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Assessment of Hydrokinetic Potential at Downstream of Koteshwar HEP and Pilot Deployment of Grid connected 2x50kW Surface Hydrokinetic Turbine for Performance Analysis

Presented by:

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Outline of Presentation

- Concept of HKT
- Classification of HKT
- Surface Hydro Kinetic Turbine
- Assessesment of SHKT potential at D/s of Koteshwar HEP
- Pilot Installation of 2x50kW SHKT at Koteshwar Downstream
- Performance Assessment Parameters
- Conclusion

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Concept of HKT

- **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.**

Theoretically, the hydrokinetic energy can be expressed as per following equation:

$$P_{Theoritical} = \frac{1}{2} \rho A V^3$$

where "ρ" is the density of water, "A" is the swept area of rotor and "V" is the flow velocity.

- **SHKTs are capable of extracting only a fraction of the kinetic energy present in the flowing water that traverses their cross-section. This extracted fraction is quantified by the power coefficient (CP)**

$$P_{Capture} = C_p \frac{1}{2} \rho A V^3$$

- **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 velocity of fluid flow.**

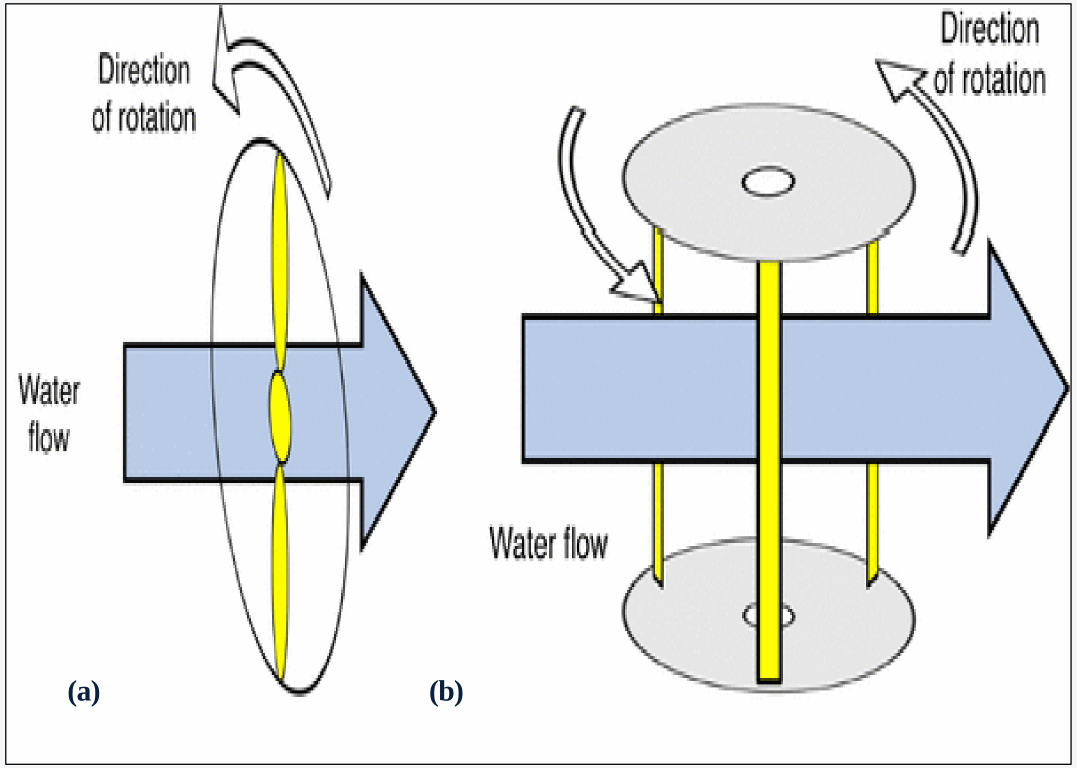
Clasifications of hydrokinetic turbines

Axial flow HKTs –

- Horizontal/ inclined rotational axis and parallel to the flow direction of water also known as propeller turbines.
- To achieve high efficiency, the alignment of the turbine rotor should be accurate according to the water stream.
- The stream flow requirement for axial flow turbines makes it more suitable for the application like ocean, and tidal.

Cross flow HKTs

- Rotational axis always orthogonal (horizontal/ vertical) to the incoming water flow.
- Cross flow turbines accept water from any direction.
- The rotor of cross flow HKTs may also have two, three or multi-blade depending on the torque requirement and flow conditions.



(a) Axial Flow, (b) Cross Flow Hydrokinetic Turbine

Surface hydrokinetic turbines

- Surface Hydro Kinetic Turbines are cross flow, radial flux, horizontal type partially submerged Hydrokinetic Turbines.

