II.C Deployment and Performance Assessment of Multi-Megawatt Device Arrays

Purpose of Deployment and Performance Assessment of Multi-Megawatt Device Arrays

To deploy and operate marine energy devices in significant numbers in order to:

(1) Generate significant amounts of power and deliver this power to electrical infrastructure on shore, and

(2) Demonstrate safe processes and acceptable cost in deployment, commissioning, operation, maintenance and decommissioning of devices and their infrastructure, leading to reduced costs per device associated with an increased scale of deployment at a single site.

Objectives of Deployment and Performance Assessment of Multi-Megawatt Device Arrays

A. To plan and install a large number of devices in the marine environment in order to extract energy and convey this energy to shore;
B. To plan effective deployment and maintenance schedules such that:
   i. The need for direct intervention is minimised in terms of number of operations and their duration;
   ii. Where intervention is required the associated difficulty is reduced to an acceptable level;
C. Identify the most appropriate configuration and electrical connection of devices;
D. To optimise the energy capture of individual devices such that the efficiency of power conversion is maximised from the array;
E. To standardise performance parameters from an array. Due to potential device interaction these will be different to those of an individual device operating in isolation;
F. To share systems (such as electrical connections) between devices such that the costs are reduced compared to an equivalent number of individual devices operating in isolation or a smaller-sized array.

Reporting from Deployment and Performance Assessment of Multi-Megawatt Device Arrays

The pre-deployment actions should:

1. Identify supply-chain bottlenecks and potential barriers to successful installation. This will break down into the following categories, each considered for land-based and marine-based actions:
   a. Device support structure fabrication and transportation

    b. Device installation
    c. Subsea cabling, including any device hub structure.

2. Characterisation of the key Operation and Maintenance issues that will lead to disruption, based upon a set of criteria similar but not exclusive to the following:
    a. Cost of operational/maintenance action
    b. Frequency
    c. Ease (weather window, availability of equipment, etc.)
    d. Array down-time (availability)

3. Indentify the optimal electrical connection of the array to convey power to shore. Issues such as safety, power quality and reliability should be addressed.
4. Identify present data sources for quantification of marine energy resource at suitable array sites. Produce a matrix to cross compare data sources (separate for wave and tidal) to appraise the following qualities:
    a. Measurement source (measured, empirical, numerical simulation)
    b. Measurement frequency (e.g. daily, monthly)
    c. Spatial coverage (adequate for array energy calculations?)
    d. Accuracy
5. Consider previous documented evidence of device performance, flow field effects and device interaction.
6. Review the envisaged array energy capture efficiency with regard to inter device spacing. This will be coupled to the individual devices specified or rated performance parameters that may vary with position within the array.

The performance assessment should:
1. Classify wave and tidal devices:
    a. To aid cross-comparison of array performance and match specific devices to their optimal sites.
    b. To define and quantify device performance parameters
2. Address risk reporting and remediating actions taken in order to improve future array design and performance.
3. Qualitatively address the effect of the array on the surrounding resource.

Contents of Protocol

1.Pre-deployment

This section of the protocol will:

1) Classify devices according to a systematic template.

2) Provide guidance on assessing the supply chain for the devices and their installation.

3) Provide guidance on determining appropriate electrical connections and the intra-array electrical design taking into account the exported power quality.

4) Provide guidance on shared sub-systems.

5) Provide guidance on the spatial layout of the array to optimise power production and ensure ease of access for operation and maintenance.

2.Performance assessment

This section of the protocol will:

1) Provide assessment methods for a systematic approach to quantifying performance parameters for

    a) individual devices within the array
    b) whole array performance

2) Describe a systematic approach to the recording and reporting of temporal information including device performance, service and inspection logs and reliability data.

3. Exclusions

1) Marine spatial planning considerations for large-scale deployments.
2) Permitting issues.
3) Operation and maintenance issues will not be covered in detail as they are highly device-specific in nature.

