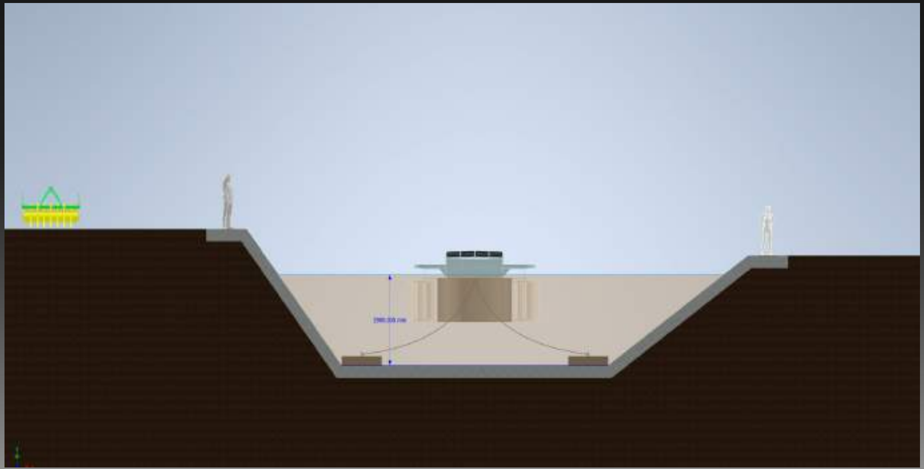
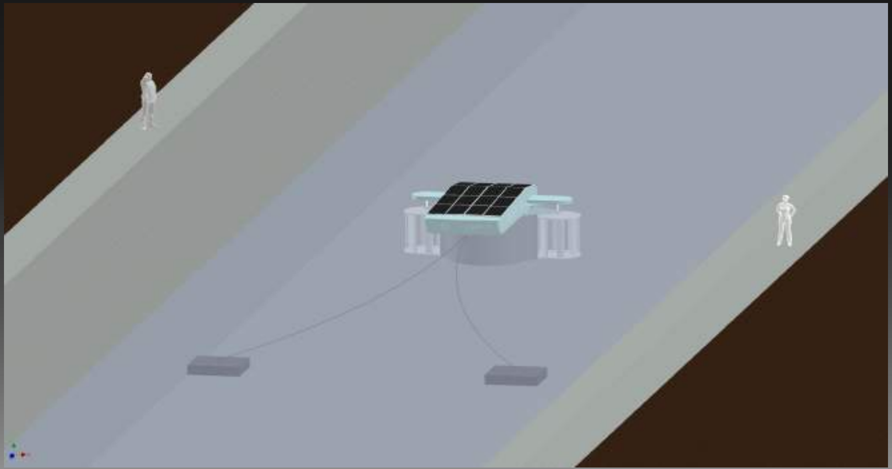
Industrial Canal Simulation



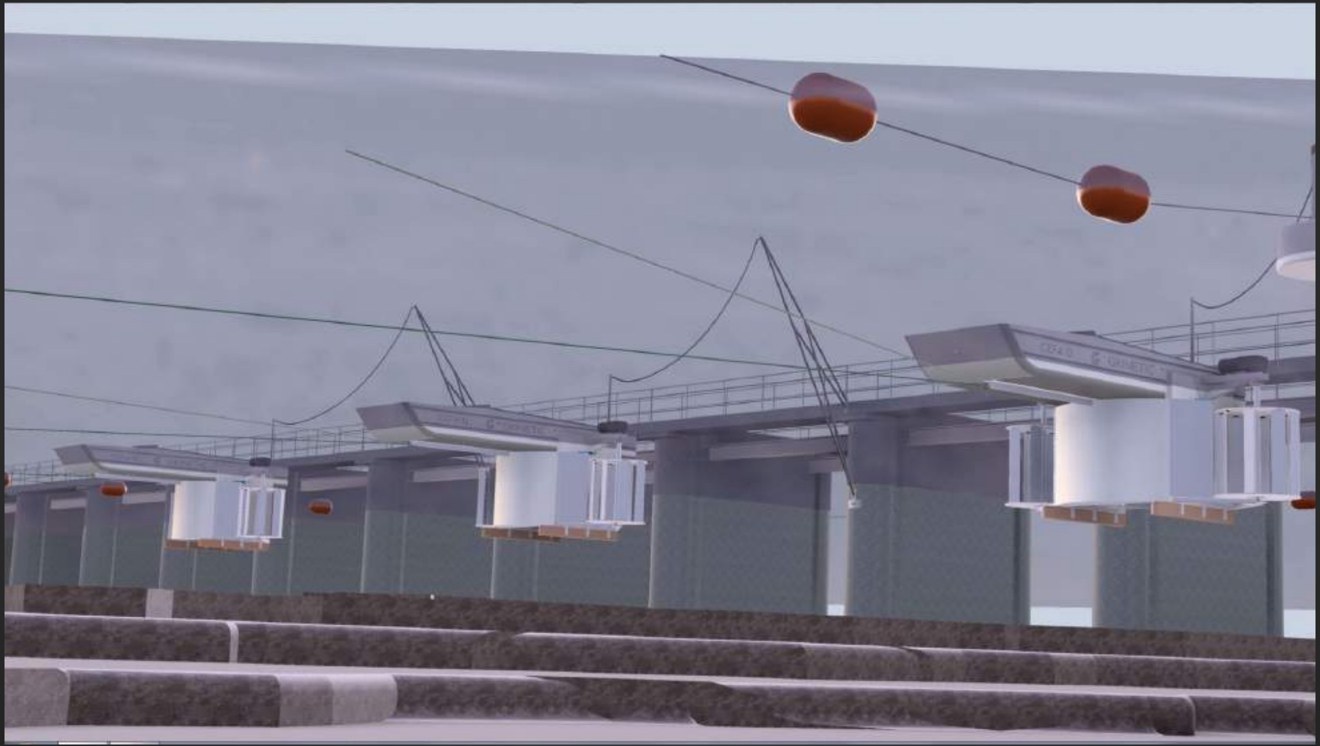


Existing infrastructure

Existing infrastructure

Photo credit Thierry David, source:
https://www.sudouest.fr/environnement/bordeaux-une-hydrolienne-irlandaise-en-test-sur-la-garonne-en-2018-3238281.php

Existing infrastructure



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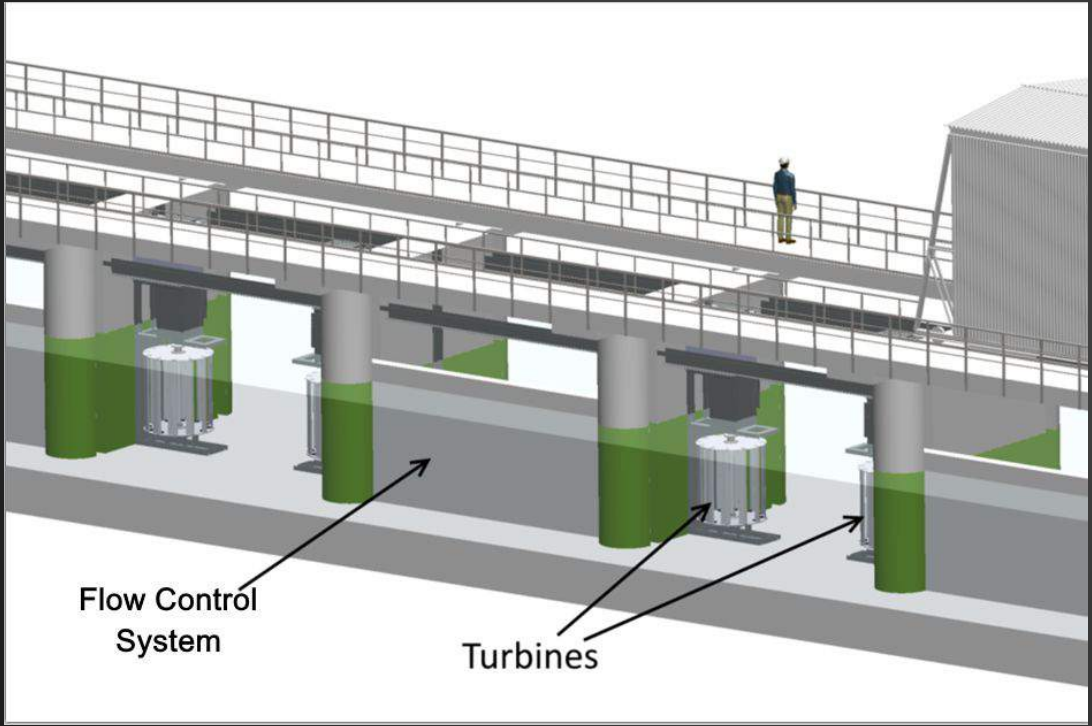
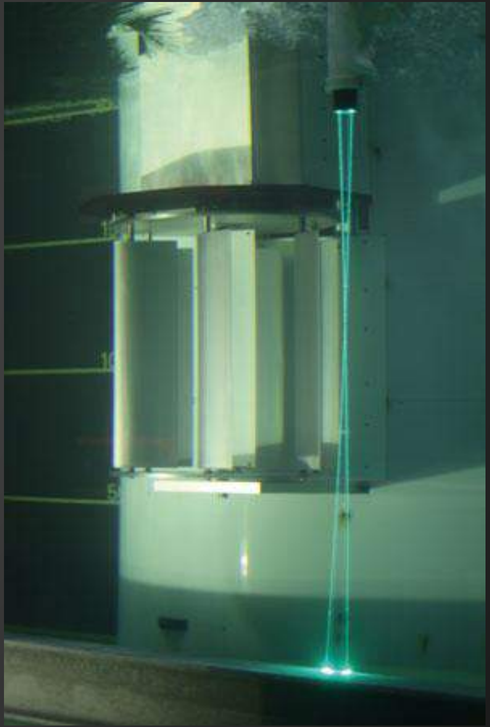
Existing infrastructure





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CEFA 12 - Mobile, Flexible, Low Impact

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Here's the Competition:

emrgy

SMART HYDRO POWER

ORPC

Diesel & Petrol Generators

Small scale wind and solar

Here's Why GKinetic is Better:

We hit rated capacity at 2mps and are more efficient in lower flow speeds

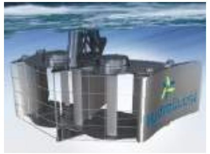
- Naturally deflects debris
- Mobile
- Does not need to block channel
- Can be scaled cost effectively
- Can be accessed from surface

No reliance on fossil fuels

- Zero Carbon
- Sustainable & Independent Generation

100% Predictable

- No land use
- No backup generator required

	GKINETIC	SMART HYDRO	ORPC	EMRGY	HYDROQUEST
FEATURES					
Accelerates ambient flow	✔	X	X	X	✔
Self-starts in 0.5mps	✔	X	X	X	Uncertain
Can be on or off grid	✔	✔	✔	Uncertain	Uncertain
Deployed on anchor	✔	✔	X	X	✔
No civil works required	✔	✔	✔	X	✔
Easy access for O&M	✔	✔	X	X	✔
Can sit on riverbed	✔	X	✔	✔	X
Naturally diverts debris	✔	X	X	X	X
Viable in flow of 1-2 m/s	✔	X	X	X	X

COMPETITION

GKINETICENERGYLTD

Product Journey

G. Technology readiness levels (TRL)

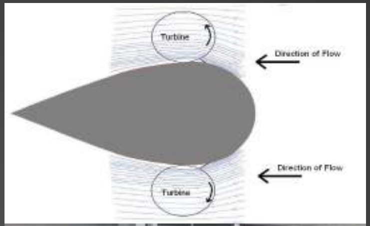
Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

TRL Levels as per EU funding programmes:
https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

TRL 1-3 | 2011 - 2014

Field tests in Shannon River, Ireland



1/20 scale prototype tested

NUI Galway tidal basin with GKinetic 1/40 scale prototype

Experimental proof of concept

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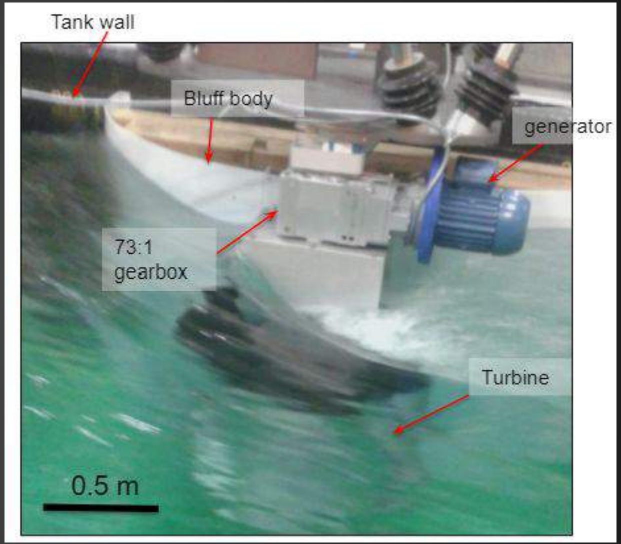
TRL 3-4 | 2014 - 2015

Technology validated in lab: IFREMER Test Tank at Boulogne-Sur-Mer, France



- 1/20th scale device extensively tested
- Flow velocities around the device characterised
- Mechanical power generated
- Optimum rotation speeds
- Drag forces on the device
- Efficiency of 40% achieved
- Potential for higher efficiencies

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TRL 5 | 2015 - 2016

Technology validated in relevant environment:

Limerick Docks controlled tow tests (10 months)

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TRL 5 | 2015 - 2016

-Tow speeds (inflow speed) of 0.5 m/s up to 2.5 m/s.