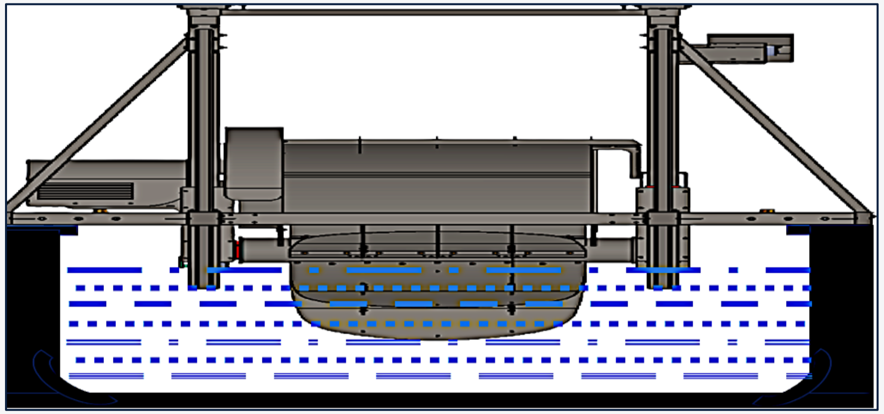
- Specially designed to extract the power from the mass of flowing fluid (water) without diverting/pounding/ heading-up the natural flow.

- The site-specific customizability of SHKTs makes this technology a plug-and-play type, grid-independent, scalable, replicable in modular form, and installable in any kind of running stream (such as rivers, rivulets, canals, backwaters, and even sewage drains)

Surface hydrokinetic turbines

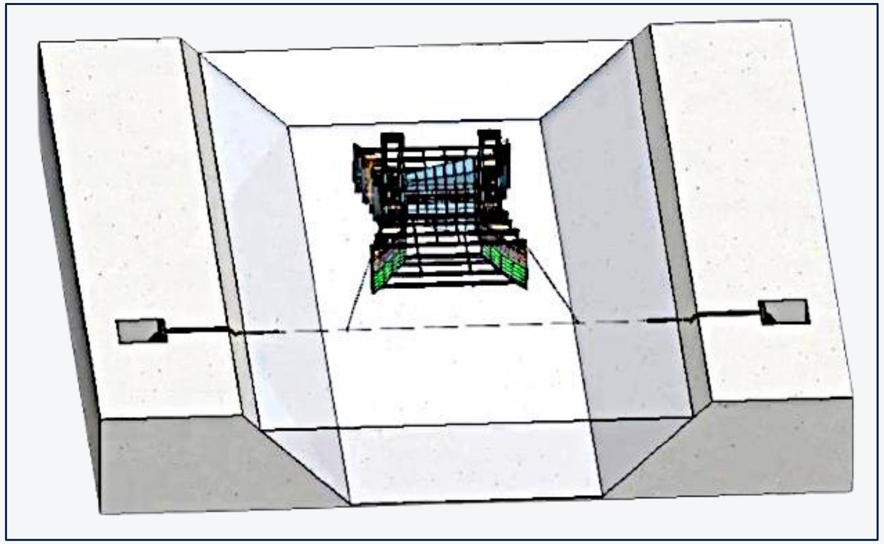
Fixed Type SHK Turbine

- Designed to be mounted on the linings of small canals and rivers with less width and water depth.
- Ideal for micro-irrigation canals, rocky terrain with discharge variation, shallow rivers, etc



Floating Type SHK Turbine

- Suitable for rivers and canals with greater width and adequate depth.
- Ideal for major irrigation canals, rivers, tidal streams, etc

