Optimized guiding vane for propeller turbine

J. Ab Razak[1,2,*], M. Musa[1,2], M.F. Abdul Razak[3]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] EFFECTS Research Group, Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Linatex Rubber Products Sdn Bhd, Lot Pt 19245, Lorong Haji Abdul Manan 2,
Batu 5, Off Jalan Meru, 41050 Klang, Selangor, Malaysia

[*]Corresponding e-mail: juhari@utem.edu.my

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ABSTRACT – Small scale hydro turbine is used for off-grid villages near the river. Pico hydro is usually selected for this purpose. One the efficiency criteria for this turbine is the velocity of water intake to the blade. The water enters the propeller turbine via the guide vane. Several parameters of the guide vane, which include number of guide vanes, and attack, inlet and outlet angles, are simulated in computer fluid dynamic (CFD) software. The optimized guide vane is further tested with varied flow rate. The simulation result shows a significant increase of water velocity intake to the blades**.**

1. INTRODUCTION

Most of current rural electrification program is using generator set to provide light and power to the off-grid villages. The problems of escalating fuel prices and its availability to these rural areas are making the generator set to be unattainable for long period usage [1]. In most villages the duration its operation is rationed to several hours at night. Concerns of the effect this type of fuel to the environment drive the authority to change to renewable energy alternatives. The location of off-grid villages usually near river, which make hydro power to be a suitable option for rural electrification.

Small scale turbine, a Micro or a Pico, can be utilized for this purpose, depending on the power produced and the load demand [2]. A micro turbine could produce up to 100 kW and a Pico turbine has a maximum capacity of 5 kW power. Pelton, propeller and cross-flow turbines can be used for micro hydro while Pico hydro can utilize propeller and cross-flow turbines [3][4]. The power production depending on two main variables; the head and the flow rate of water.

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

P	*Power*	*(Watt)*
η	*Efficiency*	
ρ	*Density*	(kg/m^3)
g	*Gravitational constant*	(m/s^2)
H	*Net Head*	*(m)*
Q	*Volumetric Flow Rate*	(m^3/s)

The head is the vertical height from the water intake into the penstock to the water intake to the turbine. The flow rate is in the form of volumetric flow rate at the inlet of the turbine. In certain cases both of the head and flow rate can be low, which require a good judgement in the selection of turbine type.

This research is intended to look at the effects of guide vane parameters to the propeller turbine performance. These parameters are expected to influence the water intake velocity to the blades. The water flow rate will be varied to ensure the consistency of the results.

2. METHODOLOGY

Guide vane parameters which most likely to effect the water inlet velocity to the blade are [5]:

a. Number of guide vane
b. Attack angle
c. Inlet angle
d. Outlet angle

It is important to determine the influence of the guide vanes parameters on water velocity since the kinetic energy of the water from the guide vanes affected the speed rotation of the turbine's blades [6]. Indirectly, this scenario will influence the overall performance of the propeller turbine. Other guide vane's parameters such as length, width and the height are fixed. Table 1 shows about the values of guide vane's parameters that involved in the investigation.

Table 1 Guide vanes parameters for the investigation.

	Standard	**New guide vane 1**	**New guide vane 2**	**New guide vane 3**	**New guide vane 4**
Length of guide vane			55 mm		
Width of guide vane			6 mm		
Height of guide vane			74 mm		
Number of guide vane	12	3	5	5	5
Angle of attack	67.5^0	14.09^0	22.23^0	42.72^0	10.3^0
Inlet angle	67.5^0	9.5^0	9.11^0	32.48^0	10.3^0
Outlet angle	67.5^0	67.51^0	45^0	69.56^0	69.08^0

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3. RESULTS AND DISCUSSION

The final overall design of the guide vane is as shown in Figure 1.

