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Introduction

This paper is the second in a continuing series detailing the findings of technology and market based research carried out by Scottish Enterprise to identify opportunities open to Scottish industry, higher education and other organisations in segments of the energy market.

The offshore wind opportunity

The potential investment of £100 billion (BN) UK offshore wind markets over the next 10 years offers a significant economic growth opportunity for Scotland.

World class offshore oil & gas operating experience, engineering and higher education expertise and the ports infrastructure Scotland possesses, together with its wind resources, means we are well positioned to reap the benefits that offshore wind development offers. Success in Scottish & UK markets could be a springboard for Scottish companies to access global markets.

As a result offshore wind has been identified as a key strategic priority by Scottish Enterprise and the Scottish Government [1].

Innovation in offshore wind

With respect to offshore wind innovation, these papers aim to highlight ways of:

- cutting the cost of energy of offshore wind projects by 30% [a challenge outlined in the Offshore Wind Industry Route Map] [1], particularly at more challenging sites (for example with deeper water, difficult seabed conditions, smaller weather windows)
- reducing the risks and uncertainty associated with these projects
- promoting the mass manufacture and deployment of offshore turbines in order to deliver economies of scale and meet ambitious renewable policy targets
- enabling companies to win more value from local projects and grow their export earnings

This paper outlines some opportunities for the application of remote condition monitoring and control systems.

Remote condition monitoring and control systems

The engineering and quality control challenge required to operate wind turbines offshore is considerable. Higher wind speeds coupled with the corrosive effect of saltwater means that structural and mechanical component failure is more common than onshore. But because of high costs of access and maintenance offshore, higher levels of reliability and reduced time spent on site are needed. Site access is also restricted by weather windows and the availability of maintenance platforms can also be restricted.

New offshore strategies need to be developed to minimise work done at sea. Management and condition monitoring systems are generally seen as essential for offshore wind farms [2] and there could be considerable scope for improvement (for example, through use of condition monitoring and self-diagnosis systems able to minimise down time, reduce on site repairs and optimise use of weather windows). These systems have the potential to not only pay for their own installation but provide increased lifecycle earnings for the owners of wind farms through increased availability and decreased maintenance costs.
**The challenges**

Offshore wind operation and maintenance (O&M) costs need to be reduced. Currently they are about double onshore costs (£80/kW/pa offshore vs. £40/kW/pa onshore) [3]. These costs are high because the frequency of O&M work and the cost of doing this work are significantly higher than onshore.

There are particular cost challenges for operation and maintenance (O&M) at Scottish offshore projects. Smaller weather windows (relative to the southern North Sea) at these sites could have a significant impact on the cost of installation and O&M.

The limited track record of offshore wind farms makes estimating O&M costs difficult and it is generally felt that underlying cost trends will only become apparent after a sustained period (5 years+) of operation. In the relatively small near shore projects built to date, annual O&M expenditures have varied hugely but the main components of the cost are as follows:

Annual O&M cost breakdown

- **53%** Equipment
- **24%** Grid Maintenance, Lease & Insurance
- **9%** Personnel Access
- **8%** Labour
- **6%** Installation/ Repair Vessels

*Source: Douglas-Westwood [4]*

Annual O&M spend is in the region of £80/kW/pa which is equivalent to around £23/MWh or around 15-20% of the overall cost of an offshore wind project.

Over half of O&M costs are associated with replacement equipment. This cost could be reduced if equipment could be maintained or repaired before it failed.

A further significant consideration is the potential for avoidance of secondary damage as defects develop into failures. For example, a bearing defect within a gearbox can, if identified early, be repaired with minimal machine down time. If the bearing defect is not detected and seizes, the secondary damage to the gearbox can be catastrophic, requiring a complete gearbox replacement and additional machine down time.

As an example, a new gearbox may cost upwards of £60,000 whilst reconditioning the same gearbox, should a defect be found in time, may cost just £15,000 [5].
The diagram below shows some examples of key component problems and failures that remote monitoring might be able to detect.

**Key component issues**

- **Rotors**
  - Surface roughness, icing
  - Imbalance
  - Fatigue, impending cracks
  - Faults in pitch adjustment

- **Bearings, Shafts**
  - Wear, pitting, deformation of outer face and rolling elements of bearings
  - Fatigue, impending cracks of shafts

- **Gear Box**
  - Tooth wear or breaking
  - Eccentricity of gear wheels

- **Generator**
  - Stator insulation failure
  - Cracks in rotor bars
  - Overheating

- **Tower, WEC Structure**
  - Resonances
  - Fatigue, clearance, cracks

- **Yaw System**
  - Yaw angle offset

Source: SKM (6)

A significant portion of the O&M cost (15%) is also associated with the accessing turbines. Remote working would reduce this need.

**The opportunities**

Next generation condition monitoring and self-diagnosis systems could help minimise turbine failure rates, while use of predictive or reliability centred maintenance techniques could allow better management of O&M weather windows.

Effective remote operating systems could allow wind farm operators to have full information and control of turbines and reduce the amount of work done on site at sea.

As turbines increase in size, controller algorithms will become increasingly important to reducing fatigue loading, as well as controlling the pitch of the turbine blades in order to increase the turbine efficiency, in varying wind conditions.

On a larger scale, co-ordinated supervisory control of wind turbines in a wind farm, building on process industry controls used in more mature industries, could significantly improve the overall performance of large wind farms. Process improvement in other industries often leads to a 10% reduction in production costs.