-Turbine rotational speeds from 10 rpm up to 45 rpm.

-Further analysis of the IFREMER data showed the possibility of achieving higher efficiencies than that recorded of cp 0.41.

TRL 5 | 2015 - 2016

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TRL 6-7 | 2017 - 2020

System prototype demonstration in operational environment:

Full scale 25kW and 60kW designed, built, installed and tested by IP Licensee and manufacturing partner 'DesignPro Ltd' with Vincent McCormack acting as Innovation Manager.

HORIZON 2020

A range of economically viable, innovative and proven HydroKinetic turbines that will enable users to exploit the huge potential of clean, predictable energy in the world's rivers, canals and estuarie

Fact Sheet | Results in Brief | Reporting | Results | News & Multimedia

Periodic Reporting for period 2 - DP Renewables (A range of economically viable, innovative and proven HydroKinetic turbines that will enable users to exploit the huge potential of clean, predictable energy in the world's rivers, canals and estuarie)

Reporting period: 2018-08-01 to 2020-03-31

Summary of the context and overall objectives of the project

The DP Renewables project set out to develop, demonstrate and commercialise a range of economically viable, innovative and proven HydroKinetic turbines that will enable users to exploit the huge potential of clean, predictable energy in the world's rivers, canals and estuaries. DP Renewables carried out the design, fabrication and testing of 2 novel hydrokinetic turbines, as well as definition of a detailed business plan for commercial launch and private investment.

The project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766499 and began 1st July 2017 lasting a total of 33 months, ending 31st March 2020. The entire project was managed and implemented by sole beneficiary and project coordinator DesignPro Ltd, an Irish company based County Limerick.

The project had 2 key outputs: namely the design, build and deployment of a 25Kw unit and also a 60Kw unit, both of which were achieved and demonstrated to TRL 8 during the project. The 25Kw unit was successfully installed at a dedicated, special-purpose test site called SEENEOH on the River Garonne in Bordeaux, France. The 60Kw unit was deployed and tow-tested just outside Kirkwall harbour in the Orkney Islands, Scotland.

Project Information

DP Renewables
Grant agreement ID: 766499

Closed project

Start date 1 July 2017
End date 31 March 2020

Funded under
H2020-EU.3.3.
H2020-EU.2.1.1.
H2020-EU.2.3.1.

Overall budget
€ 2 927 031,25

EU contribution
€ 1 934 656,50

Coordinated by
DP DESIGNPRO LIMITED
Ireland

Deployment to River

Aerial overhead view of 60kW unit deployed in Scotland

Deployment Vessel 1

Connection to Mooring 2

Credit and Source: DesignPro Renewables
https://cordis.europa.eu/project/id/766499/reporting

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TRL 8 | April 2022

System complete and qualified

● Develop Annual Energy Prediction (AEP) software to evaluate deployment sites.
● Commission and test of technology.
● Continuous monitoring of environmental impact and risk assessment on marine life and birds.
● Evaluation of energy output from continuous operation over the project period.
● Financial modelling of using a battery system to transport power to end users.

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TRL 9 | Q4 2022

System complete and qualified

Currently lining up first commercial pilot projects for 2022 / 2023.

Limited capacity for 2022 of 25 units (12kW). 18 of these are already committed to projects, 7 remaining to be allocated.

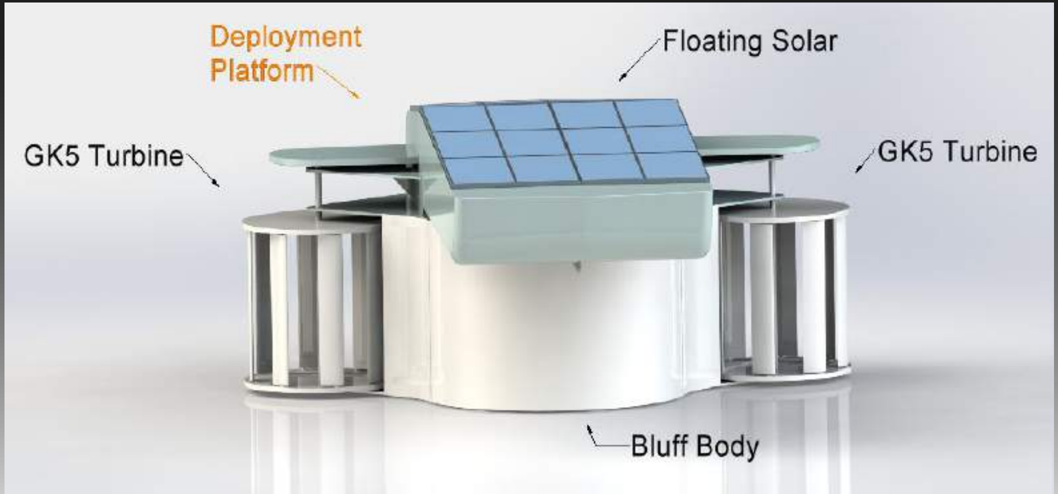
Projects with potential for repeat business and scalability will be prioritised.

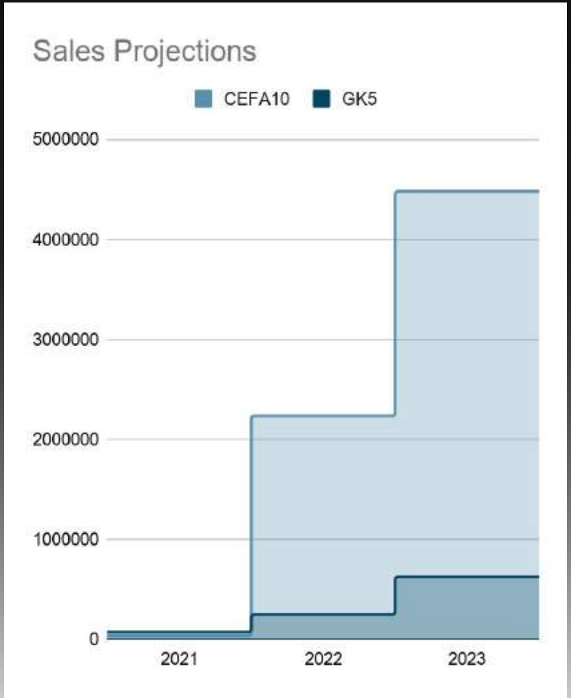
Another big advantage will be establishing strong partnerships through these first projects.

Highly interested in irrigation canals as they bypass many market blockers for us.

Finances

Single GK6 Turbine	Cost to Build €8,800	Ex Works Sale price €12,500
Complete CEFA12 Unit	Cost to Build €28,475	Ex Works Sale Price €64,000
1.6 kW Solar PV (Optional)	Cost to Supply €1,200	Sale Price €2,400





Items for discussion

- **Standards used for design, testing and operation**

  IEC standards are being developed and are in Draft Form in Technical document IEC TC 62600-300 Marine energy – Wave, tidal and other water current converters – Part 300: Electricity producing river energy converters – Power performance Assessment.

  GKinetic are supporting the development of the standards by serving as a member of the IEC industry advisory Ad Hoc Group. Working with the IEC will enable the regulatory process for tidal turbines.

- **Limitations/ scope of improvement to be worked upon in product development**

- **Policy and Regulatory support under European Union (EU) for development/ deployment of such technology and and expectations from Government of India and the Indian market**

GKINETICENERGYLTD

Thank You.
Discussion.

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APPENDIX - III

Presentation by **M/s Maclec Pvt. Ltd., Delhi** held on 14/09/2021 for specific discussion on Technology Readiness Level (TRL) of their product

SHK TURBINE

TECHNOLOGY DEVELOPMENT JOURNEY
2013-2021





BY

MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.

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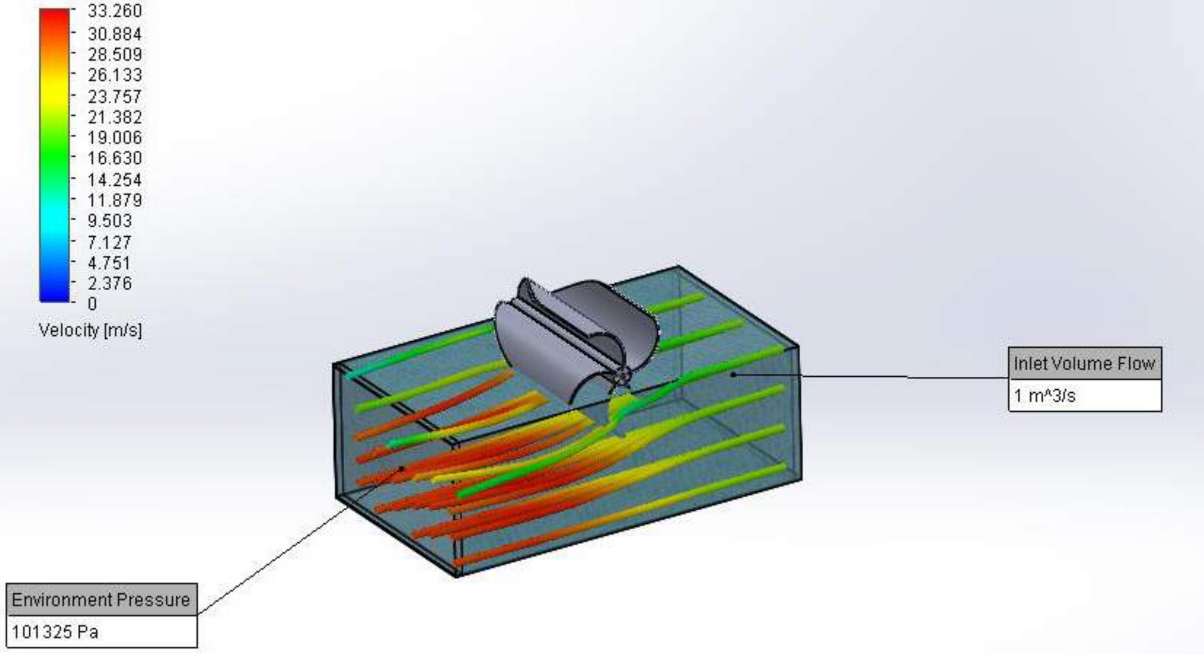
+918285948337 , +918920400909