Principles

4. Pre-deployment actions

- The parameters affecting the requirements from the supply chain should be identified with regard to their impact on full deployment of all devices in an array within an acceptable timeframe. The appropriate time in the development of the design to do this should also be identified.
- Options for installation of different types of device configuration (mooring configurations or other configuration fixing the device in an array) should be identified, and the most efficient ways of using the equipment should be discussed with the aims of reducing time required for installation of whole arrays and impact on ultimate cost of energy.
- Barriers to successful and timely installation should be identified and ranked in order of disruptiveness. Remediating measures to be specified.
- The output from previous studies (tank tests, sea trials) should be used to identify the best configuration for the farm in terms of positioning of and distance between units while considering full-scale issues such as installation and access to the array.
- The factors influencing the choice of electrical configuration of the devices such as the number of devices and distance to shore should be discussed.
- Appraisal/Comparison of existing metocean resource data (measured, simulated, historical, etc.) available for a typical array site should be critically analysed. Quantification of expected accuracy/ability to extrapolate short term/limited data sets for the prediction of long-term energy yields should be performed accompanied with method description and justification.

5. Performance Assessment

- The data required from previous stages for an assessment of the minimum maintenance requirements of an individual device should be identified. The method of extrapolating and applying this data to plan the most effective maintenance regime for the farm should be defined.

- The method of applying the data from the site assessment to the power performance predictions from the tank tests and sea trials to produce a power output prediction for the array should be defined.
- The method of estimating the overall availability of the array should be discussed.
- Continuous data collection on the metocean resource of the area of deployment should lead to reduction of uncertainties on the resource expected in the site. The data should be compared with earlier evaluation for reassessment of the expected power generation for the farm.
- Device interaction and interference should be monitored considering sea states close to the boundary and within the array. Power generation and loading forces of individual devices should also be measured.

Key Aspects

1. Early arrays are likely to be composed of less than 10 devices aligned in a linear manner perpendicular to the incoming resource direction (if device performance is dependant upon resource direction) or possible a geometric pattern (if not directional). The size of arrays, the degree of interaction between devices and general complexity of arrays will increase over time.
2. The influence of a marine energy converter upon the local spatial flow field will vary between different types of devices and also with the nature of the incoming marine resource. Therefore array design and layout is expected to be device specific.
3. As technology improves and new equipment is developed the manner in which arrays are designed and operate will invariable change. It is possible that quantitative aspects of this protocol may then require amendment. Where possible, qualitative recommendations will be given to avoid this.
4. When a device is positioned within an array and is subjected to interaction effects, the inflow of energy from the marine environment will differ to that of other devices within the array. Thus an ‘available resource’ will exist and is likely to be different for many of the devices that compose the entire array. Differentiation between this available resource to individual devices and the inflow resource to the total array will be a key aspect to understanding array performance.
5. The nominal performance metrics of devices such as rated and cut-off power generation are likely to be redefined throughout an array due to the issue raised in (4) of available device resource. Methods to standardize this will aid array performance quantification but it is acknowledged that device performance metrics are presently defined by the device developer and thus standardization of all arrays may be difficult at this time especially considering issues raised in (2) and (4) above.

6. The factors affecting site selection (including requirements for maintenance, distance to shore, probably power output) should be discussed.
7. Collection of data should separate the early stage reliability problems to the long term / degradation issues affecting reliability
8. Mean time to failure/essential maintenance for key components/sub-systems to be estimated. Methods for extending these time periods to be explored.
9. Device interaction and interference should be monitored considering the sea state at the farm, power generation and the loading response of devices. The level of monitoring; current, waves, wind between devices, condition monitoring of a few devices (how many devices to be monitored), etc. should be defined based on the criticality of monitored parameters, level of uncertainty and the urgency that the conclusions should be derived.
10. The duration of monitoring should be based on the minimum required statistical basis. Associated uncertainty should be defined and reported.