Electricity Network Integration of Wave Power Farms

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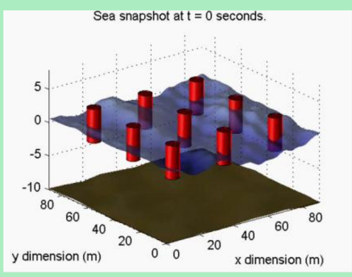
Work stream 7: Advanced Control and Network Interaction

Abstract

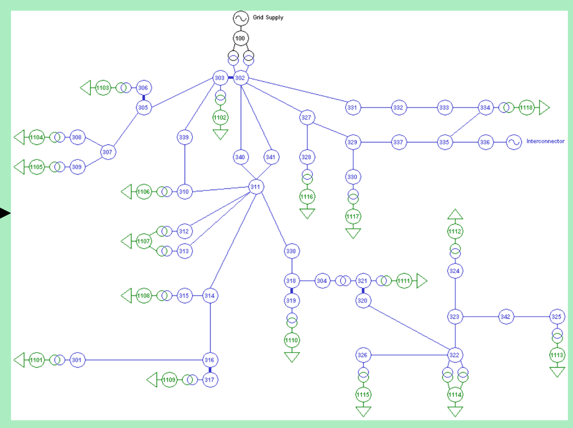
Optimally placing the wave energy converters (WECs) within a wave power farm and the use of **intelligent voltage and reactive power control algorithms** applied to the farm, reduce to a large extent the **voltage fluctuations** introduced in the network by the farm and help keep the network voltage within statutory limits. Means to **coordinate the control** of the wave power farm and the other voltage control elements in the distribution network can be devised to ensure that they complement each other.

Introduction

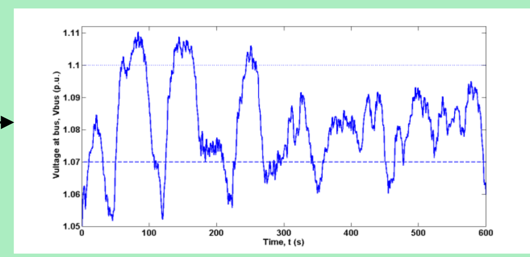
The unpredictable and random nature of the wave energy resource causes **voltage fluctuations** when wave energy converters (WECs) are connected to the electricity network. The power quality problem is compounded by the weak, rural grids to which most wave farms will be connected. Hence, some control means are required which would ensure that the **voltage remains within statutory limits** for as long as possible.



Wave power farm



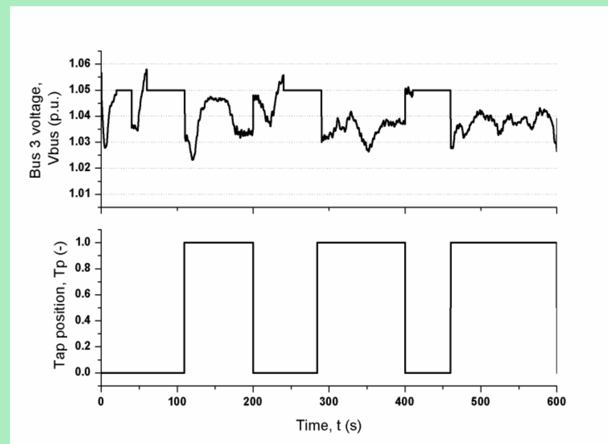
11kV UK distribution network

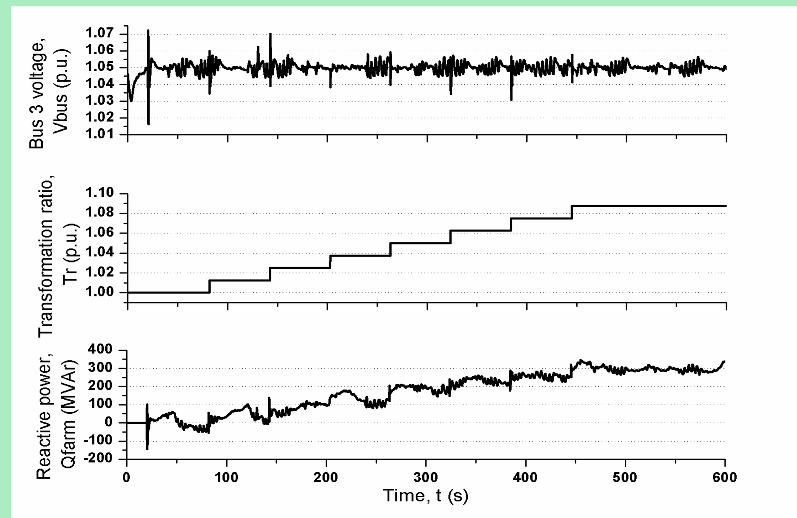


Voltage fluctuations introduced in the network

The need for coordination

The control of the substation On-Load Tap Changing (OLTC) transformer and the intelligent control of the wave farm will need to be **coordinated to avoid unnecessary tap operations and runaways**.



