1. INTRODUCTION

The International Energy Agency revealed the energy requirements of world as in 2007; the global share of energy from fossil fuels was 88% of the total primary energy consumption is consists of 35.6% oil 23.8% natural gas, 28.6% coal, 5.6% nuclear and 6.4% hydroelectricity. The depleting quantity of fossil fuel and its continued use causes concern over environmental aspects. Since renewable energy technologies are non-polluting, they can deal with both security of supply concerns and environmental issues. The green energy harvesting depends on the kinetic energy available in flowing river streams, tidal currents or other artificial water channels. Hydrokinetic turbines, similar to wind turbines, operate on the principle of turning directional power into rotational power by using a certain amount of surface area to come into contact with the fluids movement over a period of time in order to harness as much power as possible.

Hydro kinetic energy has the potential to play a valuable part in a sustainable energy future. A ‘Horizontal Axis Water Turbine’ is a rotary machine having a horizontal axis of rotation used for electric power generation using the kinetic (flow) energy of water. Some other terminologies used commonly by researchers are Water Current Turbine (WCT), Ultra-low-head Hydro Turbine, Free Flow/Stream Turbine, Zero Head Hydro Turbine or River In-stream Hydro Turbine. Approaches for extracting green energy form oceans took the form of water wheels sand wind turbines deployed in the seabed to have turbines which are similar to wind turbines. Hydrokinetic energy refers to the energy generated from the moving water of the oceans currents, tidal, rivers and artificial water channels. Several technologies have been developed to extract this energy, such as horizontal axis hydrokinetic turbines. However, these turbines are still in a developmental phase and have not been fully commercialized yet, due to their lack of reliability and low power density.

Horizontal axis turbines have some beneficial features which make them more suitable than vertical axis turbines since they are easier self-starting, have less torque fluctuation, higher efficiency and larger speed operation. The performance of the hydro turbines depends on the rotor, shaft, gear box, and the generator characteristics. The rotor consists of the hub and several blades, which are conventionally bolted to the hub.

1.1 Problem statement

Various kinds of turbines which extract hydroelectricity require a certain amount of head. Also, they require large complicated arrangements and setup. The depleting quantity of fossil fuels and its continued usage is a great threat to the environment.

1.2 Objective

- Green energy harvesting using kinetic energy of flowing river streams, tidal currents or other artificial water channels.
- The main Objective of the Project is manufacturing a working Horizontal Axis Hydro Turbine and thereby testing for its

1. Efficiency
2. The shaft power it gives in terms of kilo watt.
3. The generator power in terms of voltage. Voltage produced by the generator will indicate the electricity produced by the mechanical work of the turbine.

- If we see the greater picture, the Project aims at reducing the use of non-renewable sources and finding and efficient way too harness green energy and contribute to the health of the environment and the society at large

1.3 Scope

There are factors that affect the performance of the turbine. Number of blades, shape and profile of the blades, etc. So it is proposed to manufacture turbine with different no of blades, profile. The size of the turbine also affects its performance and efficiency. It is also proposed to manufacture turbine with large diameter and length. As to increase efficiency and performance such turbines for future works to establish a green energy farm at the site.

1.4 Methodology

The below flow chart shows the sequential operation/steps that were performed during the project process.