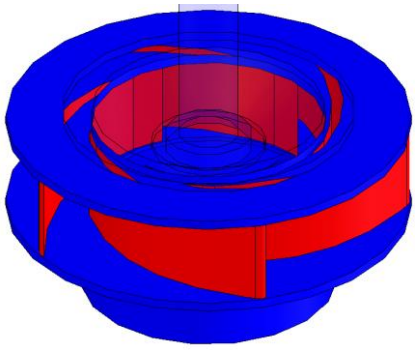

Figure 1 3-D representation of the guide vane.

The simulation indicated the flows of the stream velocity which occurred between the guide vanes. Figure 2 shows an example of CFD image for the related activities. The colours represent the values of the velocity where red colour is the highest value while the blue colour is the lowest.

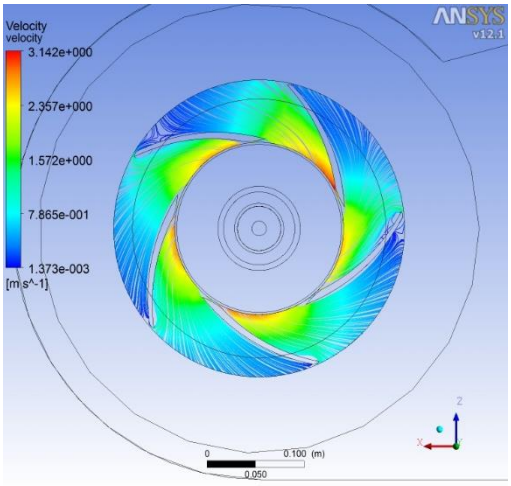

Figure 2 Stream velocity between the guide vanes.

Table 2 Maximum velocities for related guide vanes and water flow rates.

	Standard	New guide vane 1	New guide vane 2	New guide vane 3	New guide vane 4
Maximum velocity at 25 kg/s	2.27 m/s	3.93 m/s	3.14 m/s	5.67 m/s	5.81 m/s
Maximum velocity at 50 kg/s	4.52 m/s	7.87 m/s	6.32 m/s	11.33 m/s	11.63 m/s

For both water flow rate at 25 kg/s and 50 kg/s, the combination of guide vane's parameters for new guide vane 4 produced the highest amount of water velocity (Table 2 and Figure 3). The increment of the velocities for each flow rates were more than 50%. The reduction of angle of attack and inlet angle of the guide vanes from 67.5^0 to 10.3^0 contributed high significant impact on the values of the water velocity. However, in order to achieve this kind of result, the outlet angle must be increased from 67.5^0 to 69.08^0. In addition, number of the guide vane was to be decreased from 12 pieces to 5 pieces. Therefore, in order to obtain high amount of water stream velocity, the angle of attack and inlet angle should be lower than outlet angle. From the results for the flow rates of 25 kg/s and 50 kg/s, the maximum velocity are 5.81 m/s and 11.63 m/s respectively.

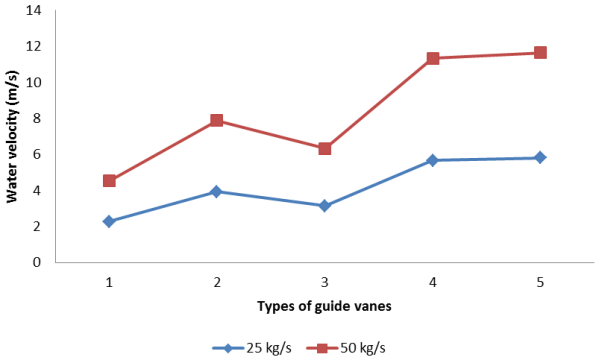

Figure 3 Graph of water velocity vs type of guide vanes.

4. CONCLUSION

Guide vane is one of the main component in propeller turbine that functions as a guide for water stream to flow through it before the water strikes the turbine's blades. This process is very important to provide high velocity impact of water stream (kinetic energy) to ensure the speed of the turbine rotates faster.

It can be concluded that the guide vanes angles and number of guide vanes will influence the stream velocity of the water in the turbine. The best combination of guide vane's parameters for both cases was new guide vane 4. The best combination of guide vane's parameters for both cases was new guide vane 4.

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