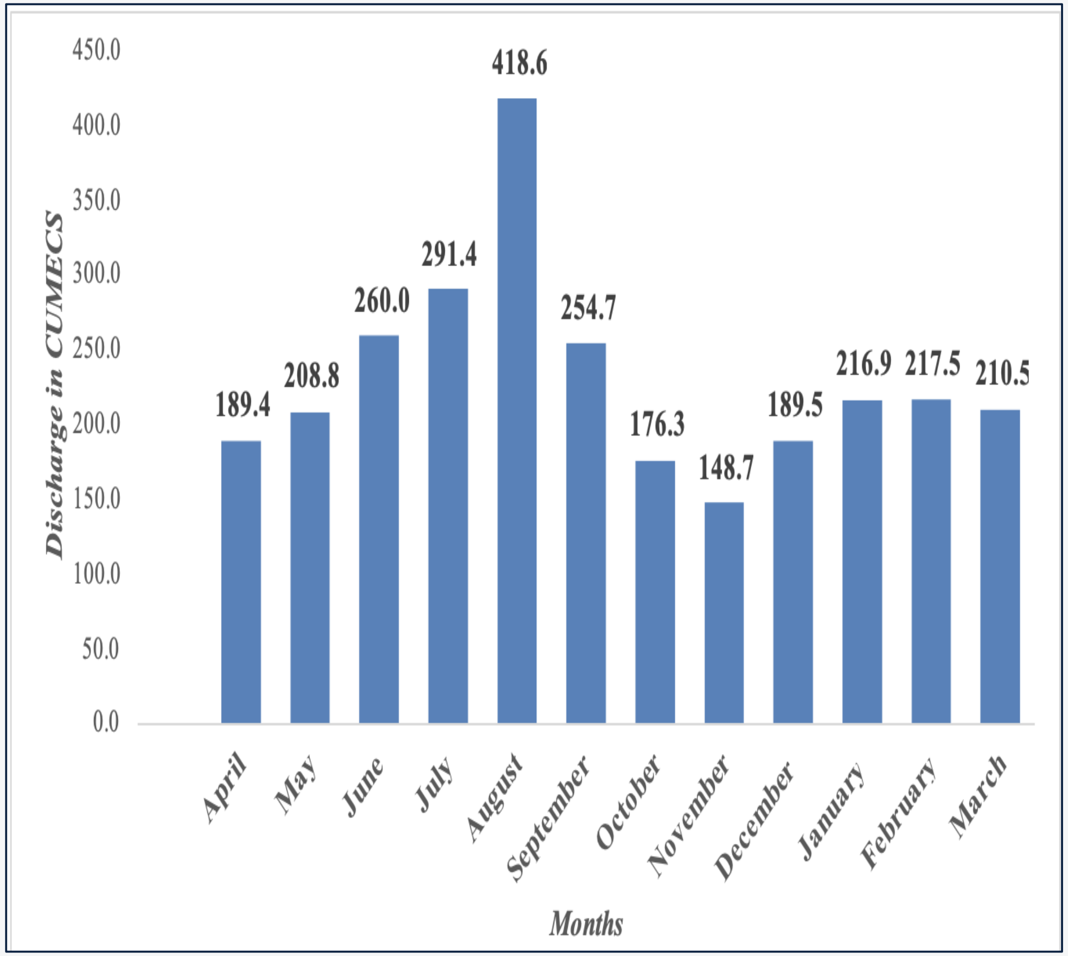


Assessesment of SHKT potential at D/s of Koteshwar HEP

- Assessesment of the feasible, extractable hydrokinetic potential of the Bhagirathi River from Koteshwar HEP downstream to Devprayag Sangam using customized Surface Hydro Kinetic Turbines.
- The assessment encompasses conducting a site survey and analyzing the discharge pattern of the KHEP along with other parameters.

Discharge Pattern of KHEP

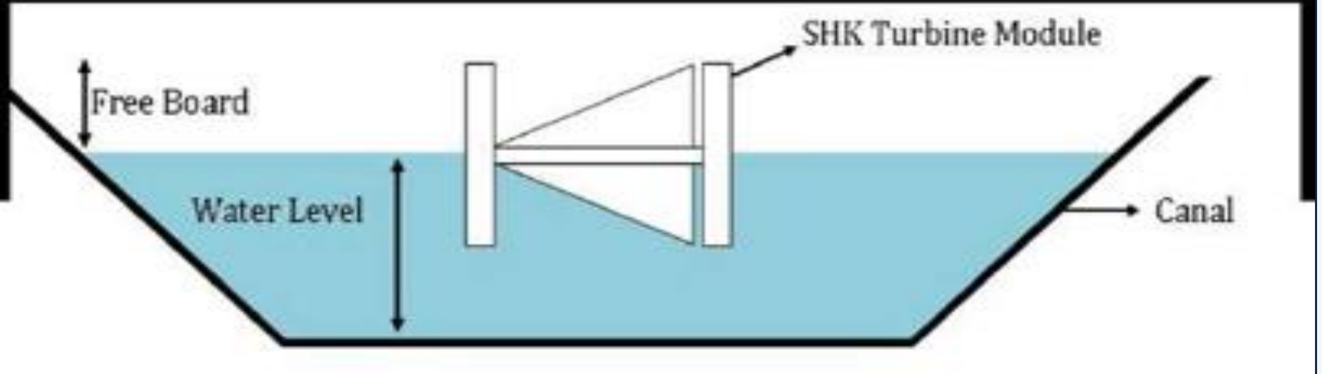
- In August, the maximum avg. discharge reaches 418.6 m^3/sec, while the minimum avg. discharge occurs in November at 148.7 m^3/sec.
- The spillway discharge capacity is 9,140 m^3/sec at FRL, with a maximum flood level discharge of 13,240 m^3/sec.
- The discharge through each 100 MW KHEP Unit is 161 m^3/sec, contributing to the maximum generation of 400 MW at discharge of 644 m^3/sec.