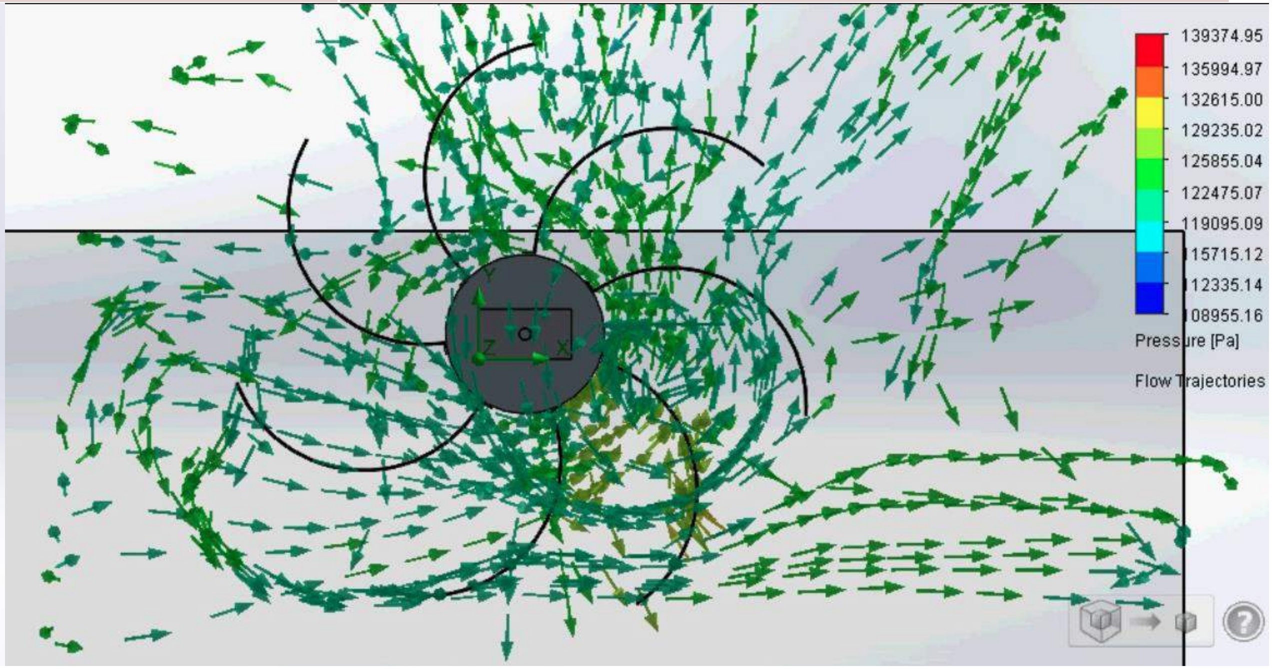
PRESENTATION OUTLINE

1.	DESIGN CAPABILITY:
	(A) Initiation of Idea
	(B) Idea validation
	(C) Prototype Testing
	(D) Determination of Ideal Site Parameters
	(E) Detailed Design Engineering & Technology Development
2.	TURBINE TESTING PROCEDURE, TEST DURATION AND RESULTS
	(I) Product Development & Standardization
	(II) Product testing and Result Validation
3.	THE INDIAN/INTERNATIONAL STANDARDS USED
4.	CONFORMANCE TO THE AVAILABLE OPERATIONAL REGULATIONS IN TERMS OF GRID CONNECTIVITY
5.	CLARIFICATIONS

1. DESIGN CAPABILITY

TESTS	DURATION	OUTCOME	STANDARDS/GUIDELINES USED
CFD ANALYSIS USING (ANSYS FLUENT , SOLIDWORKS DYNAMICS & CATIA)	2014-2019	SCALABILITY TEST, STRESS & STRAIN ANALYSIS, EFFECIENCY ANALYSIS, MATERIAL TESTING, WORKING LIFE	**IEC TS 62600-300:2020** (Part 300: Electricity producing river energy converters - Power performance assessment) & METHODOLOGY FROM HRED IIT ROORKEE





1. DESIGN CAPABILITY

A. INITIATION OF IDEA (2013)

Motivation Behind- Develop Indigenous Technology to harness inexhaustible – untapped Hydrokinetic Potential of India at lowest possible cost and with no harm to environment

SHORTCOMMINGS IDENTIFIED IN EXISTING HYDROKINETIC TURBINES –

A. REQUIRED SIE ARAMETERS ARE LIMITING THE SCOPE OF HYDROKINETICS (VELOCITY > 2.5M/SEC, DEPTH > 2M, WIDTH > 3 M)

B. CAPITAL COST & O&M COST IS TOO HIGH

C. EFFECIENCY IS TOO LOW

D. NO INDIGENOUS TECHNOLOGY IS AVAILABLE

E. EXISTING TECHNOLOGIES ARE COMPLEX, IMPORTED AND CANNOT BE CUSTOMIZED AS PER SITE PARAMETERS.

INITIATION OF IDEA & HYPOTHESIS

A. PARTIAL SUBMERGENCE OF MULTI ROTOR CROSS FLOW TURBINE CAN INHANCE THE EFFECIENCY & CUSTOMIZABILITY OF HYDROKINETIC TURBINE

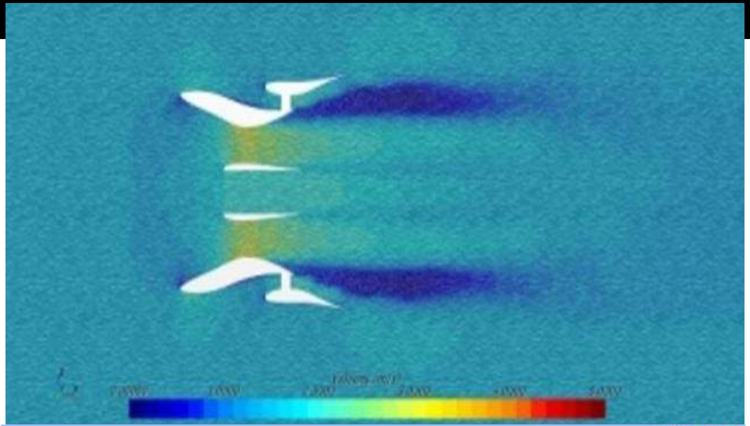
FIRST FIELD TEST	MARCH - 2013
SITE	UPPER GANGA CANAL (MURADNAGAR)
TURBINE PARAMETERS	PARTIALLY SUBMERGED MULTI ROTOR CROSS FLOW
TEST PARAMETERS	VELOCITY V/S ELECTRICAL OUTPUT
TEST DURATION	72 HOURS PERFORMANCE TESTING IN 18 DAYS
TEST OUTCOME	INITIATION OF IDEA

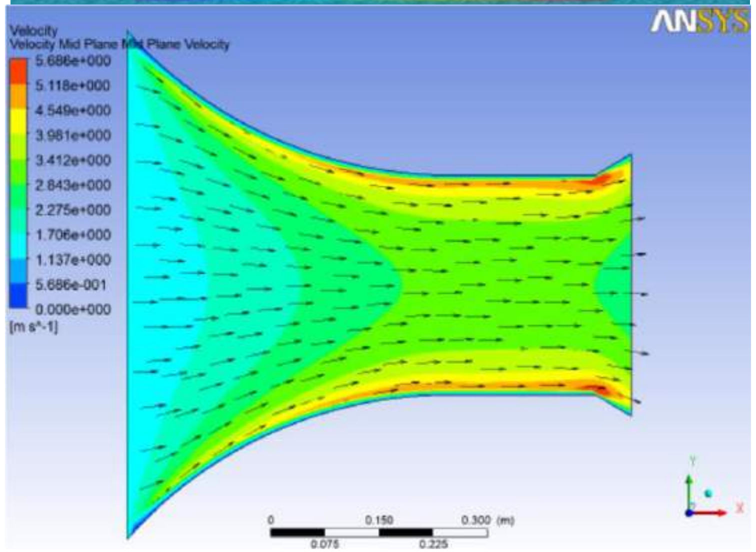
B. IDEA VALIDATION

Method – HRED IIT Roorkee
Place – Field Trials & In House Lab

(I) DESIGN VALIDATION

TOOL - SOLIDWORKS & ANSYS
PROCESS – DESIGN IMPROVISION IN BLADE PROFILE, MODULAR STRUCTURE
DURATION – MAY 2013 - SEP 2014





(II) PERFORMANCE TESTING

TOOL – CNC SHEET METAL FABRICATION
PROCESS –FIELD TESTING OF PROTOTYPE IN DIFFERENT SITE PARAMETERS
DURATION – AUG 2014 – FEB. 2015
OUTCOME – IMPROVISATION IN DESIGN

(III) PERFORMANCE VALIDATION

TOOL – HYDROKINETIC CALCULATIONS (HRED- IITR, CHTTC CANADA, AHERC US)
PROCESS – VALIDATION OF TEST RESULTS USING CFD & HYDROKINETIC CALCULATIONS
DURATION – OCT 2014 – MAY. 2015
OUTCOME – MODEL MATHEMATICAL CALCULATIONS FOR PROTOTYPING

C. PROTOTYPE TESTING

TEST PARAMETERS

VELOCITY V/S MECHANICAL POWER

MECHANICAL POWER TRANSMISSION

ELECTRICITY OUTPUT

INITIAL DESIGNS VALIDATION OF
=> TURBINE BLADE PROFILE,
=> FLOATING ARRANGEMENT,
=> ANCHORING ARRANGEMENT,
=> GEARBOX,
=> GENERATOR,
=> POWER STABILIZATION CIRCUITRY,
=> INITIAL POWER TRANSMISSION SYSTEM

PERFORMANCE OF MATERIAL USED

PARAMETERS -
(i). Power (W)
(ii). Velocity of fluid (V)
(iii). Rotational speed (ω)
(iv). Pressure change across blades (ΔP)
(v). Gravitational acceleration (g)
(vi). Density of fluid (ρ)
(vii). Viscosity of fluid (μ) and
(viii). Characteristic length of Blade(wetted depth)

SITES	DURATION	SCHEDULE	OUTCOME
RAMGANGA RIVER TAIL RACE OF KALAGARH DAM	MAY 2015 – DEC 2016	TESTING OF PROTOTYPES SIZING 100 W TO 1 KW	PERFORMANCE VALIDATION OF TURBINE, GEARBOX, GENERATOR, POWER SYSTEMS
HYDROKINETIC TEST CANAL, HRED IITR	JUNE 2017 – DEC 2017	TESTING OF DIFFERENT MODULES UNDER CONTROLLED CONDITION	DATA VALIDATION FOR SCALE UP R&D
DOWNSTREAM OF CHILLA SHP	FEB 2018 TO APRIL 2018	TESTING OF MODULAR PERFORMANCE	DATA VALIDATION FOR SCALE UP
HYDROKINETIC TEST CANAL, MACLEC DELHI	JUNE 2018 TO SEP 2018	TESTING OF IMPROVSED BLADE PROFILE	VALIDATION OF SCALE-UP TURBINE MODULE DESIGN

Method – HRED IIT Roorkee
Place – Field Trials, In House Lab & HRED IITR Test Labs
Qualifying Standards - IEC TS 62600-300:2020
(Part 300: Electricity producing river energy converters - Power performance assessment)

