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3kw Propeller Turbine Blade Design Based on Tidal Range

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ABSTRACT

Tidal energy is a largely untapped, renewable energy source based on lunar gravitation rather than solar radiation. The generation of electricity from tides is very similar to hydroelectric generation. Tidal energy is clean and not depleting. The tidal schemes may be of single pool or double pool or multi pool. Two types of tidal power plant are barrage style tidal power plant and tidal current power plant. Among them, barrage style tidal power plant was chosen to suit local condition and facilities in Myanmar. Several different turbine configuration are possible. The propeller turbine designed is based on tidal head and flow rate of Kanbalar Creek. The maximum and minimum head of tidal range is 5 m and 2 m. The available flow rate is 0.46 m^3/s. The type of turbine is chosen by using 2 m head and 0.46 m^3/s flow rate. Therefore, 3 kW propeller turbine is designed in this paper. Then, calculated runner diameter is 280 mm, hub diameter is 112 mm and number of blade is four. Two dimensional blade profile is calculated by using MATLAB program software and drawn AutoCAD software.

KEYWORDS: *Tidal Energy, Propeller turbine, flow rate, Runner*

1. INTRODUCTION

Gravitational forces between the moon, the sun and the earth cause the rhythmic rising and lowering of ocean waters around the world that result in tide waves.

The difference in the level of ocean water between high tide and low tide results in the ocean tidal energy. The potential energy is higher during high tide than that during low tide. Hence tidal energy is renewable. Tidal energy conversion schemes are identified by the number of basins and the operating modes of turbine-generator. The most common tidal schemes are single basin scheme, modified single effect scheme, two basin schemes, multiple basin scheme and pumped storage scheme. Tidal energy is a form of hydro energy recurring with every tide. The tidal range is the difference between consecutive high tide and low tide water levels as shown in Figure 1. Tidal head is distance between basin water level and sea level.

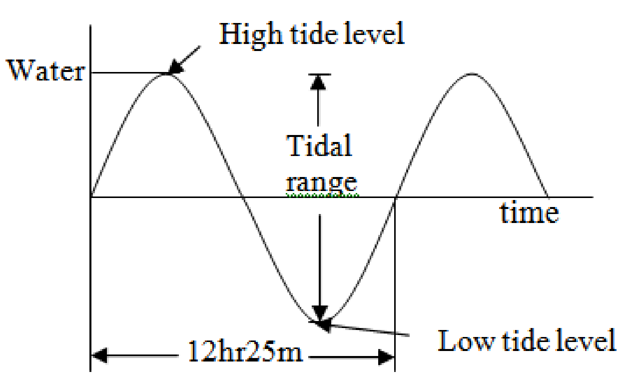


Figure1. Typical Tidal Range

2. TYPES OF TIDAL POWER PLANT

Two types of the tidal power plants are;

1. Barrage style power plant
2. Tidal current power plant

Barrage style (Old Technology) was chosen to suite local conditions and facilities available in Myanmar.

2.1. Barrage Style Power Plant

Building a dam know as barrage, retained water at high tide and generate power and electricity when released water through, conventional turbine as the tide ebbs shown in Figure 2. The purpose of this dam or barrage is to let water flow through it into the basin as the tide comes in. The barrage has gates in it that allow the water to pass through. The gates are closed when the tide has stopped coming in, trapping the water within the basin or estuary and creating a hydrostatic head.

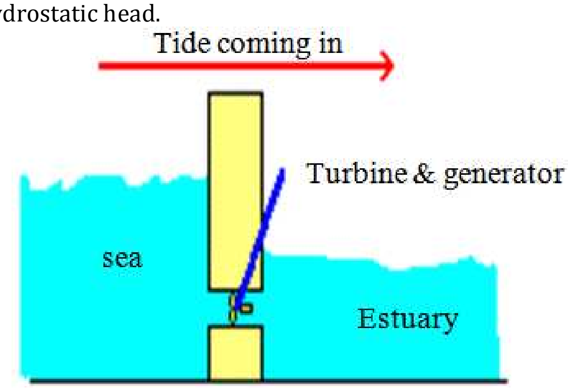


Figure2. Barrage style tidal power plant

2.2. Tidal Current Power Plant

Generate renewable, pollution-free electricity by the tidal currents or streams. Tidal current are the flow of water during changing tidal level. The tidal currents flow in horizontal direction and have kinetic energy. The energy is called tidal current energy.