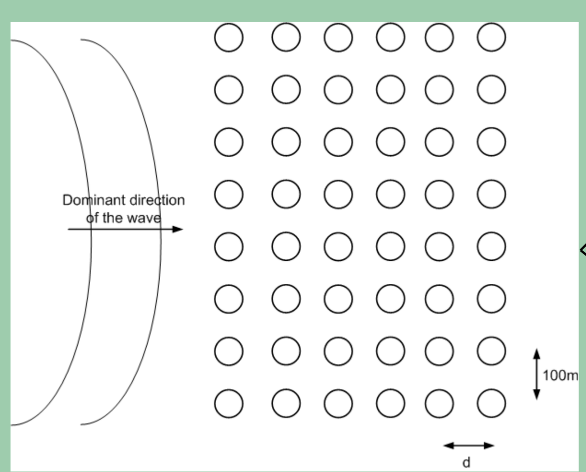


Unnecessary tap operations due to uncoordinated control

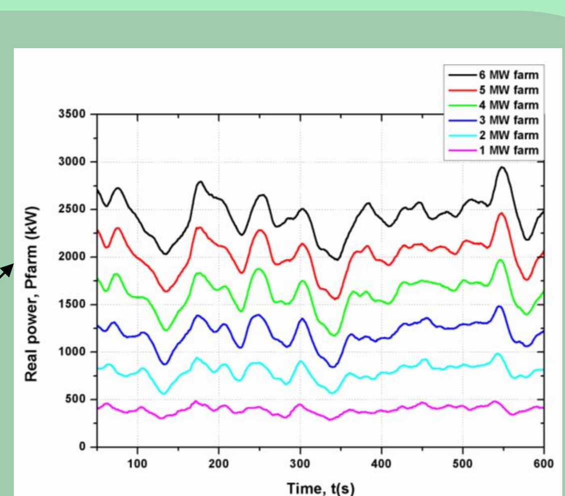
Reducing voltage fluctuations

Sea side

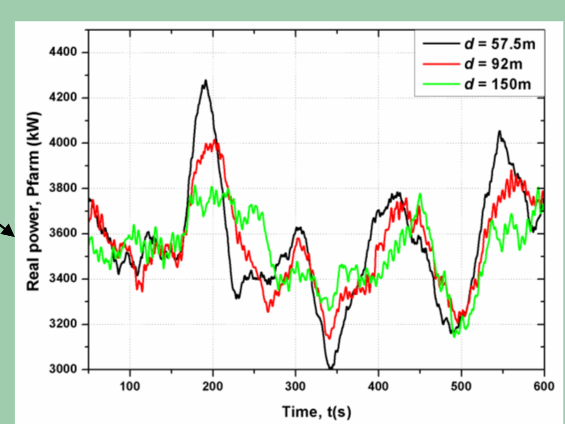
Will **optimally spacing** the WECs and **orienting** the array help?



