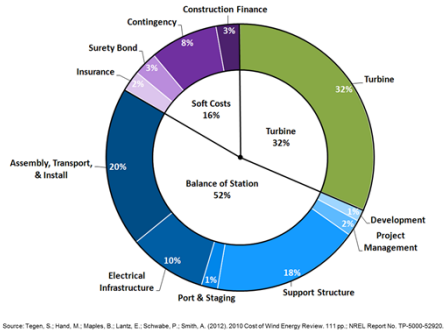
VIRGINIA OFFSHORE WIND COST REDUCTION THROUGH INNOVATION STUDY (VOWCRIS)

B. Maples • National Renewable Energy Laboratory • Golden, Colorado
J. Campbell, D. Arora • Alstom • Richmond, Virginia

Introduction

- With estimates of turbine, foundation, and installation costs for offshore wind plants upwards of two thirds of total project investment cost, there is an increasing focus on identifying opportunities to reduce these costs.
- The VOWCRIS project is an integrated systems approach to the feasibility-level design, performance, and cost-of-energy estimate for a notional 600-megawatt offshore wind project using site characteristics that apply to the Wind Energy Areas of Virginia, Maryland and North Carolina.



Source: Tegen, S.; Hand, M.; Maples, B.; Lantz, E.; Schwabe, P.; Smith, A. (2012). 2010 Cost of Wind Energy Review. 111 pp.; NREL Report No. TP-5000-52920.

- Project work has a special focus on three areas of innovation:
  - *Turbine*: using a larger turbine with a more robust drive train that captures specific benefits of a permanent magnet direct-drive (PMDD) generator
  - *Support Structure (Foundation)*: reducing foundation and substructure costs by evaluating three alternatives to a standard jacket configuration.
  - *Assembly, Transport, & Installation*: exploring cost reductions afforded by installation systems that avoid multiple offshore lifts.

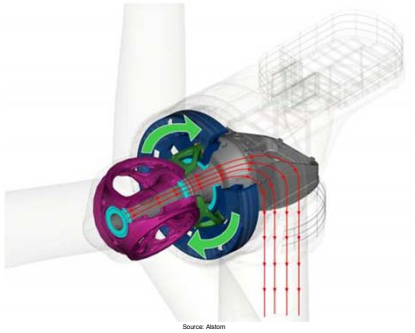
Manufacturers' Proposed Innovations

Source: Offshore Wind Power Systems of Texas

Mobile Self Installing Platform (MSIP)

According to Offshore Wind Power Systems of Texas:

- The MSIP avoids the use of expensive offshore lift vessels for the foundation and turbine installation due to its ability to float-out and self install with the turbine pre-erected.
- The caisson design requires no pile driving or sea floor prep and can accommodate uneven sea floors without change in design.
- The modular design, adapted from technology with 60 years of offshore experience, allows for high density shipping from around the globe, reducing transportation and fabrication costs.



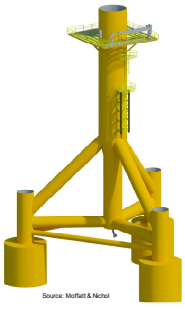
Source: Alstom

Inward Battered Guide Structure (IBGS)

According to Keystone Engineering:

- The IBGS design minimizes the amount of steel and welds needed for fabrication, significantly lowering costs with respect to a standard jacket.
- By pre-installing the lead piles and fitting more foundations per installation vessel, total foundation installation time is greatly reduced.
- The design has been installed for oil and gas as well as met mast applications with one platform surviving a direct hit from hurricane Katrina.

Source: Keystone Engineering Inc.



Source: Moffatt & Nichol

Suction Caisson Tripod (SCT)

According to Moffatt & Nichol:

- The SCT design requires no pile driving which eliminates the need for additional expensive offshore operations as well as substantially reducing environmental impacts.
- The relatively wide tripod structure makes it possible to use a system of floating pontoons/barges arranged so that the tripod foundation and turbine can be towed to site without the use of expensive offshore lift vessels.

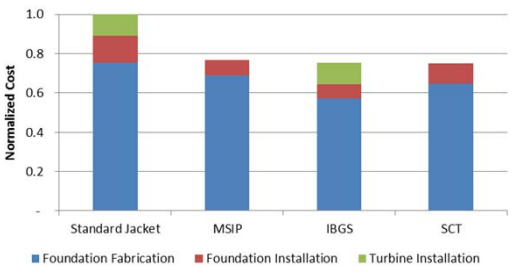
Pure Torque Direct Drive Drivetrain

According to Alstom:

- Two solid bearings transmit main bending loads safely to the tower (red arrows) while an elastic coupling ensures the generator rotor receives only pure torque (green arrows).
- The permanent magnet direct drive (PMDD) generator eliminates the failure prone gearbox, leading towards increased reliability and greater generation efficiencies.
- The design is equipped with three identical full power converters to ensure uninterrupted production.
- An optimized ratio of turbine rotor swept area to generator rated capacity coupled with the advanced drivetrain yields up to 40% more electricity generation per kilogram of material used than today's offshore turbines.

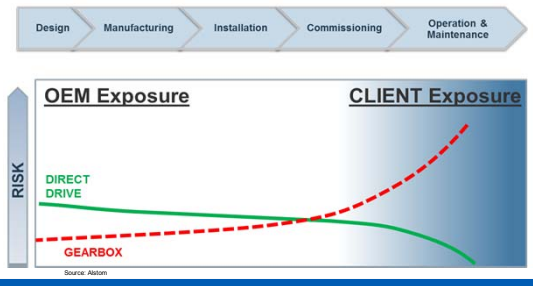
Anticipated Impacts

Foundation and Installation Costs



- Initial analysis shows that all three of the foundation designs investigated may achieve 20% to 25% cost reductions with respect to a standard jacket and turbine installation.
- Though direct drive turbines may present increased challenges to manufacturers, many OEM's believe owners assume less risk in the operation phase of a wind plant.
- Final analysis results will be available soon after the conclusion of the study (2014).

Representative Drivetrain Tradeoff



Source: Alstom

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