The tides are periodic vertical rise and fall of ocean water. The period between consecutive high tides is 12.4 hours. The tidal rise and fall of water is accompanied by periodic horizontal to and formation of water called the tidal current. Tides and tidal current are intimately related.

3. KANBALAR – WORKING CASE STUDY, KANBALAR TIDAL POWER PLANT

Kanbalar tidal power plant is the only full scale power station of its type in Myanmar, located in Ayeyarwady Division on Kanbalar River. The power plant was accomplished in 2005, with propeller turbine, capable of producing 3 kW of power. The dam itself is 30 feet (9.84m) long and 10 feet (3.28m) high.

The turbine used in Kanbalar is Propeller turbine that is capable of generating power when the basin is emptied at low tide. Kanbalar has been successful as the first full scale tidal power plant in Myanmar.

3.1. Site Location

The village was chosen due to flow rate of creek and different between spring tide and neap tide.

Name of Village	- Kanbalar
Township, District, Division	-Ngapu-daw, Pathein, Ayeyarwaddy
House hold	- 220
Distance from National Grid	- 150 km

3.2. Study Data

	March			July			August			Avg;
	H	L	D	H	L	D	H	L	D	D
Spring tide	2.52	0	2.52	2.83	0.22	2.61	3.03	0.33	2.7	2.6
Neap tide	2.22	0.2	2.02	2.63	0.44	2.19	2.83	0.55	2.28	2.16

H= High tide, L= Low tide,
D= Different between high tide and low tide

The volume flow rate of Kanbalar Creek is 7 m^3/sec. Different between high tide and low tide is 2.5m.

3.3. Calculated volume to Produce Power at 2m head

Reserved area - 5 Arce
- 4047 x 5 m^2 = 20235 m^2

Available volume - 0.5 x 20235 = 10117 m^3

Calculation of available discharge maximum available period for each tide = 6 hrs

Available discharge/hr = 10117/6
= 1686 m^3/hr

Available discharge/sec = 0.46 m^3/s

3.4. Installation

A small dam was constructed across the branch creek. Installation of turbine is indicated in Figure 3. Wooden open channel 0.33 m height x 0.33 m width x8.2m length was connected to turbine casing through outlet. Draft tube has been installed at the outlet of turbine. For filling water into the dam, there intake channel with 60 m far from the dam.

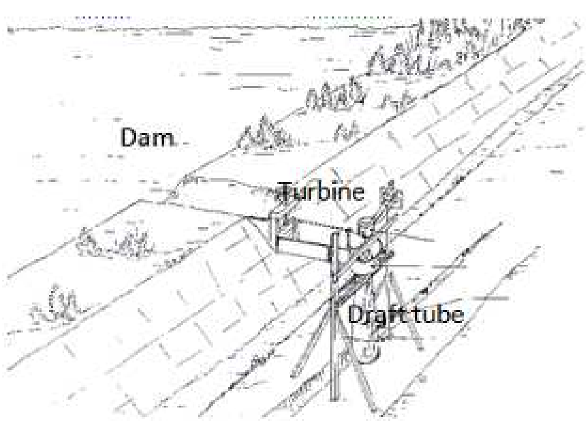


Figure3 Installation of turbine

4. PROPELLER TURBINE

Turbines are divided by their principle way of operating and can be either impulse and reaction turbine. The rotating element of a reaction turbine is fully immersed in water and is enclosed in a pressure casing Propeller turbine is axial flow reaction turbine, generally used for low head. The basic propeller turbine consists of a propeller, similar to a ship's propeller, fitted inside a continuation of the penstock tube as shown in Figure 4. The turbine shaft passes out of the tube at the point where the tube changes direction. The propeller usually has three to six blades, three in the case of very low head units and the water flow is regulated by static blades or swivel gates just upstream of the propeller. This kind of propeller turbine is known as a fixed blade axial flow turbine because the pitch angle of the rotor blades cannot be changed.