PROTOTYPE TESTING @ RAMGANGA RIVER
TAIL RACE CANAL OF KALAGARH DAM

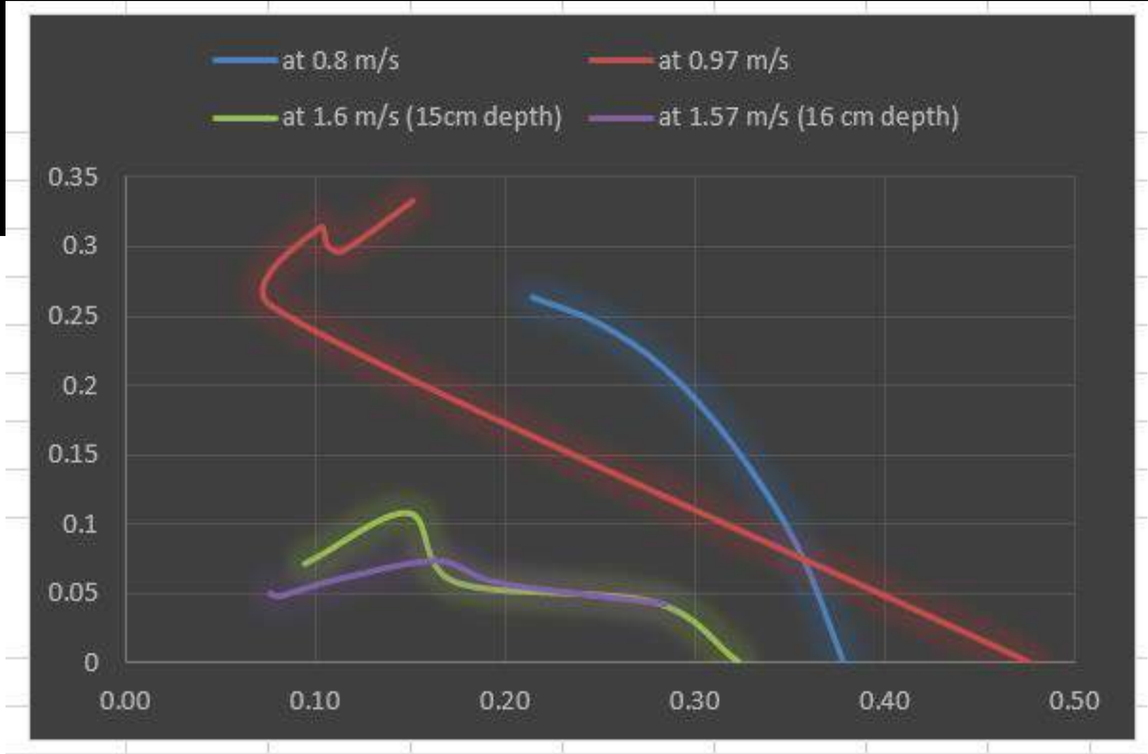
LAB TESTING @ HRED IITR

LAB TESTING @ MACLEC LAB DELHI

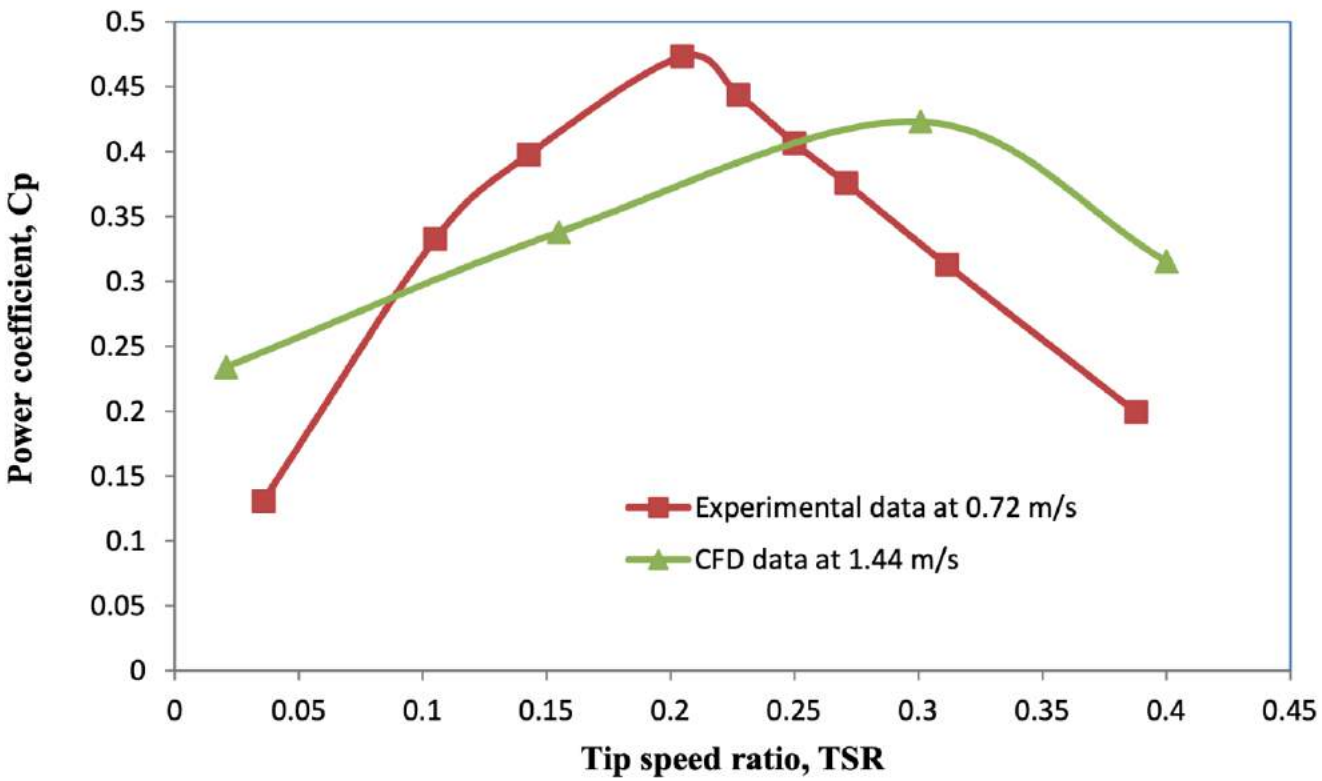
FIELD TEST @ RAMGANGA RIVER

FIELD TEST @ GURGAON CANAL

C. PROTOTYPE TESTING: RESULTS -



Cp Curve at Various Velocities



CFD V/S FIELD RESULT VALIDATION

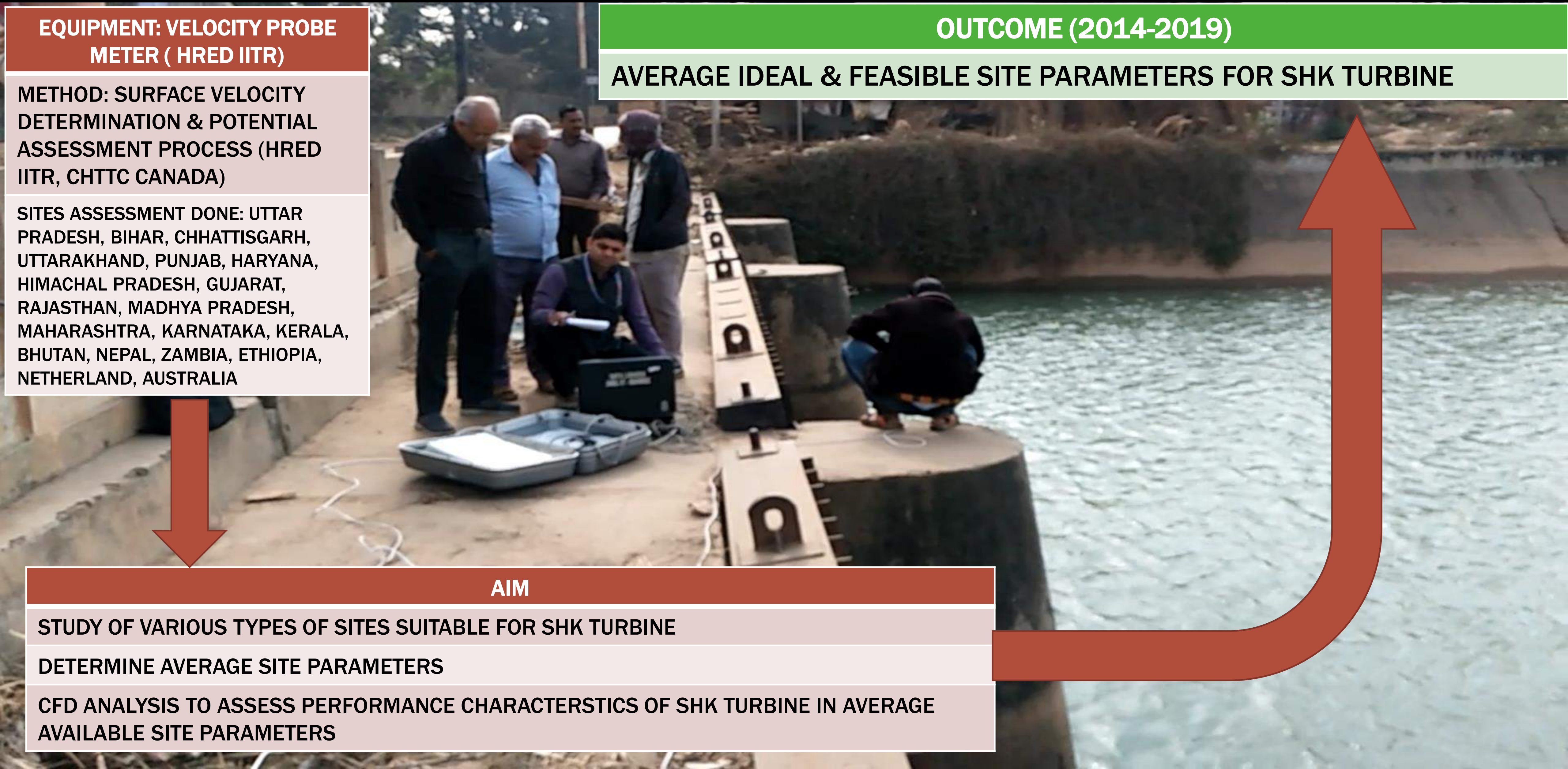
Method – HRED IIT Roorkee

Place – Field Trials, In House Lab & HRED IITR Test Labs

Standards - IEC TS 62600-300:2020

(Part 300: Electricity producing river energy converters - Power performance assessment)

D. DETERMINATION OF IDEAL SITE PARAMETERS



EQUIPMENT: VELOCITY PROBE METER (HRED IITR)

METHOD: SURFACE VELOCITY DETERMINATION & POTENTIAL ASSESSMENT PROCESS (HRED IITR, CHTTC CANADA)

SITES ASSESSMENT DONE: UTTAR PRADESH, BIHAR, CHHATTISGARH, UTTARAKHAND, PUNJAB, HARYANA, HIMACHAL PRADESH, GUJARAT, RAJASTHAN, MADHYA PRADESH, MAHARASHTRA, KARNATAKA, KERALA, BHUTAN, NEPAL, ZAMBIA, ETHIOPIA, NETHERLAND, AUSTRALIA

AIM

- STUDY OF VARIOUS TYPES OF SITES SUITABLE FOR SHK TURBINE
- DETERMINE AVERAGE SITE PARAMETERS
- CFD ANALYSIS TO ASSESS PERFORMANCE CHARACTERSTICS OF SHK TURBINE IN AVERAGE AVAILABLE SITE PARAMETERS

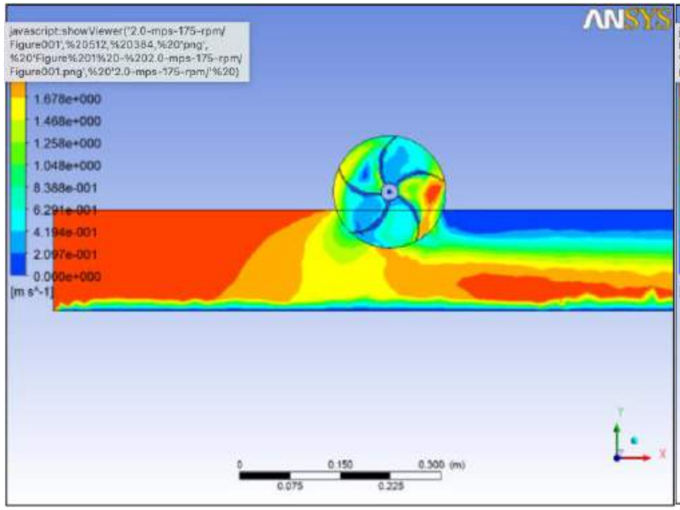
OUTCOME (2014-2019)

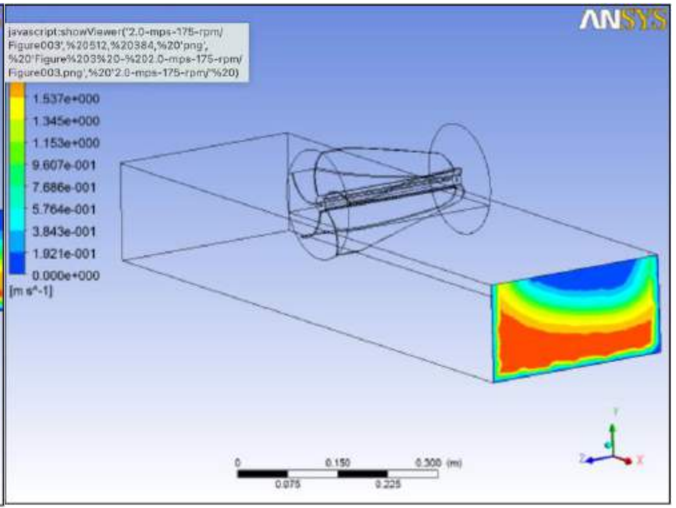
AVERAGE IDEAL & FEASIBLE SITE PARAMETERS FOR SHK TURBINE

COMMON SITE PARAMETERS AVAILABLE AT MOST SITES

TESTS	DURATION	OUTCOME	STANDARDS/GUIDELINES USED
VELOCITY V/S POWER EFFECIENCY TESTING	2013-2018	EFFECIENCY TESTING AT IDENTIFIED COMMON AND MOST AVAILABLE SITE PARAMETERS	**IEC TS 62600-300:2020** (Part 300: Electricity producing river energy converters - Power performance assessment) & METHODOLOGY FROM HRED IIT ROORKEE

SITES	CANALS, RIVERS, HILLY STREAMS, ETC.
VELOCITY RANGE	0.5 – 2 M/SEC
DEPTH RANGE	0.15 – 10 M
WIDTH	1 – 35 M
WATER QUALITY	SILT, FLOATING DEBRIS, ETC.



