Articulated Wind Column
Jean Charles DiSchino, ODE, UK
Garron Lees, ODE, UK
Dr. Peter Broughton FEng, MEES, UK
Richard Davies, MEES, UK

Abstract
The development of Offshore Wind as a source of energy is being pursued in many countries throughout the world. In the UK the development of offshore wind has been restricted to relatively shallow water locations, with many of the planned sites being a considerable distance from shore resulting in high installation, maintenance and electrical transmission costs. The development of “floating” or “compliant” substructures, such as the Articulated Wind Columns, allows development of mid to deep water sites which are closer to shore. This paper describes the main technical features related to the Articulated Wind Column. This structure can be adopted over large areas of the offshore UK and the continental shelves around the Republic of Ireland, France, Spain, India, Taiwan, China, Japan and the USA. With the capability to accommodate the largest turbinie of any configuration and the optimisation/minimisation of power transmission cable lengths, together with the introduction of modern methods of mass production/mass fabrication of substructures, this allows economic development of future offshore wind fields to be competitive with other methods/form of electricity generation, with an estimated worldwide potential market of around 4,500GW.

The Articulated Column solution, which is suitable for the support of large wind turbine turbines offshore, is considered to be an extension to proven technology with the use of development 13 similar offshore loading columns in the North Sea environment.
How did we calculate this number?

Introduction
In the UK to date, the development of offshore wind turbines has been restricted to relatively shallow water locations, with many planned sites being a considerable distance from shore resulting in high electrical transmission costs.

However, the creation of “floating” or “compliant” substructures which have enjoyed widespread use in the oil and gas industry, is allowing the development of deeper water offshore wind opportunities, which are closer to shore.

One such technological advancement is the creation of the articulated wind column (AWC) which has been developed jointly by Marine Engineering Energy Solutions Ltd and Engineering and operations support services contractor ODE, part of the Dorris Group.

The Dorris Group has a successful history in designing some of the world’s largest offshore structures. In the early 1980s, it created the world’s only concrete offshore loading columns, for the Maurene field, which operated successfully in the North Sea until it was decommissioned at the end of the field’s life in 2001.

The AWC provides a means of structural support in offshore waters for the largest wind turbines currently available (BMW6) and is designed for use in water depths ranging from 45m to 200m.

The structure’s design offers the opportunity for it to be constructed using steel, or more preferably, reinforced concrete, which allows greater cost reductions and potentially higher local content.

The use of concrete as the primary material in construction of the AWC results in a design which is also highly amenable to mass production. Versatile and modern construction methods enable the use of infrastructure and capabilities which are local to the offshore wind farm development locations. 70 to 150 m.

The Benefits

The general arrangement of the AWC can be seen in Figure 1. This particular arrangement shows the support of a BMW6 turbine located in 90 metres of water. The structure essentially consists of two main elements: the compliant vertical column and the base which is located on the seabed.

The two main parts are connected by an articulated joint, which allows rotation about both horizontal axes. The two main elements are constructed separately, but joined together prior to marine transport and installation.

The performance of the compliant column in being able to achieve a near vertical position is through the natural buoyancy of the column. Because in deeper waters, the distance between the column and base, the column and base design allows for unevenness of the seabed. The stability of the unit on the seabed is achieved by the placement of heavy iron ore ballast offshore.

Articulated Joint Design
The articulated joint and support consists of three main components:

- the cast articulated joint
- the upper support to the underside of the column
- the lower supports to the top of the transfer beam on the base

Figure 4 provides a 3-dimensional view of the steel casing (Dorris Articulated Joint) with an estimated weight of 120 tonnes with a grade of steel adapted for this unit being C34N (400/440kN/mm²). Figure 5 provides a typical stress plot of the casing when subjected to extreme conditions. The peak stress in this case equates to 2484N/m², which is considerably less than that allowed for by the grade of steel.

Onshore Fabrication
In order to achieve a high production rate, well proven modern procedures and processes have been adopted for the construction of both the columns and bases.

The compliant vertical column units are planned to be constructed as two half units, which will be subsequently joined together and post-tensioned prior to placing in the water for mating with the base.

The two half column sections, each about 45m in length, will be constructed in the vertical by the use of variable slap forming techniques. Rates of variable shaping will be about 35m/day, with the combination of a half column section being in about 20 days, allowing for sub-lab construction.

Figure 6 shows a sequence of downwinding a half column section prior to transportation to the column assembly area where the two half column sections would be joined together and post-tensioned.

Installation
Once connected the completed base and column unit will be towed either to a wet weather storage area or directly to the proposed site, as shown in Figure 7.

Figure 8 shows the final placement of heavy iron ore ballast into the 10 base cells together with the debalasting of the column. It is estimated that total ballasting of the 10 cells in each base would take approximately 6 - 8 hours. Final placement of the upper steel shaft, turbine and blades is achieved with the use of a heavy lift crane vessel.

Conclusions
The development of the AWC is based on a proven, robust technical solution suitable for the harshest environmental conditions. It has a simple installation and removal process, based on a design successfully used by the oil and gas sector in the North Sea for many years.

The solution allows for installation on an unseaman without the need for seabed preparation.

The use of deep water locations relatively close to shore (125m) allows shorter cable connections to the shore, which otherwise would provide a significant component to the overall development costs.

This type of structure provides a unique and economic solution for offshore turbines located in deeper water close to shore. The estimated levelised cost of energy in adopting the AWC in deeper water close to shore is marginally less than £69/MWh, with a rate of return (IRR) of about 18%.

Model testing and analysis combined with experience from deployment in the oil and gas industry have demonstrated that Articulated Wind Columns can be used as a means of support for a large wind turbine in deep water at northern locations.

This structural form now allows for the economic development of offshore wind technology at many nearshore sites around the world.

References