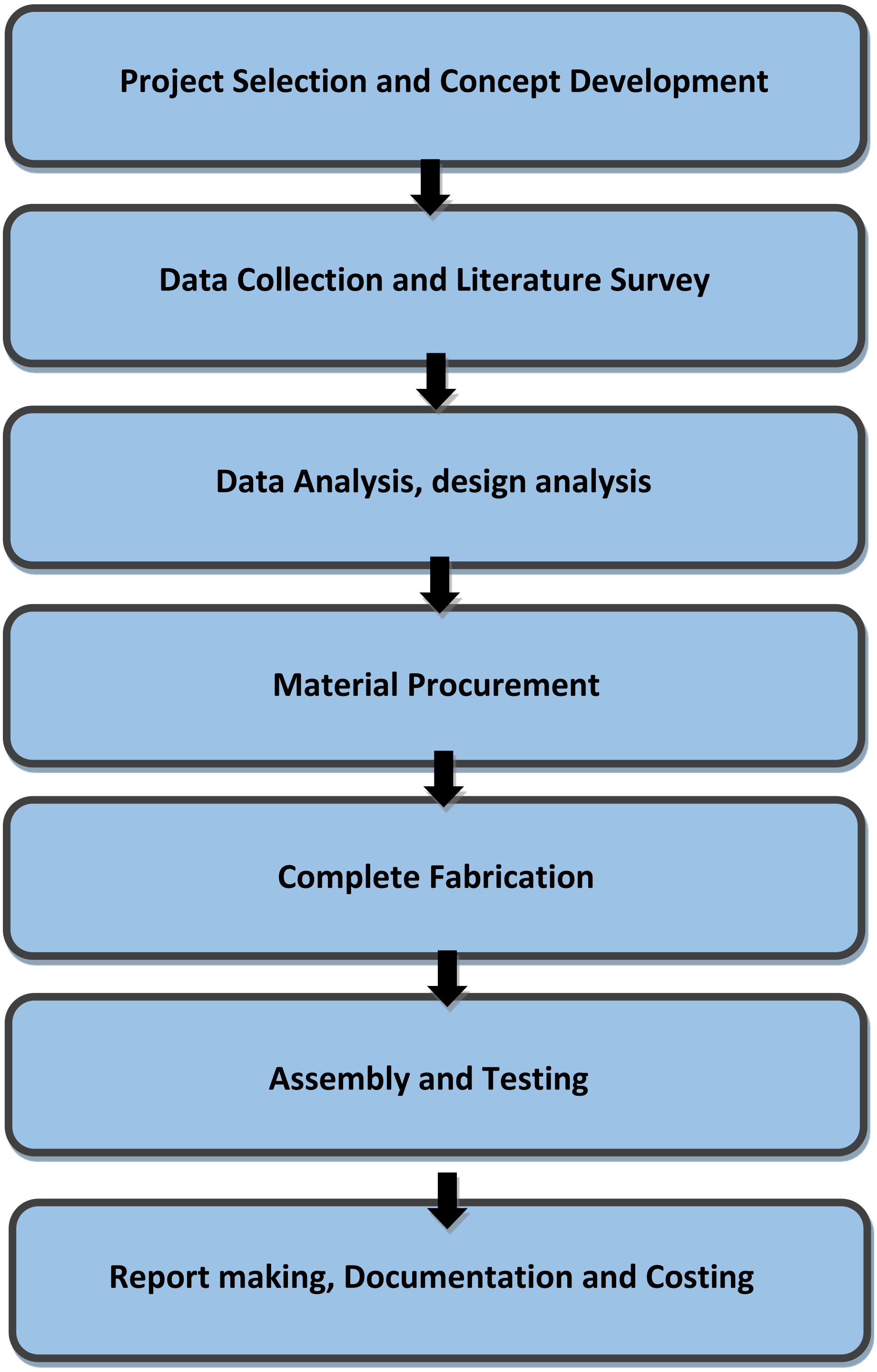


Fig.1. Methodology to solve problem

2. LITERATURE REVIEW:

Rajendra Prasad A. et al produced electrical power up to 160 watts using the developed turbine. Since the initial results are encouraging it was proposed to fabricate large diameter and longer length turbines to harvest more power to make a green energy farm. Since stream flow velocities would be increased by 3 to 4 times in shrouded turbines, it is proposed to develop such turbines for future works to establish a green energy farm at the site [1].

R. A. McAdam et al demonstrated that in a series of scale model experiments the truss variant of the HAHT produces power with a kinetic efficiency close to that of the conventional parallel- bladed device. Results show that both the parallel and truss-bladed devices are capable of producing power at efficiencies greater than the Lanchester-Betz limit [2].

M.J. Khan et al concluded that the Axial turbines are mostly being considered for placement at the bottom of a channel, whereas vertical turbines are being designed for either floating or near-surface mounting arrangements. In the presence of a wide variety of terminologies attributed to the fundamental process of kinetic energy conversion from water streams, the term ‘Hydrokinetic’ energy conversion can be used as long as sufficient caveats are given for diverse fields of application such as, rivers, artificial channels, tides, and marine currents [3].

Kamal A. R. Ismail, et al in their paper, have proposed a cheap hydrokinetic turbine system whose blades are easy to design, manufacture, replace when necessary and its operation is independent of the flow of direction. The effects of the number of blades, blade profile and water flow velocity on the turbine torque and power coefficients were presented and discussed. Fozur blade profiles were investigated, that is, flat plate, circular arc, NACA 0018 and NACA 1548. CFD simulations showed that circular arc profiles are more efficient and produce more power [4].

