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Marine current energy extraction through buffeting

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ABSTRACT

The research is an experimental study on the feasibility of marine current energy extraction through the phenomenon of buffeting. This phenomenon is a type of flow-induced oscillation of an elastic structure that is caused by the unsteadiness of the incoming flow. In order to prove the concept, a preliminary unit turbine model is designed working based on the buffeting phenomenon. The turbine model is an elastic structure, consisting of a rectangular flat plate located in a current flume. The elasticity is provided by attachment of four linear springs with equal rates (k) at the edges of the flat plate, to give an equivalent torsion spring rate. The unsteadiness is due to the wake of a bluff body located for this purpose in the upstream of the flat plate. The von Kármán street in the wake formed behind the bluff body induces oscillating moments in the flat plate which makes it to yaw with small angles of attack. The results demonstrate that one such system has the ability to extract hydrokinetic energy with efficiencies of up to 60%. The model tests results then are used to estimate the performance of the array of turbines, through the similarity analysis. Finally, a rough estimate of the manufacturing, installation and operation cost of the buffeting turbine subsea farm is presented.

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Nomenclature

A	projected area
a	distance of the elastic axis from the leading edge of the flat plate
b	damping coefficient
c	Chord length
D	D-section cylinder's diameter
h	water depth
I	mass moment of inertia of the flat plate about the yawing axis
I_{66}	inviscid added moment of inertia
k	linear spring constant
k_θ	equivalent torsion spring rate,
$M(t)$	hydrodynamic moment induced by the von Kármán street
P_{TO}	ideal power take-off per cycle by the yawing flat plate
Re_D	Reynolds number based on D
St	Strouhal number
U	current speed
ζ_T	damping ratio
η	hydrokinetic energy extraction efficiency
θ	yaw angle
Φ	phase difference between the yaw angle θ and the hydrodynamic moment M
ω	stimulation frequency
ω_n	natural frequency of the yaw motion of the flat plate

1. Introduction

In the recent years an international commitment has started to reduce the dependency on the fossil fuels, as a result of the environmental problems caused by them and also limitations of their supplies. Subsequently, several efforts have been done recently to find alternative energy sources that are clean and renewable. One of the alternatives is marine current energy and can be achieved through different ways. For instance, rotation-based turbines have been used as a conventional way of extracting energy from these resources during a long time. However, some researchers believe that the oscillation possesses important advantages compared with conventional designs [1,2]. As a result, the basic principle of the new paradigms proposed recently for marine energy recovery relies upon flow-induced oscillation, which results from the interaction between fluid flow and elastic structures.

As shown in Fig. 1, flow-induced oscillations are classified in two categories; resonance type and instability type [3]. In resonance type, the flow-induced forces and moments do not depend on the structural motion. In other word, the elastic structure begins to oscillate if the frequency of the oscillatory forces corresponds to its natural frequency. The oscillatory force can be either by the oscillating

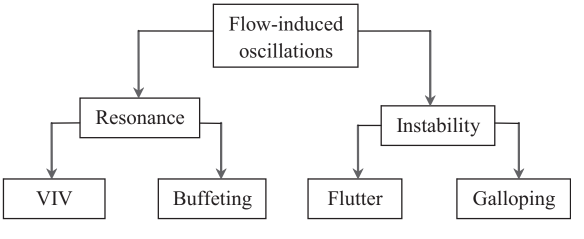

Fig. 1. Flow-induced oscillation flowchart.

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