ERPem
Edinburgh Research Partnership in Engineering and Mathematics
http://www.erp.ac.uk

Energy

Network Integration of an Array of Wave Energy Converters

Anup Nambiar, Robin Wallace, Sasa Djokic

Introduction

The unpredictable and random nature of the wave energy resource causes voltage fluctuations when wave energy converters (WECs) are connected to the electricity networks. The power quality problem is compounded by the weak, rural grids to which most WEC farms will be connected.

Objectives

1. To explore the effects of increased device numbers, array size and physical positioning of the WECs in an array;
2. To demonstrate the overall effects of storage on real power production;
3. To study the effects of imaginary power control on network voltage profile.
4. To develop voltage control techniques for the network integration of wave energy farms. A two-level control strategy is envisaged.

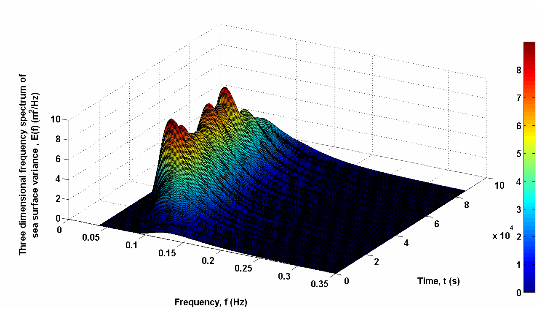

Fig 1. Frequency spectrum over a day.

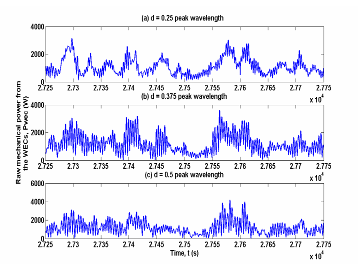

Fig 2. Instantaneous cumulative raw power for 6 WECs arranged in a line parallel to the dominant direction of wave propagation, with varying spacing (a)0.25λ_{peak} (variance=5.192e4), (b)0.375λ_{peak} (variance=2.0182e5) and (c)0.5λ_{peak} spacing (variance=2.7566e5).

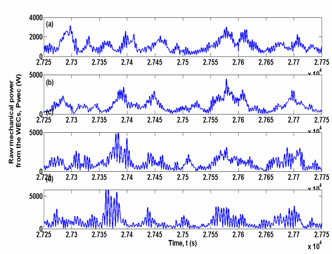

Fig 3. Instantaneous cumulative raw power for 6 WECs arranged in a line with varying orientation with respect to the dominant wave direction and with 0.25λ_{peak} spacing.
(a) α=0° (variance=5.1779e4),
(b)α=30°(variance=5.8850e4),
(c)α=60°(variance=2.1842e5), and
(d)α=90°(variance=4.7663e5).

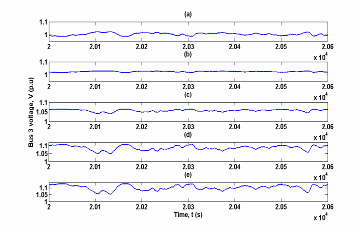

Fig 4. Voltages for various DFIG excitations with accumulator volume of 0.05m^3. (a) PF = 0.95 leading, (b) PF = 0.98 leading, (c) UPF, (d) PF = 0.98 lagging, (e) PF = 0.95 lagging.

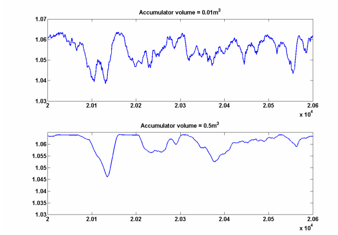

Fig 5. Comparison of the voltage, at the bus where the wave farm is connected, for two different accumulator sizes.

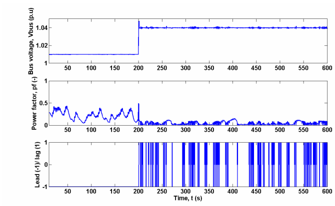

Fig 6. Constant voltage control using reference voltage 1.01 p.u. for the first 200 seconds and 1.04 p.u. for the remaining time.

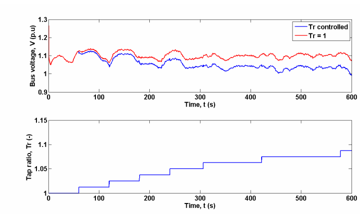

Fig 7. On Load Tap Changing transformer tap ratio and the voltage at the bus to which the wave farm is connected.

Progress

- Developed models of a directional, non-stationary sea suited for use on the west coast of Scotland.
- Studied the smoothing obtained in the raw mechanical power produced by physical positioning of the WECs within an array.
- Investigated methods to quantify voltage fluctuations in the network.
- Analysed the effects of a wave farm on the flicker intensity levels of the network.
- Currently examining the voltage control options available and their applicability to wave farms.

References

1. Kiprakis, A.E, and Wallace, A.R, "Time Domain Modelling of Wave Energy Converter Arrays in 3-Dimensional, Non-Stationary Seas", Proc. 1st UKERC SuperGen Conference, Oxford, 2008.

2. A. E. Kiprakis et al., "Modelling Arrays of Wave Energy Converters Connected to Weak Rural Electricity Networks," in Proc. of the 1st Int. Conf. on Sust. Pwr. Gen., China, 2009.

3. A. E. Kiprakis and A. R. Wallace, "Maximising energy capture from distributed generators in weak networks," IEE Proc.-Gener. Transm. Distrib., Vol. 151, No. 5, september 2004.

A.Nambiar@ed.ac.uk, Institute for Energy Systems, Joint Research Institute Energy, Edinburgh Research Partnership in Engineering and Mathematics, School of Engineering, The University of Edinburgh, Faraday Building, The King's Buildings Edinburgh EH9 3JL