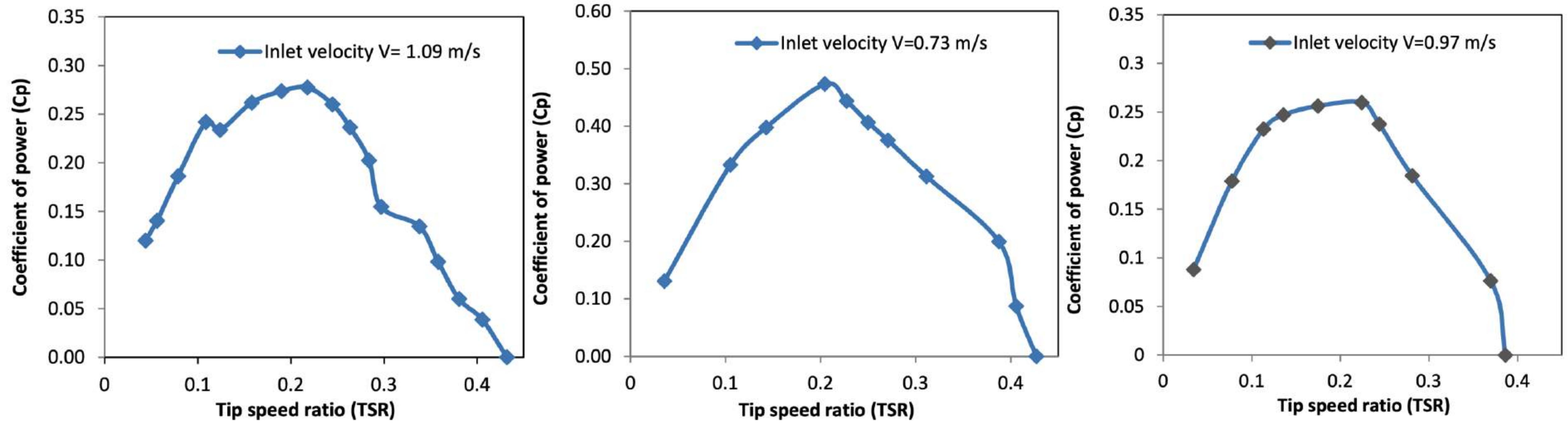


AFTER SERIES OF FIELD TRIALS, LAB TESTS, CFD VALIDATION, IMPROVISED PROTOTYPE TEST, PERFORMANCE MONITORING FROM 2013 TO 2018 WE FINALIZED –

(I) COMMON SITE PARAMETERS
(II) BLADE PROFILE
(III) OUTPUT VOLTAGE RANGE
(IV) POWER OUTPUT VARIATION WRT SITE PARAMETERS

FROM OCT 2018 ONWARDS WE STARTED PRODUCT DEVELOPMENT

D. DETERMINATION OF IDEAL SITE PARAMETERS: RESULTS -

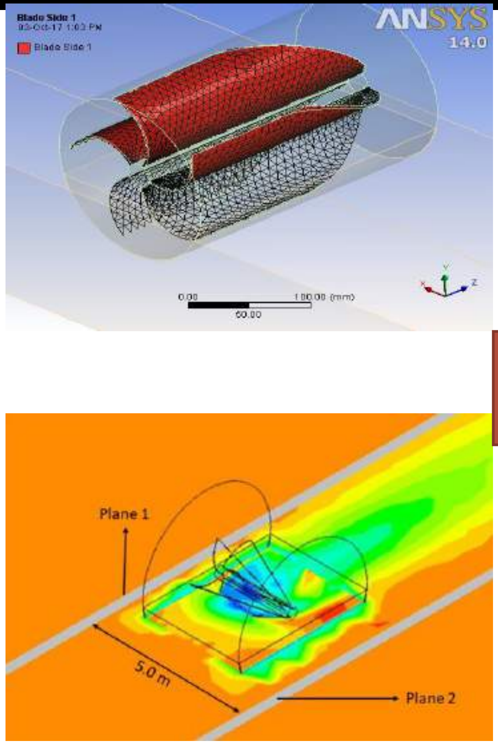


DETERMINATION OF IDEAL SITE PARAMETERS
Method – HRED IIT Roorkee
Place – Field Trials, In House Lab & HRED IITR Test Labs
Standards - IEC TS 62600-300:2020
(Part 300: Electricity producing river energy converters - Power performance assessment)

SHK TURBINE BLADE PROFILE IS EFFICIENT IN ALL KIND OF VELOCITY & SITE PARAMETERS

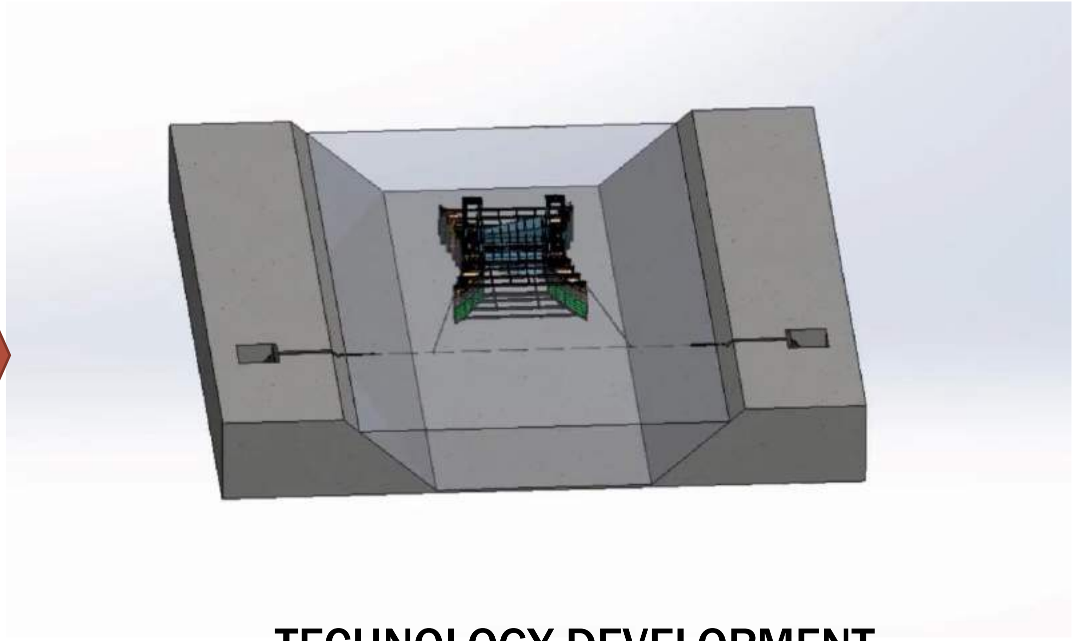
E. DETAILED DESIGN ENGINEERING & TECHNOLOGY DEVELOPMENT

DETAILED DESIGN ENGINEERING TOOLS - SOLIDWORKS, ANSYS, CATIA
METHODOLOGY – DESIGNING OF FINAL MODULE AS PER THE PERFORMANCE DATA , CFD, LAB TESTS, FIELD TRIALS, PROTOTYPE TEST, SCALE-UP TEST



CFD VALIDATION

DESIGNING & TESTING OF INDIGENOUS POWER ELECTRONICS



TECHNOLOGY DEVELOPMENT

2. TURBINE TESTING PROCEDURE, TEST DURATION AND RESULTS

TURBINE TEST PROCEDURE	TES DURATION	RESULT	STANDARDS USED
IDEA VALIDATION VIA FIELD TRIALS & METHAMATICAL MODELLING	2013 TO 2015	PERFORMANCE TESTING FOR IMPROVISATION	HRED IITR, CHTTC CANADA, PUBLICATIONS
PROTOTYPE TESTING	2015 – 2018	DESIGN & TESTING OF COMPLETE SHK TURBINE ASSEMBLY	HRED IITR, CHTTC CANADA, PUBLICATIONS
DETAILED DESIGN ENGINEERING	2018 – 2019	DESIGN OF FINAL ASSEMBLY (TURBINE-GEARBOX-GENERATOR-POWER CONDITIONING SYSTEM)	HRED IITR, CHTTC CANADA, PUBLICATIONS, CERC GUIDELINES, STATE ERC GUIDELINES

TEST, TRIALS, VALIDATION, UPGRADE, FIELD TRIALS

2013 - 2019


MACLEC TECHNICAL PROJECT LABORATORY PVT. LTD.
VARUN -III & I
Art + Science
- MACLEC

I. PRODUCT DEVELOPMENT & STANDARDIZATION

INDIGENOUS MFG PROCESS

- CNC FABRICATION
- MATERIAL SELECTION
- QAP DEVELOPMENT
- MFG PROCESS DEVELOPMENT

100% IN HOUSE R&D

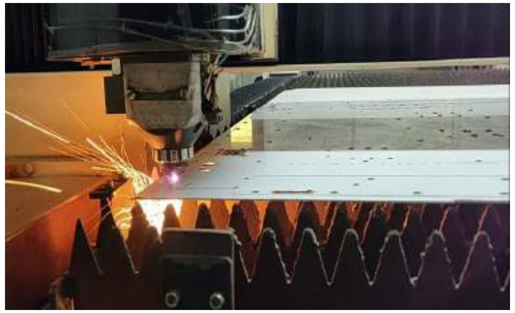
- INDIGENOUS DESIGN OF GEARBOX & GENERATOR
- PERFORMANCE TESTING
- EFFICIENCY TESTING

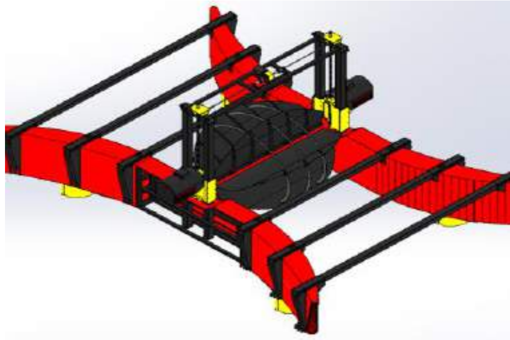
INDIGINIZATION OF COMPLETE PRODUCT

- SELECTION OF EXISTING POWER CONDITIONING SYSTEMS & CUSTOMIZATION
- PERFORMANCE VALIDATION

INDIGINIZATION OF COMPLETE PRODUCT

- FIELD TESTING OF ENTIRE ASSEMBLY IN (I) FLOATING (II) FIXED TYPE SHK TURBINE





II. PRODUCT TESTING & RESULT VALIDATION

TESTING OF MODULAR EFFECENCY
& REPLICABILITY DONE –
IN HOUSE LAB & FIELD TRIAL

TESTING OF MECHANICAL
PERFORMANCE & ANCHORING
STRUCTURE DONE
AT PUGC

FINAL PRODUCT TESTING
2020 ONWARDS
POWER CONVERSION TEST DONE
POWER CONDITIONIG CIRCUIT TESTING DONE
POWER TRANSMISSION & GRID FEED IN SYSTEM TEST DONE
STATUS – COMMISSIONING IN PROCESS

