ARTICULATED WIND COLUMN (AWC)
OFFSHORE DEEP WATER WIND TURBINE SUPPORT STRUCTURE
(45m-200m)
June 2015
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1 - Executive Summary

- The AWC is an EU and USA Patented substructure for offshore wind turbine generators, developed jointly by MEES and DORIS Engineering.
- The AWC is suitable for 45m to 200m water depths
- Shallower water depths down to about 45m can be accommodated with the adoption of the cable stayed clump weight solution
- The AWC is based on a proven, robust technical solution suitable for the harshest environmental conditions.
- The AWC has a simple installation and removal process, based on a design successfully used by Oil and Gas in the North Sea.
- The combined supply and installation cost for the AWC foundation, in the range of water depths between 80m and 200m, is highly competitive with any other offshore wind foundations.
2 - MEES / DORIS

• Marine Engineering Energy Solutions Limited (MEES) based in SE England was set up to develop renewable energy projects within a marine/offshore environment. The company contains decades of experience in the offshore oil and gas and the renewable industry.

• DORIS Engineering (DORIS) based in Paris are a substantial offshore engineering design contractor, who have been responsible for some of the world’s largest offshore structures. They also designed the world’s only concrete offshore loading column (Maureen). Set up in 1965, DORIS employ about 400 highly qualified staff.

• MEES and DORIS are working in partnership to develop the AWC through to prototype and production stage, and have been working together on the project since 2010.
Articulation at the base provides for a compliant column with reduced forces on the column and base.

Buoyancy and hydrodynamic inertia provide stability.

Behaviour/performance of the column is achieved by designing the diameter to suit the water depth and environment

The performance of the AWC is best suited in the range of 50m to 150m.

For water depths in the range of 45m to around 80m the cable stayed clump weight solution is used.

Technology of the articulated column is based on 40 years well proven oil and gas experience.
Maureen Articulated Column, in 93 m Water Depth, installed in 1982

Comparable wind force on larger turbines:
Design load of hawser (tanker pull) equal to 210 tonnes

Designer:
DORIS Engineering

Conclusion:
This type of structure is proven/tested and has operated since the 80’s
13 Articulated columns have been installed within the North Sea for Offshore Oil & Gas Industry: 12 steel and 1 concrete, namely:

The Maureen loading column (topsides, column, and base) was installed as one single unit offshore.

The Maureen Articulated Loading Column was provided with a winch-down helideck and temporary accommodation.

Built in: 1982
Decommissioned in 2000 at end of field life.
Total operational life of 18 years.
The column, base and articulation were removed as a single unit in good working order.

Such structures should be designed for and should last many decades without maintenance.

Total operational experience of 13 columns is in the order of several hundred years, and several of them are still in operation.
5 - Safety

As an another example, North East Frigg Control Tower, 102 m water depth, 126 m high, Steel construction, 14.6 m diameter, operated from 1981 to 1995. Supported stable permanent accommodation for 12 persons in the harsh North Sea environment

Minimum seabed preparation is required and no divers are employed during installation
6 – DECC Grant Award

MEES together with DORIS were awarded a grant from the Department of Energy and Climate Change (DECC) at the beginning of 2013. This has been used to develop the articulated wind column (AWC) and to take the design process through the Front End Engineering Design phase (FEED). Funding provided by DECC represented approximately 50% of the project costs.

Current Status

• Submitted a detailed technical and commercial proposal to DECC in July 2012.

• DECC awarded a contract to cover phase 1 work, starting 2nd April 2013. This was completed in August 2013.

• DECC awarded a contract to cover phase 2 work, starting on 4th July 2014 which ended in mid June 2015.
7 – AWC Development

Phase 1 DECC Part Funded
• Reviewed with onshore fabricators, wind turbine manufacturers and UK third round licensees
• Developed soils and METOCEAN data for Phase 2 works
• Provided specification for model testing
• Provided an updated cost estimate

Phase 2 Part DECC Funded
• Performed motion analyses and design of the AWC
• Model tested 1:42.5 scale for a number of environmental and operating conditions
• Used model testing data to refine a computer simulation model in order to simulate any operating and extreme conditions
• Continued working with Wind Turbine Manufactures and third round licensees
• Provided an updated cost estimate of the AWC substructure fabrication and installation
• Investigated industrialisation/mass unit production
• Completed economic analysis in order to provide estimated Levelised Cost Of Energy (LCOE)

• All of the Phase 2 study work was completed in mid June 2015
Three weeks of model testing was successfully completed at the end of 2014 at Oceanide SA, located in the South of France near Toulon. Oceanide are owners and operators of a world class test basin, used for simulating environmental conditions such as waves, currents and wind, on fixed or mobile structures.