Wave power farm with 48 WECs



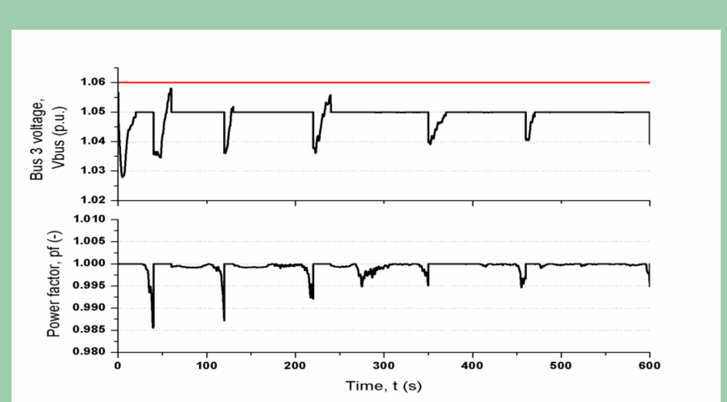
Increasing the size of the farm



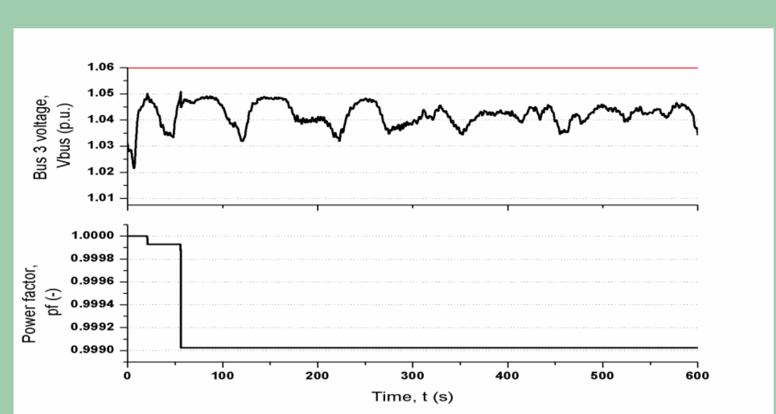
Changing the spacing between WECs in a farm

Network side

Generators have been conventionally operated either at a constant power factor or at a constant voltage. In **Automatic Voltage and Power Factor Control** (AVPFC) method the control modes are switched depending on the energy content of the seas. A **Fuzzy Logic Power Factor Controller** (FLPFC) has also been developed to control the operating power factor of the wave farm, which again ensures that the voltage lies within limits.



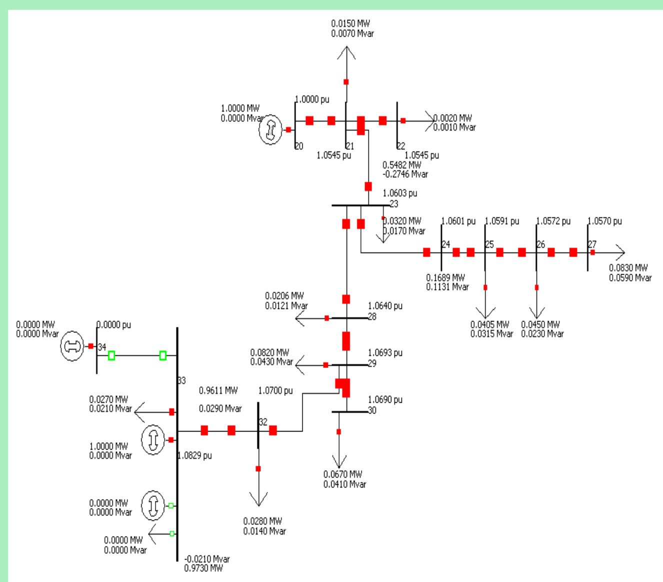
Voltage and power factor when the wave farm operates with the AVPFC controller



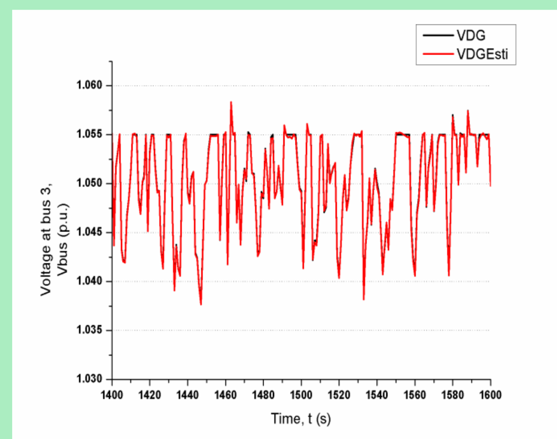
Voltage and power factor when the wave farm operates with the FLPFC controller

Voltage estimation and coordination

A procedure using which the substation OLTC transformer can **sense the voltage** at the bus where the wave farm is connected has been developed. It only requires **archives of load data**, normally collected at substations, and has **no communication requirements.**



Radial test network



The estimated and measured voltage time series

Conclusions

1. **Optimally spacing** the WECs or the columns of WECs in a farm produced much **smoother real power** time-series
2. **Intelligent voltage and power factor control** algorithms were tested and their use **improved** the **quality** of the network voltage.
3. **Coordinating** the control of the farm with the other voltage and power factor control devices in the network, through the use of the developed **demand predictor** and the **voltage estimator**, gives a chance to use the wave power farm for **benefiting the wider network**.

References

[1] A. J. Nambiar et al, "System identification of a wave power farm for power systems studies," submitted to the IET RPG, August 2011.

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