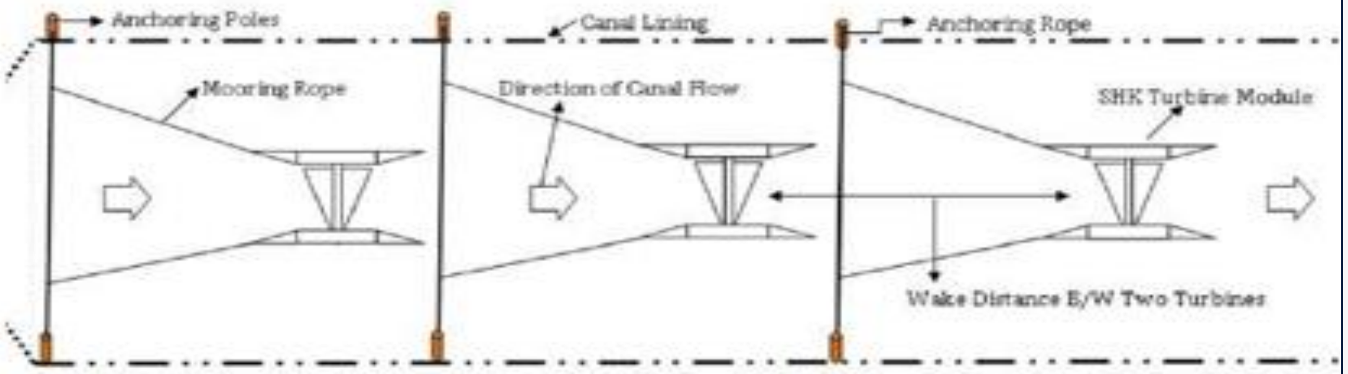


10 years avg. water discharge pattern of KHEP

Site potential assessment parameters

Parameters	Mathematics Involved
Assessment of Site Potential Parameters	P = ½ × p × A × (V)3 ➢ Average Wetted Cross Section Area of Water Stream, ➢ Annual Average Velocity, ➢ Annual Average Depth, ➢ Annual Average Discharge,
Equivalent velocity (Veq.)	$\text{Equivalent velocity}(V_{eq}) = \sqrt[3]{\frac{P_{rm}}{\frac{1}{2}\times\rho\times A}}$
Percentage reduction in flow velocity	$= \left(\frac{V - V_{eq}}{V}\right) \times 100$
Distance required to retain original velocity	$\text{Distance} = \frac{\left(\frac{V^2 - V_{eq}^2}{2g}\right)}{\tan^{-1}(\theta)}$

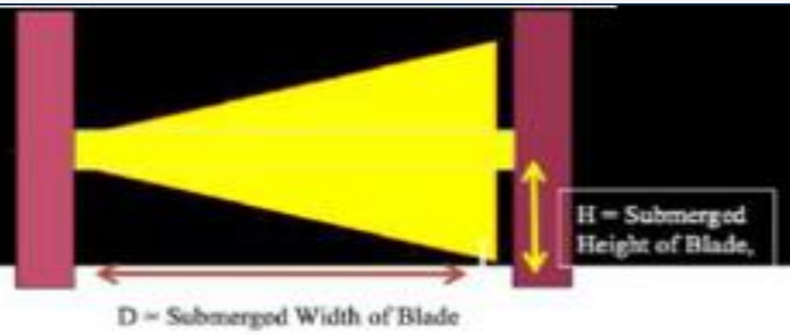


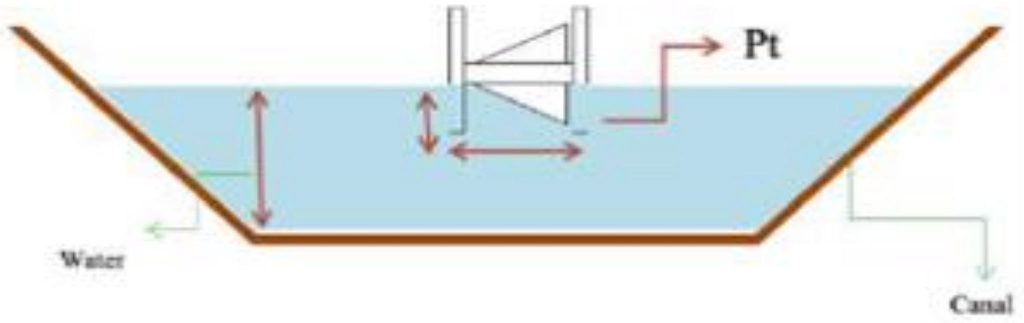


$$\text{Number of array}(N) = \frac{Totallengthofcanal}{Distancerequiredtorecoverthevelocity}$$