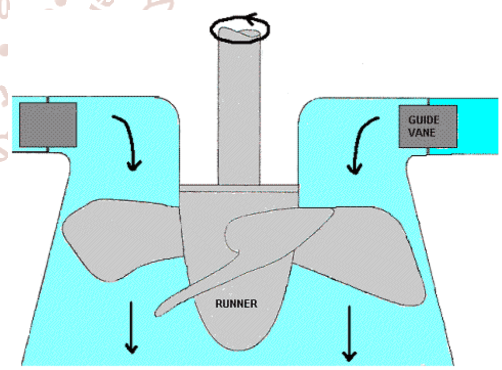


Figure4. Propeller Turbine

5. DESIGN CONSIDERATION OF PROPELLER TURBINE

The effective head and power available of this propeller turbine is considered at 2m and 3 kW. The power developed by a turbine is given by the following equation.

$$P = \eta_o \rho g Q H \quad (1)$$

P = generator output power (kW)
Q= Flow rater (m^3/sec)
H= Net head (m)
The required shaft power is 4.41 kW.

The specific speed can be calculated from the following equation.

$$N_s = \frac{885.5}{H_d^{0.25}} \quad (2)$$

The speed of the turbine can be calculated from the following equation.

$$N = \frac{N_s H_d^{1.25}}{\sqrt{P}} \qquad (3)$$

The periphery coefficient can be determined by the following equation.

$$\phi = 0.0242 \times N_s^{2/3} \qquad (4)$$

Runner discharge diameter can be calculated by the following equation.

$$D_3 = \frac{84.5 \times \phi \times \sqrt{H_d}}{N} \qquad (5)$$

5.1. Design Calculation of Blade Profile

Design Data: Power = 3 kW
Head = 2 m
Flow rate = 0.28 m^3/sec

In the space of the runner, it can be divided into five cylindrical sections. This sections are can be calculated by the following equation.

Section I,

$$r_1 = \frac{d}{2} + 0.015d \qquad (6)$$

Section III,

$$r_3 = \frac{D}{2}\sqrt{\frac{1 + D_d^2}{2}} \qquad (7)$$

Section II,

$$r_2 = r_1 + \frac{r_3 - r_1}{2} \qquad (8)$$

Section IV,

$$r_4 = r_3 + \frac{r_5 - r_3}{2} \qquad (9)$$

Section V,

$$r_5 = \frac{D}{2} - 0.015\,D \qquad (10)$$

Calculation of runner blade angle at outlet and inlet blade at various diameters, tangential speed and whirl velocity must be known.

$$U = \frac{\pi r N}{30} \qquad (11)$$

To find tangential component of absolute velocity,

$$\eta_h = \frac{U\,C_{u1}}{g\,H_d} \qquad (12)$$

$$C_{u1} = \frac{\eta_h\, g\, H_d}{U} \qquad (13)$$

So, the blade inlet angle at Section I,

$$\tan\beta_1 = \frac{V_{f1}}{U - C_{u1}} \qquad (14)$$

Therefore the blade outlet angle at Section I, $V_{f1} = V_{f2}$

$$\tan\beta_2 = \frac{V_{f2}}{U} \qquad (15)$$

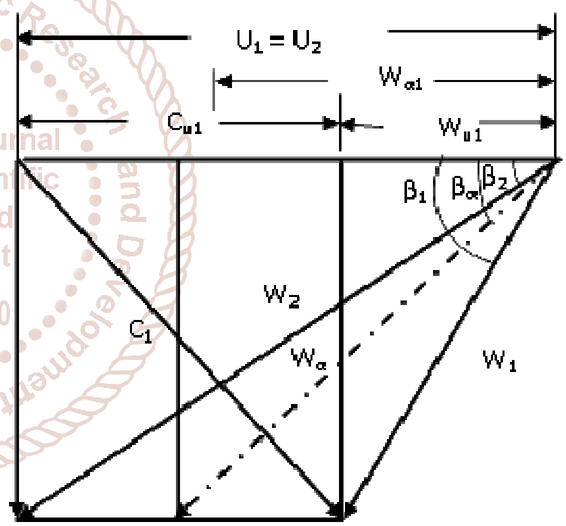
The spacing of the blade can be determined by this equation

$$t = \frac{2\,r\,\pi}{z} \qquad (16)$$

From Figure 5, the velocity triangle, determine the average angle β_α,

$$\tan\beta_\alpha = \frac{V_f}{W_{\alpha 1}} \qquad (17)$$

$$W_{\alpha 1} = U - \frac{C_{u1}}{2} \qquad (18)$$



Figuer5 Velocity triangle of Propeller Turbine

Circulation (Γ) can be determined from this equation.

$$\Gamma = t\,(C_{u1} - C_{u2}) \qquad (19)$$

The lattice angle,

$$\beta = 90 - \beta_\alpha + \alpha_\alpha \qquad (20)$$

5.2. Result Data of Blade Profile

Calculated data are described in Table 1.