Edwin Chica et al stated that the effect of the material and the blade structure shape on its structural behaviour were presented and discussed. Safe working stresses and strains were identified and checked. There is a good comparison between the turbine design power and obtained from numerical simulation [5].

Ridway Balaka et al stated that the selection of the blade number is very important aspect in design. This study deals with the findings of effect of the blade number on the performance of the horizontal axis river turbine for low speed Condition. The high bladed turbines have the higher performance than those with lower number. The high performance of the high bladed turbine at a low rotation operation requires a high gearing ratio for the mechanical transmission system [6].

Himanshu Joshi et al concluded that to draw the attention to a new method of hydropower generation which doesn't require construction of large dams and tunnels to store energy. The turbine can be assembled vertically, horizontally or in any other cross flow combination using a common shaft and generator for an array of multiple turbines. This helps in reducing the construction, expansion and maintenance costs for any such power generating unit. The NACA 0018 hydrofoil used as the blade profile is symmetric and has an 18% width-to-thickness ratio [7].

A. Rubio-Clemente et al stated that a horizontal axis hydrokinetic turbine blade is designed and verified with the help of the momentum theory, the blade element momentum theory and numerical simulation. Focuses on the description of the steps involved in the design and numerical simulation of a small horizontal axis hydrokinetic turbine rotor used [8].

3. ANALYTICAL / NUMERICAL BASED WORK

Basic Formulae

Kinetic energy of a fluids in motions is given by,

$$\mathbf{E = 12m}\boldsymbol{v}^{2} \text{ ----------(1)}$$

The hydro-kinetic power is defined as the rate of change of energy of water, which is given by,

$$\mathbf{P=}\boldsymbol{dE/dt}\mathbf{=12}\boldsymbol{v}^{2}\mathbf{.}\boldsymbol{dm/dt}\text{-----(2)}$$

And the mass flow rate is given by-

$$\boldsymbol{dm/dt}\mathbf{=\rho A.}\boldsymbol{dx/dt}\text{---------}\{\ dx/dt=v\}$$

After substituting, we get

$$\boldsymbol{dm/dt}\mathbf{=\rho A}\boldsymbol{v}$$

From equation (2), the power can be written as-

$$\mathbf{P= 1/2.\rho A}\boldsymbol{v}^{\mathbf{3}}$$

The power captured by the rotor of the wind turbine and the total power available is not the same That is why the coefficient of performance comes into picture,

$$\mathbf{P_{avail}=1/2*\rho*A*}\boldsymbol{v}^{\mathbf{3}}\mathbf{*Cp}$$

Where,

P_{avail} =Power available

ρ = Density of Water

A= Swept Area= πdl

V= Free stream velocity

Cp= Coefficient of Performance

DESIGN

P_{input} = 1500 watt ………………………………….. (assumed)

V = 2 m/s …………………………………………… (calculated)

ρ = 1000 kg/m^3

D/L = 0.66 ………………………………………….. (according to references)

Power in = $\frac{1}{2}$*1000*A*V^3

1500=1/2*1000*A*(2)^3

A=0.375 m^2

A= π/4 * d^2

0.375= π/4 *d^2

D= 0.69 m

L=d/0.66

L=1.232 m

Convert linear velocity 'V' into RPM

V= Radius * RPM * 0.10472

Speed (N)= 55.351 RPM

To find force exerted on moving curved blades

M= ρ*A*V

Where V=2 m/s

ρ = 1000 kg/m^3

d= 0.69 = 0.6m

L= 1.232 =1m

u= πdn/60

u=1.7391 m/s

F= ρ*A*V(V-u) (1+cos θ)

At an angle θ = 5 degree

F=390.60 N

Torque = Force * Radius

T=117 Nm

P out = 2πNT/60

P out = 679.312 watt

For different values of **(θ)** we get the different outputs

θ	FORCE (N)	TORQUE(Nm)	P output (W)
5°	390.60	117.18	679.30
10°	388.37	116.51	675.42
15°	384.68	115.404	669.00
20°	379.54	113.862	660.06
25°	373.01	111.90	648.71
30°	365.13	109.53	635.01
35°	355.96	106.788	619.35

Table No.1 Output Values of variation θ

A Turbine is basically a component design to convert kinetic energy of water to rotational energy which in turn produces electricity. When water (fluid) strikes on the turbine blades, it pushes the blades and makes them rotate, harnessing kinetic energy (energy of flow) and converting it into mechanical energy. More and more kinetic energy is harnessed if there is more pressure of the flow of water.

