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Applicability of Darrieus-Type Turbine for Extra-Low Head Tidal Power Generation

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INTRODUCTION

At present, few tidal power stations throughout the world are equipped with conventional-type turbines operating at the total head of over 5 m, below which they become uneconomical. Therefore, a new kind of turbine system is proposed, equipped with the Darrieus-type cross-flow runner, having economically attractive features of simple construction, cost-effective structure, easy installation with little site work and easy adaptability for reversible flows caused by high and low tide condition with maintenance-free operation.

DARRIEUS-TYPE CROSS-FLOW TURBINE CHARACTERISTICS AND TIDAL GENERATING ARRANGEMENT

Darrieus runners are a lift device, in which the useful power is determined by fluid forces generated corresponding to the relative flow W and attack angle α^* as the aerofoil-shaped blade is passed by a flow of absolute velocity V. The flow passage configuration was selected to comprise either a parallel walled (denoted as P) or convergent inflow (denoted as C) section based on past investigations (Furukawa et al., 1998), which is then followed by a draft tube arrangement having $\theta_d = 9.5°$. Both types enable operation under reversible flows caused by high and low tides as shown in Fig. 1.

By considering the fundamental relationships for flow continuity, conservation of energy and power, under steady operating condition of the turbine, the following nondimensional similarity parameters with respect to flow rate (Q_{11}), rotational speed (N_{11}) and the output power (P_{11}) are derived (Furukawa et al., 1998):

$$Q_{11} = \left[C_h \cdot \left(1 + \frac{\zeta + C_v}{C_h}\right)\right]^{-\frac{1}{2}}, \quad N_{11} = (U/\overline{V}) \cdot Q_{11},$$
$$P_{11} = \eta_w \cdot Q_{11} \tag{1}$$

The Darrieus turbine configuration is characterized by these similarity parameters. Here $U/\overline{V}$ is the tip-speed ratio. These parameters are evaluated using experimental values of coefficient of head C_h, coefficient of flow loss ζ and coefficient of discharge loss C_v. η_w is measured turbine efficiency calculated as the ratio of the average output power of blades to the power with respect to total head H_t.

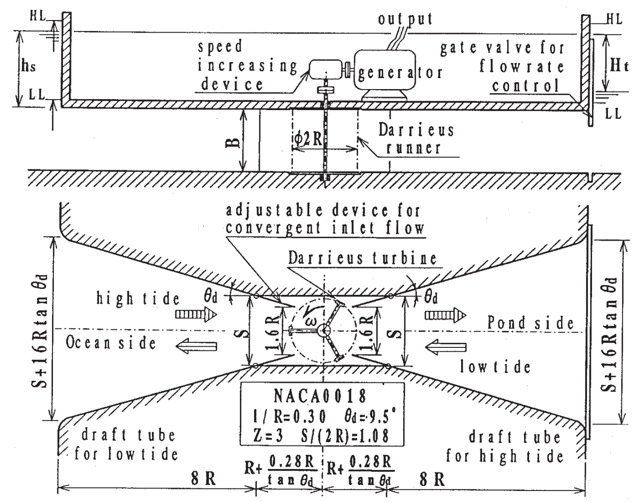

Fig. 1 Schematic view of tidal energy generating system

Table 1 indicates the values of the nondimensional similarity parameters of Q_{11}, N_{11} and P_{11} as well as the coefficients of C_h, ζ and C_v corresponding to the maximum turbine efficiency point for each duct type considered here. The quantities of power P, flow rate Q and rotational speed N can be evaluated by using Eqs. 2~4 as follows:

$$P = \rho \frac{BS}{2}(2\mathbf{g}H_t)^{\frac{3}{2}} \cdot P_{11} \tag{2}$$

$$Q = BS\overline{V} = BS(2\mathbf{g}H_t)^{\frac{1}{2}} \cdot Q_{11} \tag{3}$$

$$N = \frac{60}{2\pi R}(2\mathbf{g}H_t)^{\frac{1}{2}} \cdot N_{11} \tag{4}$$

where the size of turbine is specified as the cross-sectional area through the runner shaft, which is the product of blade span B and duct width S.

An induction generator equipped with a VVVF-type inverter was selected out of concern for the stability of the output power under unsteady input power (Kihoh et al., 1990). The generator efficiency of 80%, which is a typical value for a small generator of 5 to 10 kW rating (Mahon, 1992), and AVR (automatic voltage regulator) setting ON at 150 rpm were assumed for simulation.

Duct Type	C_h	ζ	C_v	P_{11}	Q_{11}	N_{11}	η_w
P	3.251	0.364	0.778	0.241	0.477	1.671	0.505
C	5.172	0.326	0.690	0.227	0.402	1.606	0.565

Table 1 Performance of Darrieus turbine at best efficiency point

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