Turbine sizing parameters

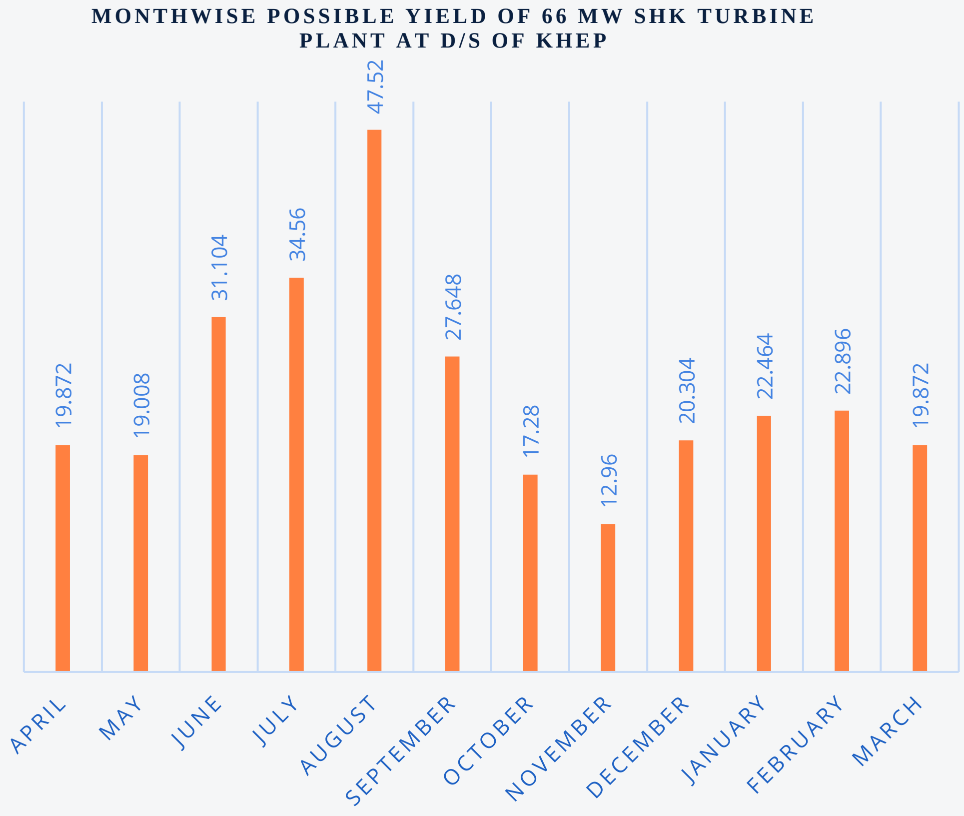
Parameters	Mathematics Involved	Details
Rotor Area	A = H × D	**A**= Cross Section Area of Turbine **H** = Submerged Height of Blade **D** = Submerged Width of Turbine
Available Hydrokinetic Energy (Pt)	Pt = ½ × p × A × (V)3	**A**= Cross Section Area of Stream **p** = Density of fluid **V**= Velocity of Stream
Generated Hydrokinetic Energy (Pg)	Pg = ½ × p × A × (V)3 × (Cp)	**A**= Cross Section Area of Turbine **p** = Density of fluid **V**= Velocity of Fluid **Cp**= Efficiency of Turbine + Power Conversion & Evacuation System
Remaining Energy (Pr)	Pr = (Pt) – (Pg)	**Pt** = Theoretical Power Available in Stream **Pg** = Actual Power Harnessed through Hydrokinetic Turbine Module





Assessesment of 66 MW potential of SHK Turbine at D/s of Koteshwar HEP

1	**Possible Modular Capacity of SHK Turbine(considering avg dependable discharge & overloading capacity)**	**550 kW**
2	Wake Distance b/w two units	150 M
3	Total No. of feasible turbines in 21 Kms stretch b/w Koteshwar dam and Devprayag	120 Modules
4	Turbine array sizing	20x550kWx6 arrays
5	Total Potential of SHK Turbine deployment from Koteshwar dam till Devprayag	66 MW
6	Achievable annual yield from 66 MW SHK Turbine plant	295.5 MUs
7	Achievable Plant Load factor	51.1 %
8	Deployment Scheme of Turbine Modules	Riverbed mounted Anchored
9	Anchoring Type	Bar Anchor
10	Mooring Type	GI wire based