Kinetic energy of a mass in motions is given by,

$$E = \frac{1}{2}mV^2 \qquad \text{.................(1)}$$

The power in the water is given by the rate of change of energy:

$$P = \frac{dE}{dt}\frac{1}{2}V^2\frac{dm}{dt} \qquad \text{............(2)}$$

As mass flow rate is given by:

$$\frac{dm}{dt} = \rho AV \qquad \text{..............(3)}$$

Hence, from equation (2), the power can be defined as:

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

The power captured by the rotor of the wind turbine and the total power available is not the same That is why the coefficient of performance comes into picture,

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

where, Pa =Power available

ρ = Density of Water

A= Area = d*l

V= Free stream velocity

C_p= Coefficient of Performance

Water carries a lot of energy even when it flows at low speed and is heavy thus, these turbines can also be relatively slow.

Hydroelectricity energy conversion can be well understood in three simple steps.

1. The potential energy of water is converted to kinetic energy when it flows through the river.
2. Kinetic energy of moving water is converted into rotational (mechanical) energy by a water turbine.
3. Rotating water turbine drives a generator that turns mechanical energy into electrical energy.

Horizontal Axis Water Turbines are used in seas and oceans in a large scale, which are various HAWT units joined together. Single units can be used in local river bodies and rivers according to the geography of the river.

Horizontal axis water turbine has a main rotor shaft and electrical generator. Most turbine have a gearbox, which turns the slow rotation of blades into quicker rotation that is the more suitable to drive electrical generator.

1. Rotor –

Rotor is having a shaft at the centre and blades. Rotor is designed to capture the max area of flow of water in order to spin with high speed. Blades must be perpendicular to the flow of water and made up of light weight, durable and corrosion resistance material. The best material is fiberglass and reinforced plastic. When the flow of water comes in contact with the rotor, the rotor starts to rotate simultaneously shaft also rotate which is connected to gearbox.

2. Gearbox –

Gearbox magnifies or amplifies the energy output of rotor the gearbox is situated directly between the rotor and generator. The gearbox increases the speed ratio. The shaft further connected to generator.

3. Generator –

Generator comes in various sizes relative to output we wish to generate. the work of generator is to produce the electrical energy from mechanical energy. As rotor rotates the shaft which is connected to generator the generator produces the electricity from rotation of rotor

WORKING OF HORIZONTAL AXIS HYDRO TURBINE

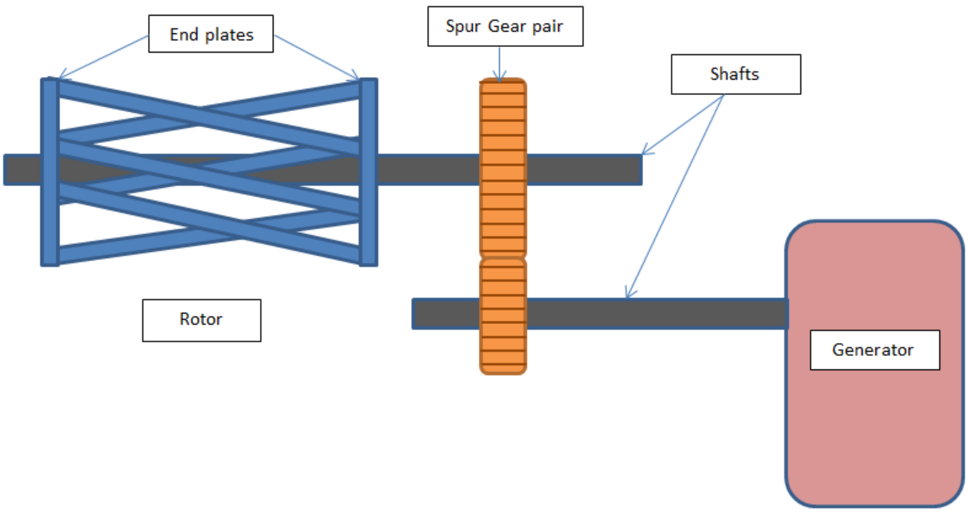


Fig No.2 Conceptual Design of HAHT

A machine designed to capture kinetic energy of moving fluid is known as a turbine. As the flow of fluid strikes on the turbine blades, they rotate harnessing kinetic energy (energy of movement) and converting it into mechanical energy. Faster the fluid flows the more the kinetic energy it contains.