However, it should be noted that these systems can themselves cause false alarms. Operators are also sometimes sceptical of the benefits of new systems so underpinning evidence to support their use would be valuable.
The market for remote condition monitoring and control systems

Assuming the cost of a new monitoring package of £15,000 [7] and using recent information on UK sites the table below estimates geographical market sizes for remote condition monitoring and control systems.

<table>
<thead>
<tr>
<th>Potential market size</th>
<th>Installed capacity 2010 (MW)</th>
<th>Forecast of installed capacity by 2020 (MW) [a]</th>
<th>Forecast annual O&amp;M spend on projects by 2020 (£M) [b]</th>
<th>Approximate no. of installations by 2020 [c]</th>
<th>Forecast spend on remote monitoring and control by 2020 (£M) [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Scottish sites (e)</td>
<td>190</td>
<td>9,130</td>
<td>548</td>
<td>1,826</td>
<td>27</td>
</tr>
<tr>
<td>Non Scottish sites</td>
<td>1,151</td>
<td>17,800</td>
<td>1,068</td>
<td>3,560</td>
<td>53</td>
</tr>
<tr>
<td>UK total</td>
<td>1,341</td>
<td>26,930</td>
<td>1,616</td>
<td>5,386</td>
<td>81</td>
</tr>
<tr>
<td>Rest of Europe</td>
<td>1,623</td>
<td>28,200</td>
<td>1,692</td>
<td>11,280</td>
<td>169</td>
</tr>
<tr>
<td>Rest of World</td>
<td>102</td>
<td>8,100</td>
<td>486</td>
<td>3,240</td>
<td>49</td>
</tr>
<tr>
<td>Non UK total</td>
<td>1,725</td>
<td>36,300</td>
<td>2,178</td>
<td>14,520</td>
<td>218</td>
</tr>
<tr>
<td>Global total</td>
<td>3,066</td>
<td>63,230</td>
<td>3,794</td>
<td>19,906</td>
<td>299</td>
</tr>
</tbody>
</table>

(a) after Scenario A - 2020 numbers - Vision for Offshore Wind
(b) assumes £0.06M/MW/pa
(c) assumes 5MW turbines
(d) assumes £15K per installation
(e) leasing capacity less Bell Rock, Forth Array, Kintyre, Wigtown Bay and Solway Firth sites

Source: Scottish Enterprise, developed from [7][8]

In other words, there is a potential UK market of around £81 million and around £218 million elsewhere in the world.

How Scottish Enterprise supports innovation

Scottish Enterprise has worked with partners to develop the National Renewables Infrastructure Plan to set out a clear framework for delivering the investment required in our port infrastructure that will open up opportunities for the growth of a strong Scottish supply chain.

In addition to the targeted inward investment in areas of supply chain gaps being pursued by Scottish Development International, Scottish Enterprise has developed a programme of support for Scottish companies to help them make the most of the offshore wind opportunity. This programme includes providing market intelligence, awareness raising events, workshops and one-to-one expert help and advice. A database of Scottish companies’ skills and capabilities relevant to offshore wind is also available.

In addition to investing in companies in the sector through the Scottish Seed Fund, Scottish Co-Investment Fund and Scottish Venture Fund, Scottish Enterprise, is helping attract international investment liquidity into Scottish low carbon opportunities with our partners in the Scottish Low Carbon Investment Project.

Working closely with the Scottish industry, areas have been identified where Scottish companies have a lead in innovation and where innovation support can be focused, for example substructures and innovative installation methods. Scottish Enterprise has a number of Research & Development
and Innovation support mechanisms that can assist companies from the early stages of investigating market and technical feasibility; through product, process or service development; to market launch.

Where a company’s R&D or Innovation project presents a convincing technical and commercial case Scottish Enterprise will identify how best to support your project. This could include reimbursement of eligible costs at:

- up to 75% for technology feasibility studies
- up to 45% for close to market Research & Development projects

Research and Academic Institutes with early stage, ‘proof of concept’ projects that present a convincing case could be awarded up to 100% reimbursement of eligible costs.

**Summary**

New off-shore strategies need to be developed to minimise work done at sea. The use of management and condition monitoring systems are generally seen as essential for offshore wind farms [2] and there could be considerable scope to improve these (for example, through use of condition monitoring and self-diagnosis systems able to optimise O&M weather windows, minimise down time and reduce on site repairs).

Remote condition monitoring and control systems have the potential to not only pay for their own installation but provide increased lifecycle earnings for the owners of wind farms through increased availability and decreased maintenance costs.
Useful Links

Scottish Enterprise – Business sectors – Energy – Offshore wind
http://www.scottish-enterprise.com/offshorewind

Scottish Enterprise – Fund your business – Scottish investment bank – Equity funding
www.scottish-enterprise.com/fund-your-business/scottish-investment-bank/sib-equity-funding

Scottish Enterprise – Fund your business – Innovation and R&D grants
www.scottish-enterprise.com/fund-your-business/innovation-and-rd-grants

Scottish Enterprise – Start your business – Proof of Concept Programme
www.scottish-enterprise.com/start-your-business/proof-of-concept-programme

Sources

2. SKM, Condition Monitoring of Wind Turbines, August 2006 http://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=441
4. As ref 3 above
5. As ref 2 above, page 25
6. As ref 2 above, page 17
7. As ref 2 above, page 33
8. IPA, Scottish Offshore Wind: Creating an Industry, August 2010, page 26 [Scenario A]