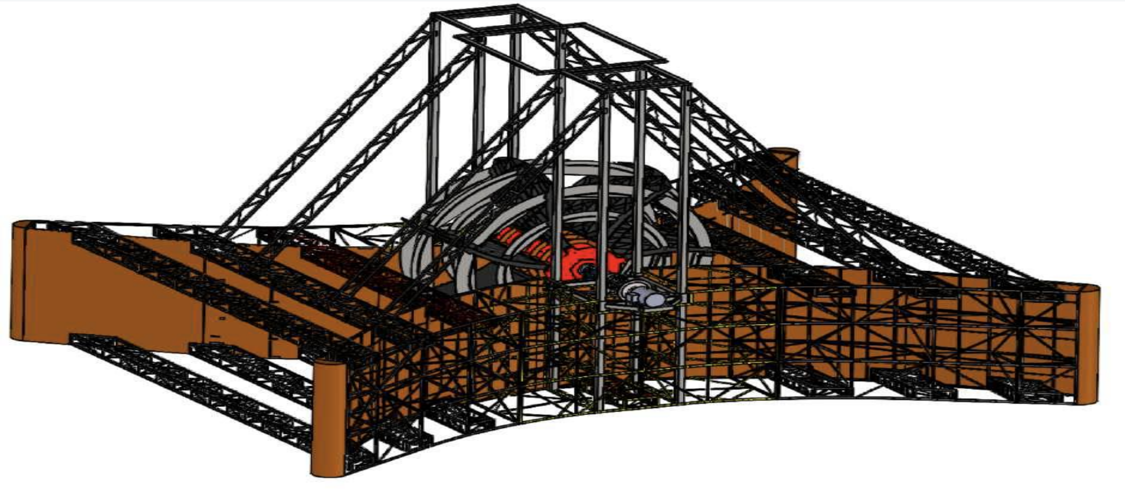


Possible yield of 66 MW SHKT Power Plant at KHEP D/s

Pilot Installation of 2x50kW SHKT at Koteshwar Downstream

- Pilot project encompassing two 50 kW modules, focusing on assessing turbine performance under site-specific conditions for widespread deployment.
- Turbine sizing optimized for a minimum discharge of 105 m^3/sec, ensuring a 50 kW generation per site-specific Hydro Kinetic Turbine, with dimensions tailored for a fixed-rated output of 50 kW per module.
- Hydrokinetic calculations conducted to determine the turbine's parameters:

SHK Turbine Swept Area(Sq. m)	**10.85**
Velocity (m/s) @ 105m^3/sec disch.	2.84
Power out put	50.47kW
Maximum power out put	53.74kW
Speed	25RPM
Gear Ratio	1:30



SHK Turbine complete 3D Assembly for Koteshwar

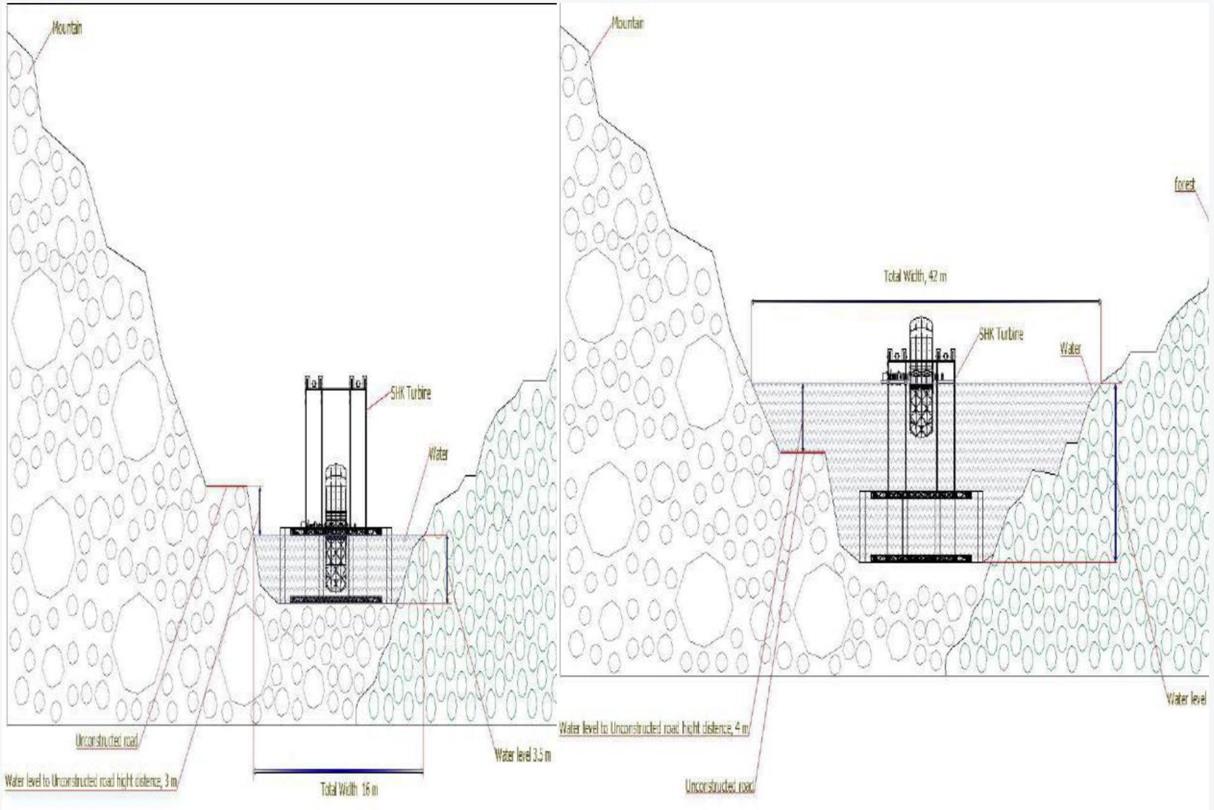
Pilot Installation of 2x50kW SHKT at Koteshwar Downstream