II. PRODUCT TESTING & RESULT VALIDATION

TESTING OF MODULAR EFFECENCY & REPLICABILITY DONE – IN HOUSE LAB & FIELD TRIAL

TESTING OF MECHANICAL PERFORMANCE & ANCHORING STRUCTURE DONE AT PUGC

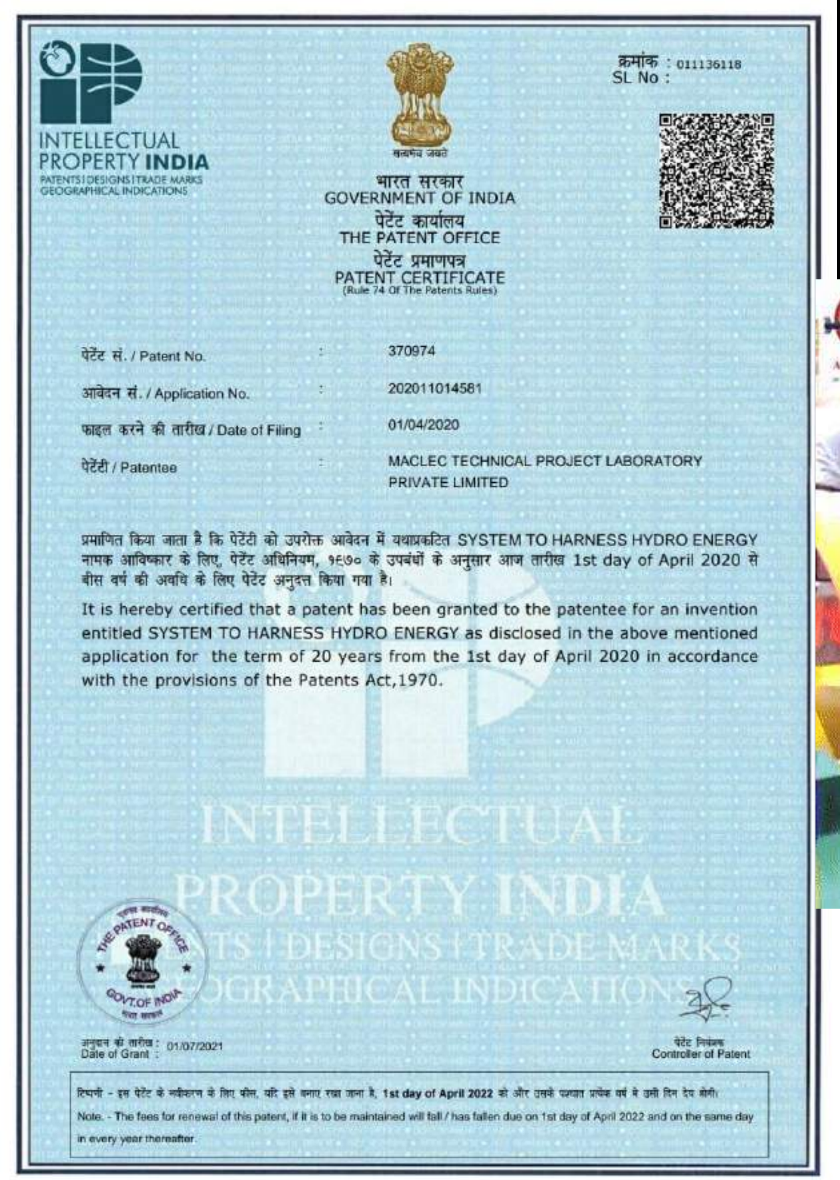
FINAL PRODUCT TESTING
2020 ONWARDS
POWER CONVERSION TEST DONE
POWER CONDITIONIG CIRCUIT TESTING DONE
POWER TRANSMISSION & GRID FEED IN SYSTEM TEST DONE
STATUS – COMMISSIONING IN PROCESS

• PRESENT STATUS OF SHK TURBINE

S/NO.	SHK TURBINE	STATUS
1.	TURBINE DESIGN CAPABILITY	CAN BE SCALED UP & CUSTOMIZED AS PER SITE PARAMETERS
2.	MODULAR LIFE	UP TO 40 YEARS
3.	O&M PLAN	REGULAR O&M IN EVERY 6 MONTHS & SCHEDULED MAINTENANCE IN EVERY 3 YEARS
4.	MAJOR TECHNICAL TRANSFORMATION REQUIRED	ONLY IN ELECTRICAL PARTS IN 10-15 YEARS (AS PER NEXT GENERATION OF ELECTRICAL/ELECTRONICS)
5.	ROBUSTNESS OF MAJOR RUNNING PARTS	TURBINE ROTOR, GEARBOX AND GENERATOR ARE DESIGNED INDIGENOUS AND TESTED IN FIELD, IN-HOUSE LAB. READY TO INSTALL
6.	POWER ELECTRONICS	DESIGN COMPLETED; FIELD TESTING & IN HOUSE LAB TESTING DONE,
7.	ANCHORING & MOORING STR.	DESIGN SCALABILITY TESTED, FIELD TESTED, LAB TESTED

REQUIRED: OPPORTUNITY TO INSTALL PILOTS IN FIELD TO TEST THE PERFORMANCE FOR LONGER DURATION AS PER IEC 62600-300

PATENTED TECHNOLOGIES



INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

क्रमांक : 011136118
SL No :

भारत सरकार
GOVERNMENT OF INDIA
पेटेंट कार्यालय
THE PATENT OFFICE
पेटेंट प्रमाणपत्र
PATENT CERTIFICATE
(Rule 74 Of The Patents Rules)

पेटेंट सं. / Patent No.	:	370974
आवेदन सं. / Application No.	:	202011014581
फाइल करने की तारीख / Date of Filing	:	01/04/2020
पेटेंटी / Patentee	:	MACLEC TECHNICAL PROJECT LABORATORY PRIVATE LIMITED

प्रमाणित किया जाता है कि पेटेंटी को उपरोक्त आवेदन में यथाप्रकटित SYSTEM TO HARNESS HYDRO ENERGY नामक आविष्कार के लिए, पेटेंट अधिनियम, १९७० के उपबंधों के अनुसार आज तारीख 1st day of April 2020 से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled SYSTEM TO HARNESS HYDRO ENERGY as disclosed in the above mentioned application for the term of 20 years from the 1st day of April 2020 in accordance with the provisions of the Patents Act,1970.

अनुदान की तारीख : 01/07/2021
Date of Grant :

पेटेंट नियंत्रक
Controller of Patent

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, **1st day of April 2022** को और उसके पश्चात प्रत्येक वर्ष में उसी दिन देय होगी।
Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 1st day of April 2022 and on the same day in every year thereafter.

SURFACE HYDROKINETIC TURBINE

A Floating Hydro Power Generation System

3. THE INDIAN STANDARDS USED IN SHK MODULE

MECHANICAL STANDARDS OF SHK TURBINE	
Length x Width x Height x Swept Area (L x W x H x S) mm	As per technology and Module design
Anchoring cable thickness (A) – mm	As per Drag force x 2
Mooring cable thickness (A) – mm	As per Drag force x 2
Overall Gross Weight of Module (kg)	As per technology and Module design
Minimum Generation of per Module (Units)/arrangement	3500 Units/KW/Annum
Preferred Hydrokinetic Turbine Technology type	Cross Flow, Radial Flux, Floating type Hydrokinetic Turbine Technology
Generator Type	PMG,/Excitation type Field Generator with 95% efficiency, operating temp. range 0 – 95 degree centigrade
Gearbox	Oil emersed, IP 65, with 97 % efficiency, operating temp. range 0 – 95 degree centigrade
Turbine Blades	Hydrofoil blade profile with minimum 40% cp
Floating arrangement	Capable to float with entire turbine assembly with automated submergence level managing capability
Power Evacuation Arrangement Junction Box (Protection degree/ Material)	IP 67 rated / Weatherproof PPO enclosure with
Connector	MC4 compatible or MC4, IP67 rated
Cable	4sqmm cross section
Fire safety class	C
Safety application class	A
Safety class	II

Ambient Characteristics of SHK Turbine	
Temperature coefficient of Current (I_{sc}), α (% / °C)	0.0681
Temperature coefficient of Voltage (V_{oc}), β (% / °C)	-0.2941
Temperature coefficient of Power (P_m), γ (% / °C)	-0.3845
NOCT (°C)	46 ± 2
Operating temperature range (°C)	-10 to 85
Operating Velocity range (meter/second)	0.5 – 7 m/sec
Operating minimum water depth	0.5 meters
Operating water quality	Silt (up to 30000 ppm), floating debris (up to 200 mm), sand, boulders (up to 300 mm)
Environment Impact	Should be no environment impact, no impact on fish and aquatic wildlife

Technical Specifications of Power System of SHK Turbine

Sl.No	Items	Range
1.	Substation Output Rating	60 KVA – 600 KVA
2.	MPPT Voltage Range	90V to 900V
3.	AC Output with 50Hz frequency	415V/11 kV/33kV/132 kV 3 phase AC
4.	Integrated MPPT Input Regulator	As per design KVA
5.	Minimum Efficiency above 30% input power	Above 90%
6.	Accuracy of AC voltage control	+ / - 1%
7.	Accuracy of frequency control	+ / - 0.5%
8.	Grid frequency Synchronization range	+ / - 3 Hz
9.	Maximum Input DC Voltage	Based on make, should follow standard
10.	Ambient temperature considered	50 degree C
11.	Humidity	95% Non-condensing
12.	Protection of Enclosure	IP – 65 (Minimum) for outdoor
13.	Grid Frequency Tolerance range	+ / - 3%
14.	Grid Voltage tolerance	- 20% & + 15%
15.	No-load losses	Less than 1% of rated power
16.	THD	<3%
17.	Type of Loads	all types of loads, resistive, inductive, complex and non-linear
18.	Cooling	Fan Forced
19.	Protections	Output peak overload, short circuit, phase imbalance, over voltage, under voltage of the grid, Surge protections (input and output SPD)
20.	Control type	Voltage source, microprocessor assisted output regulation
21.	Certificatios	IEC 600068-1,2,14and 30 or equivalent – Environment IEC 61000-3-15 EMC IEC 61683-Efficiency requirements as Specified above
22.	SURGE PROTECTION	as per IEC 60364-5-53 & NFEN 50539-11
23.	LAYING OF CABLES	XLPE insulated unarmored / armored with copper / aluminum conductor conforming to IS 7098/part 1/1988
24.	Other standards	VDE 0126- 1-1, IEC 60255.5 / IEC 60255.27 / IEC 621 , IEC 62109-1, IEC 62109- , Efficiency Measurements as per IEC 61683 / IS 61683 and Environmental Testing as per IEC 60068-2 (1, 2, 14, 30) /Equivalent BIS Std .