Table 1 Result Data of Blade profile

Parameters	I	II	III	IV	V
$R_1 = R_2$(m)	0.0576	0.082	0.107	0.121	0.136
$U_1 = U_2$ (m/s)	5.12	7.2	9.5	10.7	12.1
V_f (m/s)	5.4	5.4	5.4	5.4	5.4
β_1	74°	48.06°	35.13°	30.43°	27.08°
β_2	47.2°	36.66°	29.63°	26.58°	24.22°
C_{u1} (m/s)	3.37	2.4	1.82	1.62	1.43

$W_{\alpha1}$ (m/s)	3.435	6	8.59	9.89	11.3
β_{α}	57.5°	41.98°	32.15°	28.63°	25.54°
W_{α} (m/s)	6.3	8	10.14	11.26	12.52
t (m)	0.09	0.128	0.168	0.19	0.213
Γ (m^2/s)	0.31	0.31	0.31	0.31	0.31
l/t	1.1	1.0125	0.925	0.84	0.74
l= l/t × t (m)	0.099	0.129	0.155	0.16	0.157
β	42.5°	54°	61.38°	64°	66°
α	10°	6°	3.5°	2.7°	1.5°

After calculating the blade profile, three dimensional runner blades are drawn by AutoCAD software, shown in Figure 6.

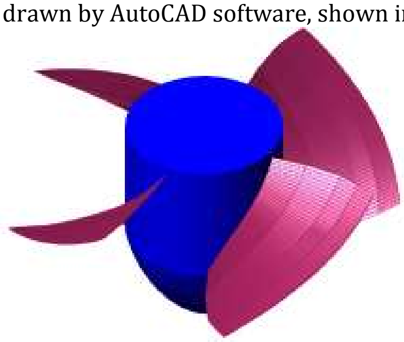
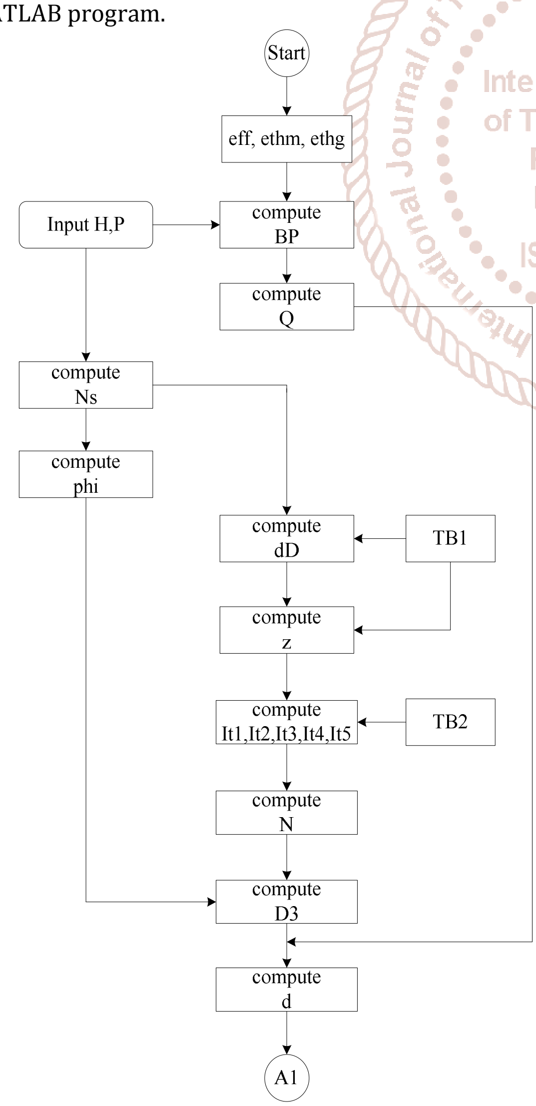


Figure 6 ISO View of Runner

6. DESIGN PROGRAM FOR BLADE PROFILE

The design of the runner can be determined by using MATLAB program.