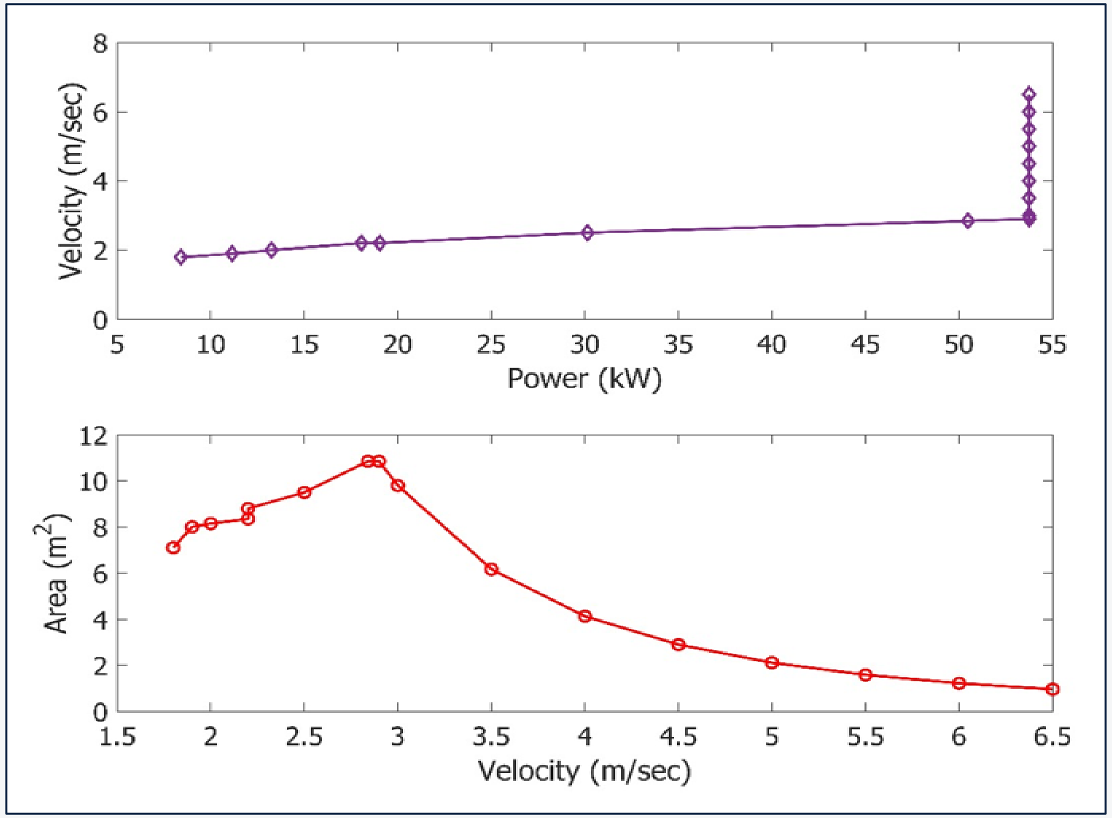
Challenges

- Variable discharge,
- Uneven natural streams,
- Rocky terrain.

- The topographical challenge of a 12-meter difference between zero and 14000 m^3/sec discharge, compounded by the RBM at downstream of Koteshwar Dam, deems the floating SHK Turbine unsuitable.
- Site-specific solution emerged—a riverbed-mounted, front side-anchored SHK Turbine with a 12-meter submergence adjustment system.
- Submergence adjustment tower with a sliding frame for the turbine-gearbox-generator drive train system,
- Electro-mechanical sliding mechanism with up to 2 mm precision.
- Governing System driven by motor drive mechanism encompasses PLC and sensors (water level and power).