There are four kinds of turbine according to type of fluid that drives them.

1. Water 2. Wind
3. Steam 4.Gas

We are interested in water turbine so, water turbines are often very big because they have to extract energy from an entire river, dammed. They can turn relatively slow because water is heavy and carries a lot of energy even when it flows at low speed.

Hydroelectricity is effectively a three-step energy conversion.

1. The rivers potential energy is turned into kinetic energy when water fall through height.

2. Kinetic energy of moving water is converted into mechanical energy by a water turbine.

3. Spinning water turbine drives a generator that turns mechanical energy into electrical energy.
Different types of water turbine are used depending on geography of area, how much

Water available and distance over which it can made to fall.

DESIGN OF CROSS FLOW HYDROKINETIC TURBINE

Power coefficient:

It is used to measure the hydrodynamic efficiency of the turbine. Power coefficient CP relates the power output Pout of the rotor to hydrokinetic power input Pin. Power coefficient CP has a maximum value 0.59 and it is known as the Betz limit, which has a numerical value of 0.59.

$$P_{out} = C_p \times P_{in} \qquad \text{...........(1)}$$

$$P_{out} = \frac{1}{2} C_p \rho A V^3 \qquad \text{...........(2)}$$

Where, A is the swept area of the turbine rotor, V is the velocity of the fluid at inlet of the turbine and ρ is the density of fluid.

Tip Speed Ratio (λ): It is an index of rotor's rotational speed, ω having radius r against the velocity of fluid V. Power coefficient Cp and the tip speed ratio λ are used for illustrating the effectiveness of a turbine's power extraction at various rotational conditions. It can be defined as;

$$\lambda = \frac{\omega r}{V} \qquad \text{..........(3)}$$

Torque coefficient (CT): It is also a very important parameter used to define the performance of the turbine. It can be expressed as;

$$C_T = \frac{C_p}{\lambda} \qquad \text{.........(4)}$$

Solidity (σ): It is defined as the ratio of total blade chord to turbine circumference. Solidity of a turbine with rotor diameter d and n number of blades, having c as the blade chord length can be defined as;

$$\sigma = \frac{nc}{\mathrm{d}} \qquad \text{...........(5)}$$

Reynolds Number (Re): Reynolds number is an index of turbulence created by a body placed in the fluid. For a rotor diameter d, velocity V and υ as the kinematic viscosity of water, re can be expressed as;

$$R_e = \frac{Vd}{\upsilon} \qquad \text{...........(6)}$$

Aspect ratio (AR): Aspect ratio of a blade is measure of its length and slenderness. It can be defined as,

$$AR = \frac{h}{c} \qquad \text{..........(7)}$$

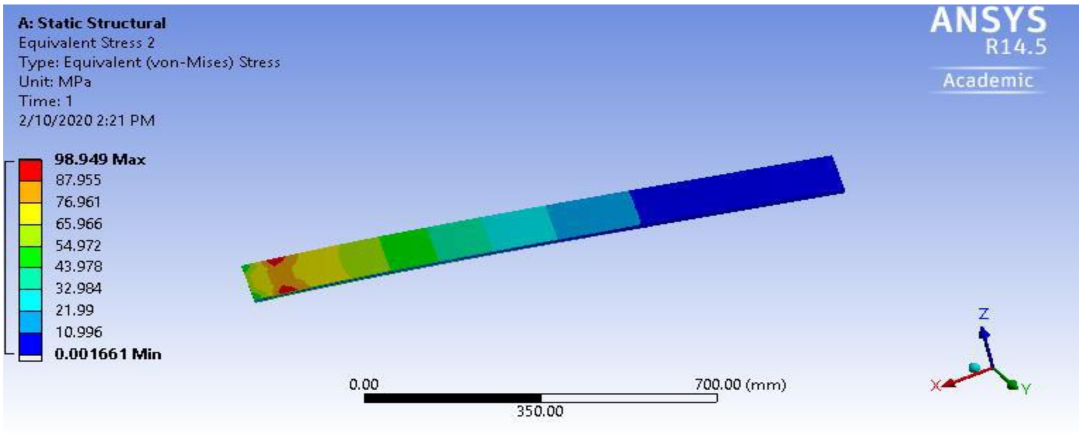
where, c is the chord length of the blade and h is the height of the turbine rotor.

