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

Wanan Sheng, Tony Lewis
Hydraulics and Maritime Research Centre, University College Cork, Ireland

ABSTRACT

Oscillating Water Column (OWC) is one type of promising wave energy devices due to its obvious advantage over many other wave energy converters: no moving component in sea water. Two types of OWCs (bottom-fixed and floating) have been widely investigated, and the bottom-fixed OWCs have been very successful in several practical applications. Recently, the proposal of massive wave energy production and the availability of wave energy have pushed OWC applications from near-shore to deeper water regions where floating OWCs are a better choice.

For an OWC under sea waves, the air flow driving air turbine to generate electricity is a random process. In such a working condition, single design/operation point is nonexistent. To improve energy extraction and to optimise the performance of the device, a system capable of controlling the air turbine rotation speed is desirable. To achieve that, this paper presents a short-term prediction of the random process by an artificial neural network (ANN), which can provide near-future information for the control system. In this research, ANN is explored and tuned for a better prediction of the airflow (as well as the device motions for a wide application). It is found that, by carefully constructing ANN platform and optimizing the relevant parameters, ANN is capable of predicting the random process a few steps ahead of the real time with a good accuracy. More importantly, the tuned ANN works for a large range of different types of random process.

KEY WORDS

Artificial Neural Network; Short-Term Prediction; Oscillating Water Column; Wave Energy Converter; Power Take-off and Control

NOMENCLATURE

RRE root relative error
W weights for the hidden layer
\( \theta \) biases for the hidden layer
ANN Artificial Neural Network

SUPERSCRIPTS/SUBSCRIPTS

\( \text{new} \) modified values
\( \text{old} \) old values
\( i \) indicate the numbering of the input layer
\( j \) indicate the numbering of the hidden/output layer
\( n \) time step

INTRODUCTION

Oscillating water column (OWC) is one popular type among the wave energy converters due to its simplicity and non-moving component in sea water (the only moving component is the air turbine for power take-off), and has been widely investigated either bottom-fixed or floating devices. Both types of OWCs work in a same principle where the reciprocating flow of air due to the inside oscillating surface of water drives an air turbine (mounted on the top of the structure) to generate electricity. The bottom-fixed OWCs have been very successful so far, but they are only applicable in a few sites where the water depth is shallow, and where wave energy is well concentrated. For massive energy production and availability of wave energy, the OWC devices need moving from seaside or near-shore to open and deeper water regions, and the devices are hence evolved to floating structures. Obviously, the floating types have many more difficulties, such as working in more severe wave/tide/current conditions, mooring design and device survivability etc. In addition, some other engineering and economic issues must be addressed before any massive commercial wave energy production. A good example is the Irish Protocol Development Phases, in which 5 step-by-step phases in the Ocean Energy Development process have been proposed (Lewis 2009). The very first phase starts with a small scale model (1:50~1:100); and progresses to the second phase when a larger scaled model (1:15~1:25) is used. The first two phases with relatively small models can be studied physically in laboratory as well as numerically, addressing the device functionality and early-stage optimisation. The third phase is a sea test with a scaled model (~1:4), followed by a larger model (~1:1.25) in Phase 4. In these two phases, a complete device, including control system, power take-off system, mooring system, and grid connection etc. has been assembled. In this scaled level, some