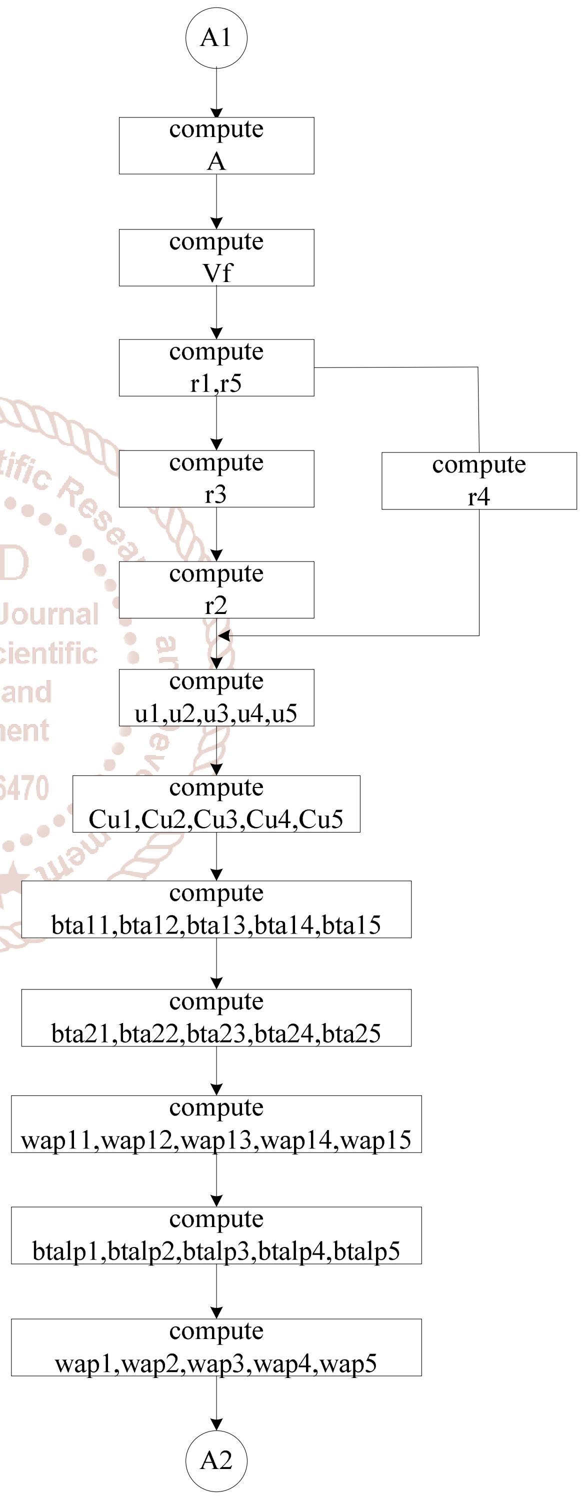


Figure7 Flow Chart for Blade Profile

7. CONCLUSIONS

Tidal power plant is low head plant, tidal range is 1 m to 5 m in Myanmar. Turbine is the most important parts to generate electricity. Among these turbine propeller turbine is the best for low head to generate electricity. This turbine can be used for families in remote areas to produce 3kW power for 220 household are easily and inexpensively for only lighting. The selection of turbine was chosen depending on head and flow rate. The maximum different between high and low tide of Kanbalar Creek nearly 2.5 m and volume flow rate is approximately 7 m^3/s. The available period of each tide is 6 hr and then the available discharge is 0.46 m^3/s. So the propeller turbine type is chosen for 2 m head and 0.28 m^3/s flow rate to generate 3 kW power. The calculated runner diameter is 280 mm, hub diameter is 112 mm and number of blade is four. The calculated speed of turbine is 844 rpm. The runner blade is divided into five cylindrical sections. Two dimensional propeller blade of each section is calculated by using MATLAB programming and drawn by AutoCAD software. The type of three dimensional runner blades are also drawn. It is possible to construct this propeller turbine locally and can be replaced by imported turbine.

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