Angle of Attack (α): It is the angle between the relative aerofoil and the chord line of an aerofoil. Lift and drag data are generally available for low angle of attacks ranging from 10^{o}-20^{o}.

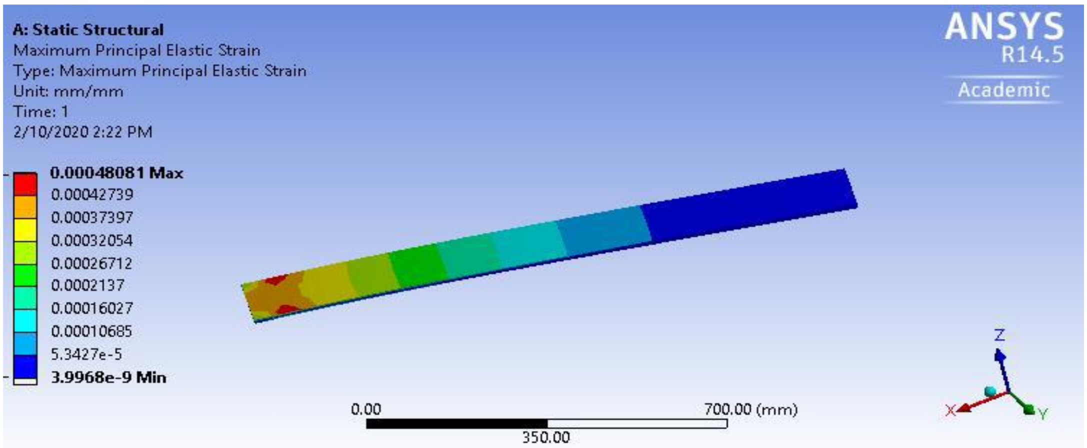
Lift Coefficient (C_L) and Drag Coefficient (C_D): These two parameters depend on the shape of the blade and Reynolds number under a given operating condition. The lift coefficient, C_L refers to the dynamic lift characteristics of a two-dimensional foil section, with the reference area replaced by the foil chord. C_L is a function of the angle of the body to the flow and its Reynolds number [26]? The drag coefficient, $C_D$is a dimensionless quantity that is used to quantify the drag or resistance of an object in fluid environment. It is used in the drag equation, where a lower drag coefficient indicates the object will have less aerodynamic or hydrodynamic drag.

4. Experimental Validation

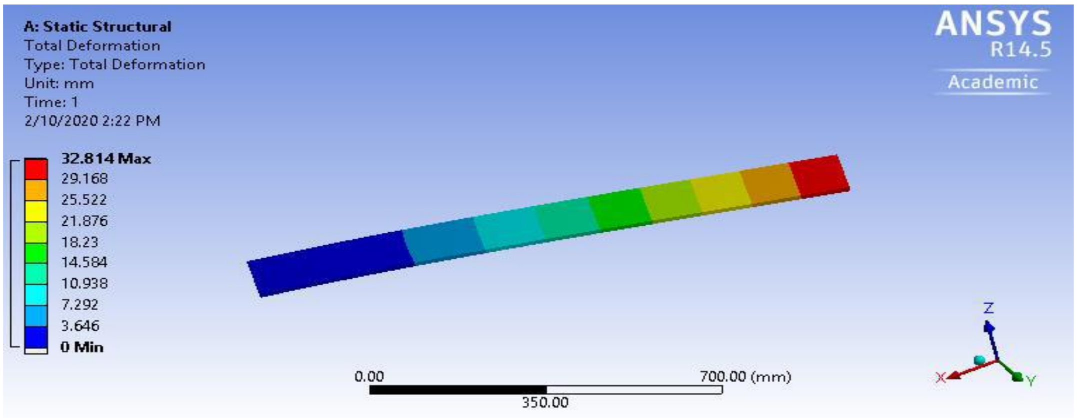
Structural Analysis for blade- Equivalent stress



