**Abstract**

Universal Foundation has in cooperation with a group of Carbon Trust Partners and Aalborg University conducted an offshore campaign on Dogger Bank, Hornsea and Dudgeon to confirm the bucket concept installation process.

The UNIVERSAL FOUNDATION bucket is a novel foundation concept with potential for significant cost reduction in the water depth range of 15-55 m with large rotor wind turbines.

These benefits, include reductions in installation costs (no piling or seabed preparation, no hammer/vibrator noise, fast installation process) and fabrication costs (simple monopile design with no Transition Piece), and the ability to function on a wide range of soil conditions.

**The Offshore bucket Project History:**
- Summer 2011 project initially proposed by Carbon Trust in OWA
- Summer 2012 interested partners E.ON, DONG, Statkraft, Statoil
- Statoil nominated as Lead Participant
- Scaled down SMM design planned to be trialled
- 4 x test locations on Dogger Bank
- Cost indication: £4.5 project (£2.0m from OWA and £2.5m from UF and EUDP)

**Objectives**

The trial Installation activity was undertaken by the Carbon Trust Offshore Wind Accelerator to further de-risk the Universal Foundation bucket concept and move it towards full commercialization. A main issue is to calibrate the calculation factors for the penetration prediction used in DNV - Foundation 1992 - classification notes NO. 30-4 and the Aalborg University method.

It is generally considered complicated to install skirts"buckets" in multi-layered soils including "impermeable" clayey layers and other profiles containing dense sandy soils. Furthermore, the verticality control for single compartment structures is not so well documented.

The main risks associated with the installation process have been identified as:
- Installation of the bucket foundation in difficult soils (e.g. clay and layered soils)
- Achieving verticality during installation
- Robustness of the skirt during handling and installation

The trial bucket foundation was a scaled-down foundation design, 8 x 6 m (D x H), weighing approx. 60 tons. The multi-shell skirt design with clay chambers was used. For reference a cylindrical probe of 4 x 6 m was installed in parallel.

**Project goal:**
- Planning operations at Dudgeon, Hornsea and Dogger Bank wind farm zones
- Acquire as many tests as possible in a 28 day offshore period using the Fred. Olsen Windcarrier jack-up vessel Brave Tern
- Site selection aim to test performance in challenging layered soils (clay over sand) and other conditions representative for UK Round 3 wind farm sites

**The Trial Campaign**

The trial bucket and the reference bucket were fitted with instrumentation at quay side in Frederikshavn, DK. The instrumentation for the different measurements compiled of:
- Accelerometers: Movements during splash-zone penetration
- Inclinometers: Verticality during installation
- Pressure gauges: Driving force during installation and penetration depth
- Flow meters: Seepage and water injection
- Echo sounders: Penetration depth and plug heave
- Strain gauges: Stress in skirt and lid structures.

The deck layout on the jack-up vessel Brave Tern. Right side: Reference bucket ready for deployment.

**Results**

**Route and Positions**

Full penetration

Full penetration was demonstrated by use of an internal soil levelling system which enable to remove the plug heave.

**Examples of test results**

The plots presented from left to right: Predicted maximum penetration calculated in accordance with the standards. Actual penetration. Inclination during installation.

**Conclusions**

The Bucket trial Installation project has gathered a substantial amount of data in a unique soil database which enable update of the used standards for penetration prediction. This update will lead to less conservative design of bucket foundations and is vital for the aim of cost reduction in the offshore wind business. Furthermore serial offshore operation with the bucket concept was demonstrated, achieving full installation depth and inclination within given tolerance.