Submergence adjustment & Turbine Operation





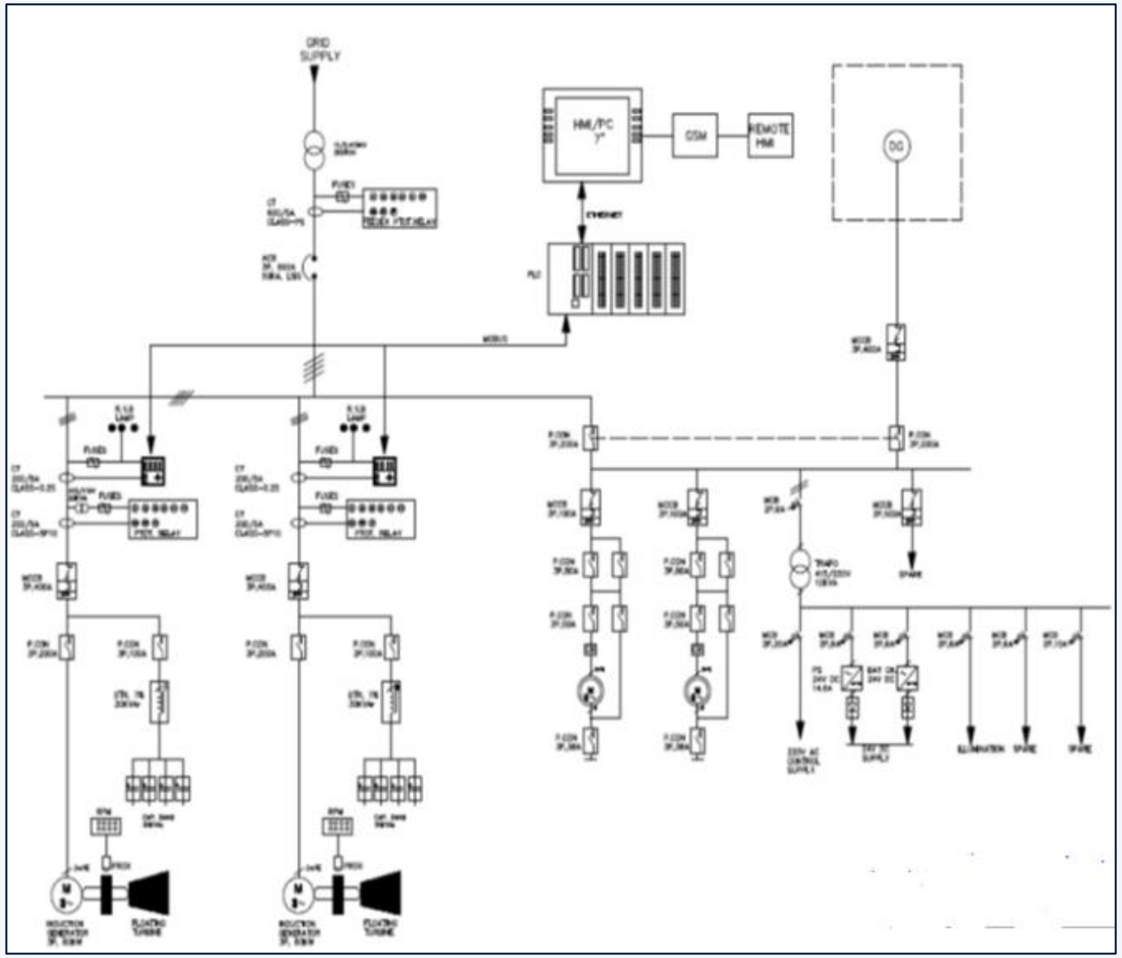
Position of turbine at 105m^3/sec and 14000 m^3/sec discharge

Turbine operation in variable discharge conditions

Grid Interconnection

- 60kW induction machines employed to deliver power when the machine speed exceeds synchronous speed.
- Encompasses machines with cage-type rotors and low negative slip.
- The IM draws magnetizing current from the grid, complemented by a system-integrated capacitor bank to enhance the power factor (PF).
- In the integrated system, both induction machines are coupled to the respective SHKT through gearbox, with electrical connection facilitated by a 200kVA, 415V/11kV step-up transformer to the 11kV system of KHEP.

Rated Power	**60kW**
Rated speed	737 RPM
Rated Voltage	415 V
Rated current	117.3A
PF at full load	0.74
Capacitor bank per IG	40kVAR



2x50kW SHKT System SLD

Performance Assessment Parameters

- The primary objective of this pilot deployment is to assess the performance of SHKT along with the entire interconnected system. The evaluation will focus on key parameters

Sr. No	Performance Parameter
1.	Gross Energy Generated
2.	CUF
3.	Outages
4.	Cost of Maintenance
6.	Tariff (Rs./Unit)
7.	Reliability assessment of Units under all-weather condition and disturbance in the system
8.	Safety Aspects assessment under all-weather condition
9.	Impact on TR level of KHEP

Conclusion

- The customized pilot deployment of the 2x50kW SHKT system at downstream of the 400MW Koteshwar Hydroelectric project provides a crucial platform for evaluating performance under diverse operating conditions.
- This assessment lays the groundwork for potential large-scale deployment, unlocking a 66 MW hydrokinetic potential within a 21 km range of downstream of KHEP.
- The predictability and continuity of water flow water bodies, making SHK turbines a promising source for non-intermittent, base load renewable energy worldwide.
- The integration of cutting-edge technology opens the possibility for further enhancements to the capacity of Surface Hydro Kinetic Turbines.

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