Structural Analysis for blade- Max. Principal elastic strain



Structural Analysis for blade- Total Deformation



Character istics	Horizontal turbine	Vertical flow turbines
Placement	Designed for either bottom structure mounting (BSM), floating (FSM) and near surface arrangements (NSM). This provides flexibility in selection of mounting systems.	These turbines are mainly placed with NSM arrangement allowing the generator to be placed above the water level resulting in lesser power production.
Efficiency	Possess higher efficiency due to lower incidence losses.(A loss that refers to any work done in turning the working fluid from its direction of approach to the rotor to the direction required by the blade passage)	Flow enters over one half of the periphery radially inward, and emerges over its other half flowing radially outward. The velocity near the centre of vortex is higher than the velocity further away from centre resulting in lower efficiency
Self starting	Blades are designed to have sufficient taper and twist such that lift forces are exerted uniformly along the blade. Turbines are self starting in nature.	Turbines suffer from low or negative torque at tip-speed ratios which prevent the turbine from accelerating up to operating speeds. This creates a significant problem to low head less water speed sites
Vibration	Not subjected to any vibration as a result of continuously changing angles of attack.	Turbine blades are subjected to cyclic tangential pulls and generate significant torque ripple at the output. Serious problem if frequency of vibration coincides with the resonant frequency of the support structure.

Table No.2. Comparison of axial Turbines

Work plan- Executed

- Selection and Analysis of Project
- Need Of project
- Availability of resources
- Determination River velocity
- Design and calculation of Diameter, length, torque, power, force and output
- To determine Blade size and angle
- Material selection

Work plan- On hold due to Pandemic

- Material Selection test- which includes UTM test
- Actual material selection from market
- Fabrication job and work of turbine and other utilities
- Assembly of turbine and other requisite components

5. Remarks and Scope for the Future Work

Conclusion

A Horizontal Axis Hydro Turbine of diameter 650 mm and length 1000 mm can be fabricated using blades of hydrofoil Specific Blade profile. Special generator, Direct Drive, Permanent Magnet Generator used to generate the electric power. The analytical result is nearly 78% obtained. The project aimed at voltage generation helpful for the electrification. The large-scale production of such Horizontal Axis Turbines would give greater scope for it. Output can be increased by manufacturing these turbines with larger dimensions. The analytical results show the amount of power output for the designed turbine. The state of the hydrokinetic energy conversion technologies has been revisited with an emphasis on indicating the current trends in research and development initiatives. While the initial discussions encompassed various definitions and classifications, the core analysis has been undertaken based on a comprehensive literature survey. The Horizontal Axis Hydro Turbines are really worked upon in many parts across the globe because of its unique advantages. However, due to the fewer past studies over river applications, they lack the complete satisfaction of the understanding of the required parameters as compared to Ocean based applications. The fabrication and usage of Horizontal Axis Hydro Turbines in rivers and local water bodies, portraying on to a larger picture about this in the near future would prove to be a boon to the green energy farms and its special applications with multiple product variations.

Remarks

India is a Country with billion peoples, precisely saying country with billion brains. This is the third generation of peoples which are currently existing in Independent India. We have seen depression, Poverty, Hunger and unending Problems. But slowly and steadily, The Linear Progress and wellbeing of our nation is recovering. As of now there are 5202 dams in India out of which 197 Dams have Hydro Electric power plant. The Gross energy consumption in 2019-20 was 1,383.5 TWh out of Hydroelectric Power plant contributed 22 % in total which is a good amount of sustainable energy if you take the nature of needs in Accounts.

But at the same time if you look at solar energy which is less efficient energy as compare to hydroelectric energy.

In India as of today,

- Renewable energy has a share of 23.39% in the total installed generation capacity in the country i.e. 368.98 gw
- Solar capacity increased in the last 5.5 years from around 2.6 gw to more than 34 gw
- World's largest renewable energy expansion programme 175 gw till 2022
- Solar power tariff reduced by more than 75% using plug and play model
- Renewable energy installed capacity increased 226% in last 5 years
- Solar park scheme doubled from 20gw to 40gw
- Record low solar tariff rs 2.44/unit achieved in bhadla, rajasthan
- Highest ever wind capacity addition of 5.5 gw in 2016-2017

Sustainable Green and clean Energy's future is Bright in India. The success lies in decentralizing the application which can be seen in the solar energy. We just have to find ways to decentralize the hydro electric energy.

FUTURE SCOPE

There are factors that affect the performance of the turbine. Number of blades, shape and profile of the blades, etc. So it is proposed to manufacture turbine with different no of blades, profile. The size of the turbine also affects its performance and efficiency. It is also proposed to manufacture turbine with large diameter and length. As to increase efficiency and performance such turbines for future works to establish a green energy farm at the site.

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