The 1:42.5 scale model was tested in simulated weather conditions of extreme storm, operating and also maintenance in a water depth of 90 metres. This included testing the model under wind loadings, current and wave forces, providing results which were in line and in some cases better than calculated.
8 - Patents

- MEES and DORIS have been awarded an EU Patent on 23rd April 2014.

- Patent in the USA, was also granted on 21st October 2014.

- The patents cover several variations of the AWC which includes a compliant buoyant column attached to a joint and foundation located on the seabed providing a structure onto which a Wind Turbine Generator (WTG) can be mounted.

- The patents cover all European Union (EU) countries. At the present time the UK, France, Spain, Ireland and Norway have been listed and other countries within the EU will be added shortly
9 - AWC Advantages

• The AWC is a low cost (construction, installation and operation) wind turbine substructure for water depths in the range 45m to 200m

• Suitable for Large Wind Turbines (e.g. 8MW MHI Vestas, 7MW Siemens or 6MW Senvion)

• The AWC requires **MINIMUM** seabed preparation and can accommodate an uneven seabed

• Foundation stability is not affected by any possible scour, as the base does not need to be horizontal. Design of base is also expected to generate reduced scour

• The AWC is based upon a robust design concept which has been proven to resist harsh North Sea conditions over several decades

• Quick, safe and environmentally friendly installation and decommissioning processes.
Its application in DEEPER WATERS CLOSER TO SHORE provides lower Levelised Cost of Energy (LCOE) since it also benefits from lower grid connection costs and lower transmission cable electrical losses than alternative shallower water sites which are located further from shore.

The most obvious advantage of selecting locations close to shore (20 km to 40 km) are:

- lower electrical losses
- reduced connection costs to shore
- reduced maintenance costs
- less potential damage to cables
- no need for offshore electrical transformation (AC to DC), which usually applies to distances greater than 80km from shore

As an example, the recently developed DolWin Alpha and Beta fields offshore Germany were located 75km from shore and required offshore power transformation (from AC to DC). The weight of the topsides units for these projects was around 9,000 tonnes and 10,200 tonnes respectively, with consequentially significant costs for procurement, fabrication, and installation.
10 - Construction

- The AWC is suited to volume construction and can be manufactured at one or multiple sites to suit production requirements.

- The column and base can be constructed in either concrete or steel.

- The bases and columns can be fabricated at different locations, then mated before transport to site.

- The figures below show the previous assembly of the Maureen Articulated Loading Column (at Kishorn, West of Scotland).
• Fabrication yards around the UK and European shores have been visited to identify suitable multiple manufacturing facilities

• An opportunity exists within the UK to develop quay areas (e.g. the Port of Hull, Ardersier, Greenock, Milford Haven, Seaton (Teesside) and Belfast), for the purposes of construction of the AWC in large numbers and over a shorter time frame

• It is considered that 50 units per site per year is achievable. This would generate significant job opportunities within the UK and also the AWC column production could be considered for non-UK license areas (EXPORT).
11 – Prototype Testing

Whilst the main components (column, articulation and base) of the AWC are proven, prototype testing is considered necessary in order to demonstrate the adequate performance of the turbine and foundation. We are currently considering several offshore site locations around the UK for prototype testing. Discussions/reviews are on going.

Test Requirements

• The preference for testing is at full scale in around 80 metres of water depth. This would allow testing of the largest turbines in the range of 6 to 8MW (e.g. 8MW Vestas, 7 MW Siemens or others)
• It is possible to test at water depths between 50 to 80 metres, with a large turbine (eg 8 MW) using the Cable Stayed Clump Weight Solution
• It is also possible to test a smaller turbine size (e.g. 3MW Vestas or 2.3MW Siemens) at shallow water depths based on the current design concept
• The proposal is to test at least one AWC structure supporting a turbine
• The AWC is largely insensitive to different seabed soil conditions including any out-of-level conditions
12 - UK Wide Opportunities

UK Deep Waters

Key:

Yellow Hash = >50 metres

Pink Hash = >80 Metres