3.1. THE INTERNATIONAL STANDARDS USED IN SHK MODULE

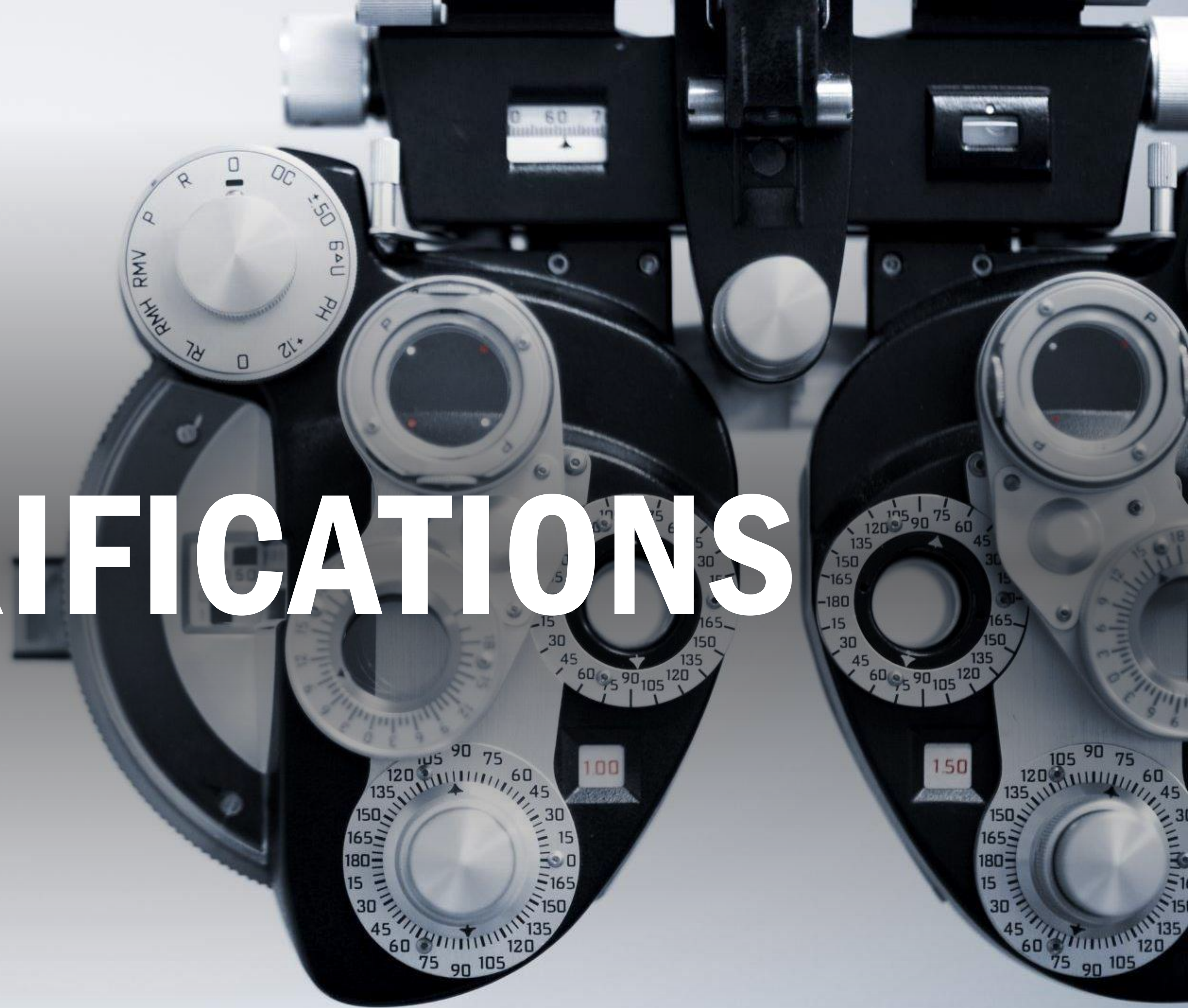
Fact Check
SHK Turbine Journey Started – 2013
The International Electrotechnical Commission was also developing their Standards in 2013 & Publish in Latest 2020 in IEC 62600 for – Wave, tidal and other water current converters
IEC 62600-100 – is for Wave Energy Converters
IEC 62600-200 is for Tidal Energy Converters
IEC 62600-300 is for River current Energy Converters (Ex. SHK Turbine)
IEC TC114 Technical Specification for mechanical load measurements for Marine Energy Converters Published in 2019 but we started Mechanical Load Testing in 2014 onwards
Presently We are qualifying the IEC Standards IEC 62600-300

Fig. 1. Overview of the standards that are being developed within TC114. The numbers indicate the 62600 standard.

4. CONFORMANCE TO THE AVAILABLE OPERATIONAL REGULATIONS IN TERMS OF GRID CONNECTIVITY

Conformation
1. All Power Electronics of SHK Turbine is selected from available and presently running technologies related to Solar, Wind, Micro Hydro and Biogas based power stations
2. Only minute customization has been done to make them compatible for SHK Turbine power evacuation and grid feed-in
3. All power electronics are confirming Latest **Indian Electricity Grid Code by Central Electricity Regulatory Commission**
4. Standard SHK Plant Monitoring & Control System for Individual Module as well as entire plant has been developed indigenously and patented by MTPL.

CLARIFICATIONS

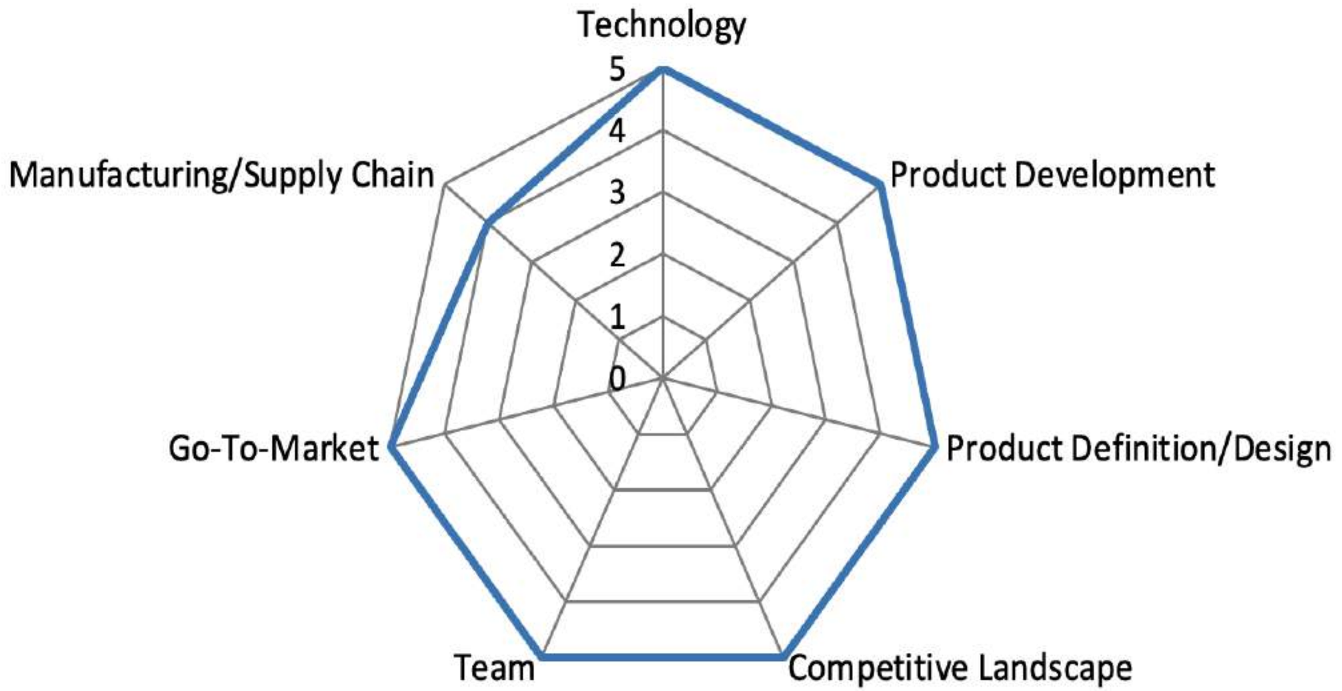


Technology & Commercialization Readiness Level Calculator

Profile

Company/Organization Name:	MACLEC
Proposal Title:	SHK TURBINE
Product/Innovation Description:	Indigenus Modular Turbine to harness base load cost competitive Hydrokinetic Energy from any kind of running stream.

Technology Readiness Level:	**9**
Commercialization Readiness Level:	**8**



European Commission

Horizon 2020
European Union funding
for Research & Innovation

CLARIFICATION OF TRL

Mission Innovation's NCI – Accelerating innovation and disruptive low and zero carbon solutions –Assessment 2020
www.misolutionframework.net

G. Technology readiness levels (TRL)

Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – SYSTEM COMPLETE AND QUALIFIED
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union

Swedish Energy Agency

ENVIRONMENT IMPACT ASSESSMENT DONE BY INTERNATIONAL ORGANIZATIONS

MISSION INNOVATION | NET-ZERO COMPATIBLE INNOVATIONS INITIATIVE

SHK Turbines by

Maclec Technical Project Laboratory PVT LTD

Avoided Emissions Framework – Level 1 beta assessment

100+ $MtCO_2e$/year in 2030

Assessment conducted: 2020

eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union

Swedish Energy Agency

WWF Climate Solver Hub INDIA

CLIMATE SOLVER 2018 AWARDEE

GHG REDUCTION: Surface Water Velocity Driven Hydrokinetic Turbine

Developed by: Maclec Technical Project Laboratory Private Limited

GHG emissions up to 2 million tonnes by 2028

No Impact to
Aquatic Life, Wildlife & Environment

11.1 THEORETICAL HK RE POTENTIAL OF INDIA

S/NO	STATES	SITE TYPE	APPROX. LENGTH (KMS)	APPROXIMATE POTENTIAL (MW)
1.	Uttar Pradesh,	Major Canal Networks & Rivers	9692	16076
2.	Punjab	Major Canal Networks	3606	6882
3.	Haryana	Major Canal Networks	2182	4380
4.	Bihar & Jharkhand	Major Canal Networks & Rivers	4632	10182
5.	Gujarat	Major Canal Networks & Rivers	3832	8217
2.	Maharashtra	Major Canal Networks & Rivers	1826	3219
3.	Karnataka	Major Canal &River Networks	1182	2820
4.	Madhya Pradesh	Major Canal & River Streams	1160	1988
5.	Andhra Pradesh & Telangana	Major Canal & River Streams	3896	6828
6.	Chhattisgarh & Odisha	Major Canal & River Streams	2310	3388
7.	NER , J&K & Ladakh UT	Canals & Hilly Streams	6960	12276
8.	Rest of India	Canals, Rivers and Streams	6682	10309
9.	NHPC & Other Existing HPP	Power Canals, Upstream & Downstream	1761	5636
	Grand Total		49721 Kms	92201 MW (92.2 GW)

THIS INCLUDES ONLY –

(I) SOME MAIN IRRIGATION CANALS

(II) MAJOR RIVERS

(III) D/S OF MAJOR HPPS ONLY

TO ASSESS COMPLETE THEORETICAL POTENTIAL FOLLOWING SITES NEED TO BE INCLUDED –

(I) ALL RIVERS (> 6 MONTH FLOWING)

(II) ALL CANALS (> 6 MONTH FLOWING)

(III) WASTEWATER DRAINS & STPS

(IV) BACKWATER CHANNELS

(V) COOLING & OTHER CHANNELS

'NHPC & OTHER EXITING HPP' includes the available theoretical Hydrokinetic potential at upstream & downstream (Canals, natural river streams, etc.) of all existing Large & Small Hydro Power Plants under NHPC, other PSUs and Private Installers in India.

