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Short-Term Prediction of an Artificial Neural Network in an Oscillating Water Column

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An Oscillating Water Column (OWC) is a promising wave energy device due to its obvious advantages over many other wave energy converters: There are no moving components in the sea water. Though the bottom-fixed OWC have been quite successful in several practical applications, the projection of a massive wave energy production and the availability of wave energy resources have pushed the OWC applications from near shore to deeper water regions where the floating OWC are a better choice. In an OWC, the reciprocating air flow driving an air turbine to generate electricity is a random process. In such a working condition, a single design/operation point is nonexistent. To increase the energy extraction, and optimise the performance of the device, a system capable of controlling the air turbine rotation speed is desirable. For this purpose, this paper presents a short-term prediction of the random process using an artificial neural network (ANN), aiming to provide near-future information for the control system. In this research, the ANN is explored and tuned for a better prediction of the airflow and the device motions. It is found that, by carefully constructing the ANN platform and optimising the relevant parameters, the ANN is capable of predicting the random process a few steps ahead of the real time with good accuracy.

NOMENCLATURE

ANN = Artificial Neural Network
cfn = confinement of input data
eps = residual
E = error
f = activation function
H_j = outputs from hidden layer
H_s = significant wave height
it = iterative number
O = outputs from output layer
R = correlation coefficient
RRE = root relative error
t_i = target data for training ($i = 1, 2, \ldots, p$)
T_p = spectral peak period
W_{ij} = weights for hidden layer
x_i = input data ($j = 1, 2, \ldots, n$)
y_i = measured data ($i = 1, 2, \ldots, n$)
z_i = normalized/confined data ($i = 1, 2, \ldots, n$)
α = training rate
η = constant for weight modification
θ_j = biases for hidden layer

SUPERSCRIPTS/SUBSCRIPTS

new = modified values
old = old values
i = indicate numbering of input layer
j = indicate numbering of hidden/output layer

INTRODUCTION

Oscillating water columns (OWC) are one popular type among the wave energy converters due to their simplicity and nonmoving components in the sea water (the only moving component being the air turbine for power take-off), and they have been widely investigated in both bottom-fixed and floating devices. Both OWC types work on a same principle: The reciprocating air flow induced by the internal oscillating water surface drives an air turbine to generate electricity. The bottom-fixed OWC have been successful in practice so far, but they are only applicable in a few sites where the water depth is shallow, and the wave energy flux is large enough. For a massive energy production and availability of wave energy, the OWC devices need installing in the open and deeper water regions; thus the floating structures may be the only choice because of economic considerations. The floating types have challenged the researchers and developers in many aspects, as the device is designed to operate in the more severe wave/tide/current conditions and to survive in the most severe storms during its lifetime. To well address the engineering difficulties and economic issues before any massive commercial wave energy production, a step-by-step development protocol has been proposed by IEA Ocean Energy Systems (Holmes et al., 2010). The Protocol Development Phases outline an evolution for the ocean energy development. The first phase starts with a small-scale model (1:25∼1:100), then progressing to the second phase when a larger scaled model (1:10∼1:25) is used. The relatively small models in the first 2 phases can be studied physically and numerically, to address the device's functionality and the early-stage optimisation. The third phase may be a sea/field test with a scaled model (1:2∼1:10), followed by a larger model (1:1∼1:2) in Phase 4. In these 2 phases, a complete device, including the control system, power take-off, mooring system and grid connection, may be assembled. In these scaled levels, the engineering issues and economics assessments can be well emphasized. The final phase is the full-scale pre-commercial device, after almost all the major problems have been addressed during the wave energy development. It should be noted that in the development process, the experimental and numerical methods are both important in every stage. From these careful evolutions, it can be understood how difficult it is for an ocean energy device development to succeed.

At HMRC, extensive research has been carried out for the floating OWC, including the backward bent duct device (i.e. BBDD or

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