CLARIFICATION:
THEORATICAL HYDROKINETIC POTENTIAL OF INDIA

SOURCES

U.S. DEPARTMENT OF ENERGY

CHTTC Canadian Hydrokinetic Turbine Test Centre

AHERC Alaska Hydrokinetic Energy Research Center

HORIZON 2020

Springer

Agency	Country	Theoretical Potential
US DoE (2004-06)	USA	identified 98,700 MW
Marine Renewables Canada	Canada	River Current Potential - Canada's river resource is staggering: 340 gigawatts
The theoretical global riverine resource	UK	**58400±109 TWh/Year which is 13333 GW in total and 10 % is recoverable – 1333 GW**
The theoretical global riverine resource	UK	**2200 TWh (502283.1 MW @ 50% PLF)**

Global Facts
The first grid-connected river in-stream project in the United States was operated briefly in August 2008 at Ruby Alaska on the Yukon River
The recoverable potential to provide electricity from hydrokinetic energy resources is estimated to be about 10% of today's electric consumption in the United States
In Pakistan (a water stressed country) the small-scale system potential was investigated and in a single region more than 290 micro hydro run-of-river schemes (of around 3-50 kW capacity) have been installed, accumulating to the capacity of around 3.5 MW

Thank You

MACLEC TECHNICAL PROJECT LABORATORY (P) LTD.
Address: A1/153, Safdarjung Enclave, New Delhi- 110029
www.maclec.com. contact@maclec.com. +918285948337

APPENDIX - IV

Presentation by **M/s Imp Powers, Mumbai** (an Indian Partner of **M/s Smart Hydro Power, Germany** having exclusive rights for India) held on 16/09/2021 on their technology/ product having more than 50% indigenous content

IMP Powers

Introduces

“SMART HYDRO KINETIC SOLUTIONS”

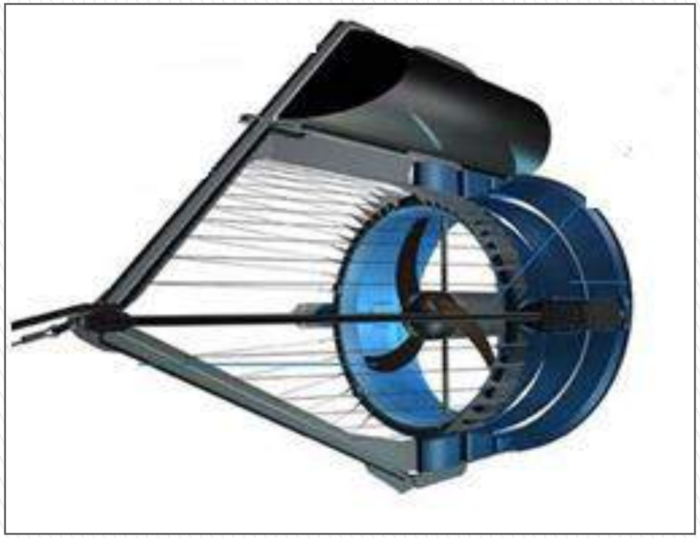
A Revolutionary Technology

IMP-SHP Collaboration

IMP in ***2018*** entered into exclusive ***'licensing agreement***' with ***Smart Hydro Power(SHP), Germany for manufacturing Smart Kinetic Turbines for setting Micro Hydro Projects in India thereby becoming the FIRST company in India to start a REVOLUTIONARY TECHNOLOGY in the RENEWABLE ENERGY sector .***

What are Smart Kinetic Turbine?

- These Smart Turbines are also known as **“In stream/Zero Head turbines”** as it harnesses energy from flowing water in rivers, canals, and other man-made water bodies.
- Offers Predictable, weather independent, **base load** power generation.
- Negligible T & D losses due to generation near load centers.
- Portable and Easy installation; possible even in running water.
- Floating and on-bed models available according to application



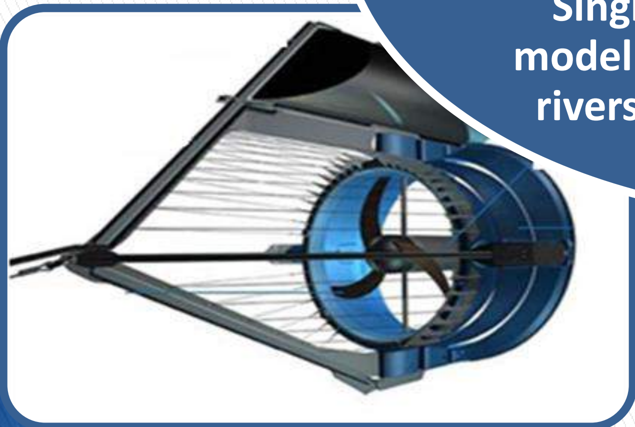
IMP Series of "Smart Hydro Kinetic Turbines"

Robust Structure fit for lower Depths

Diffusers help to achieve Max o/p at 2.8m/s

Single float model for deep rivers, canals

Dual float model for lesser depth



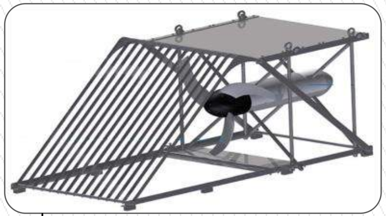
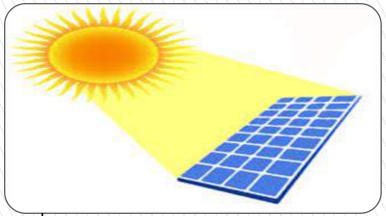
Detailed Specifications of Free-stream Turbine

- **Output** : 250-5000 W
  @velocity 1.1-3.1 m/s
- **Dimensions** : Length-1100 mm
  Width-1100 mm
  Height-1100 mm
- **Rotor speed** : 90 – 230 rpm
- **Weight** : 300 kg
- **Rotor blades** : 3, Φ1000 mm

Detailed Specifications of Floating Turbine

- **Output** : 250-5000 W @velocity 1.1-2.8 m/s
- **Dimensions** : Length-3130 mm
  Width-1600 mm
  Height-2010 mm
- **Rotor speed** : 90 – 230 rpm
- **Weight** : 380 kg
- **Rotor blades** : 3, Φ1000 mm

Comparison with other Renewable energy sources

			
LAND REQUIREMENTS	Very meager space, running water	Huge Land app.500 sq.ft. for 5kW	Huge Land, No obstruction for 100-150 m.
GENERATION VARIATION	Base-load Supply	Peak load supply	Huge fluctuations in Wind
PLANT LOAD FACTOR	70-80 % PLF, can work 24x7	Maximum 20 %	40-50 %

Site Requirements

Particulars	Models WITHOUT Diffusers	
Sweep Diameters	1000 mm	1500 mm
Depth Requirement	1500 mm	2000 mm
Width Requirement	1200 mm	1800 mm
Velocity Requirement	2.8-3 m/sec	2-2.4 m/sec

Particulars	Models WITH Diffusers	
Sweep Diameters	1000 mm	1500 mm*
Depth Requirement	2000 mm	2300 mm
Width Requirement	2000 mm	2300 mm
Velocity Requirement	2.5-2.8 m/sec	2.3 m/sec

* Model under development

Areas of Application


Thermal Power Plants


Check Dams/ Diversion gates


Tailraces of all HPP


Cooling channels in industries


Sewage Treatment plant


Fast moving Irrigation Canals

PILOT PROJECT of 20kW(4x5kW) at Neyveli Lignite Corporation India Ltd.

- Project has the installed capacity of 4 x 5kW (20 KW) and has ***successfully commissioned*** the project under R&D initiative of NLCIL

- The project has been synchronised with 0.415kV, 50 Hz NLCIL grid in the month of **October, 2017.**

- **As of August 2021, 2.2 lakh units have been fed to the grid.**

Commissioning Certificate

Energy Management Centre

(State Designated Agency to enforce Energy Conservation Act 2001)
Department of Power, Government of Kerala

Sreekrishna Nagar, Sreekariyam P.O.
Thiruvananthapuram 695 017

Tel: 0471-2594922, 2594924 Fax: 0471-2594923
E-mail: emck@keralaenergy.gov.in
Website: www.keralaenergy.gov.in

15.02.2018

TO WHOMSOEVER IT MAY CONCERN

Certified that Energy Management Centre-Kerala had awarded the work of Implementation of 4X5 kW Hydrokinetic Energy Project on Stage 2 Cooling water Channel of TPS II - Thermal Power plant at NLCIL, Neyveli to M/s IMP Powers Ltd, 35/C, Popular Press Building, 2nd Floor, PT. M.M Malviya Road, Tardeo, Mumbai-34. They had successfully completed and commissioned the project on 12.10.2017. The work was carried out satisfactorily as per our requirement within time.

Director

G. ANIL
Jt. Director &
Head - Small Hydro Power Dn.
ENERGY MANAGEMENT CENTRE
Department of Power, Government of Kerala
Thiruvananthapuram-695 017
E-mail: anilg@keralaenergy.gov.in

Development activities by IMP

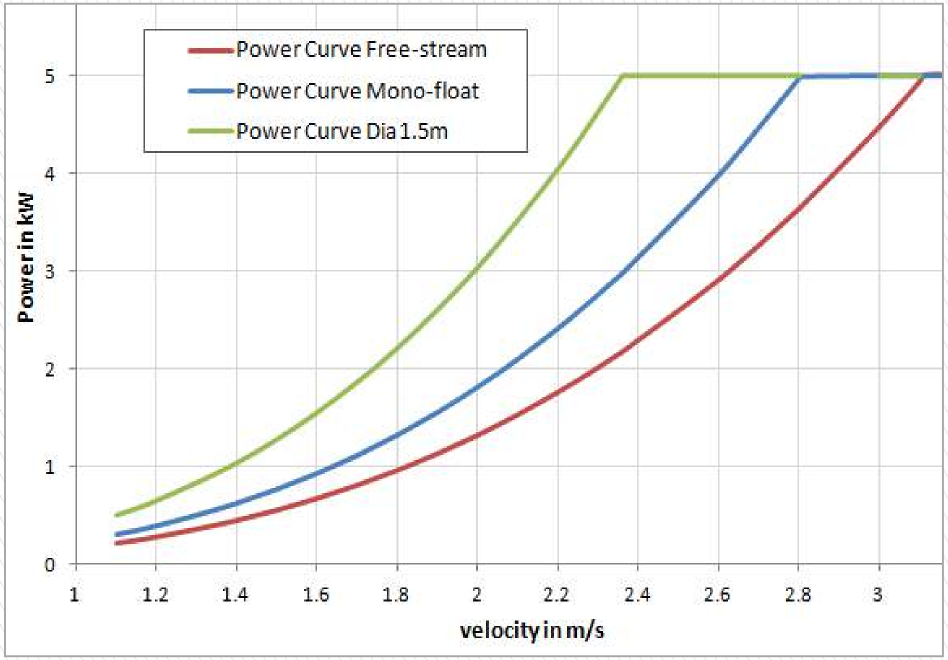
- Design and development of bigger diameter blades to extract power from low velocity water bodies

- Indianisation of most of the important parts of the turbine under MAKE IN INDIA initiative

$$P = 0.5\,\rho\,A\,v^3\,Cp\,\%E$$

- Implementation of array model of turbines and wake recovery study

- Study of constriction model for slow moving irrigation canals



Support from Government

- Need to reintroduce the Central Financial Assistance for pico/ micro hydro projects which has been lapsed 3 years back.

- Due to covid'19, we could not do site surveys & being the only company to commission 20 kW hydro-kinetic project in the country, we would need recognition to assist the promotion of this path-breaking technology.

- Need recognition of the technology under Make in India Scheme on CEA/Ministry of Power portal

- Most of the sites are at remote location, costs are incurred to survey, travel and measure data to work feasibility of sites. Please give WO to prepare state-wise DPR.

- Need duty exemption to import turbo-generators under Renewable Energy Equipments.

Projects under Execution/Finalization

- KSEB-5x5kW Kakkad Hydro-kinetic project: 25 kW project allotted under consultancy of Energy Management Centre, Kerala in the tailrace of 50 MW hydro-electric project of KSEB

- NLC India Ltd. 3x5kW floating hydrokinetic project: Repeat order under R&D in circulating water canals with floating hydro turbine in array

- KSEB - Participated in the EOI for potential survey of Kerala state and pilot installation of 100kW in irrigation canal system

- PEECA, Africa - 100 kW Irrigation canal project in Africa

- Taiwan - 20kW floating hydro-kinetic project

IMP Energy Ltd

A Subsidiary of IMP Group launched to venture into renewable energy.

❖A company focusing on Engineering, Procurement, Construction & Commissioning of Small hydro projects (SHP) less the 5MW in India.

❖Commissioned 3 no. of **1.5 MW SHP** in extremely tough terrains of ***Drass, Sangrah and Chilong in Kargil district for KREDA & running SUCCESSFULLY at EXTREME temperatures of -35 deg C since November 2017.***

1.5MW Drass SHP

1.5MW Sangrah SHP

1.5MW Chilong SHP

❖**Ongoing projects – Matayeen SHP(550 kW), Raru SHP(2x1000kW) and Khandi SHP(2x750kW)**


Thank you !
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