Introduction

The growth of the number and size of turbines installed worldwide has been large in recent years. The capital costs involved in the development and installation of wind farms have also increased. To ensure the maximum return on investment, operators are looking to maximise turbine availability and minimise Operation and Maintenance (O&M) costs. Condition Monitoring (CM) systems and Supervisory Control and Data Acquisition (SCADA) systems allow Condition Based Maintenance plans (CbM) to be used which offer possible O&M savings over both Failure Based Maintenance (FbM) and Preventive Maintenance (PM) strategies.

Fault Classification

Faults are classified as ‘Major’ and ‘Minor’ where minor faults takes less than 24 hours to clear. An FMEA is used to determine where a CMS may allow for a major fault to be repaired at a lower cost – for example, detecting bearing wear in the gearbox before damage to the gears or shafts occurs, leading to fewer replacement parts.

Additionally, faults are assigned one of six logistics classes that shows the type of vessel (Crew Transfer Vessel, Field Support Vessel or Crane Vessel), number of crew and billable hours required to complete a repair.

Condition Monitoring Systems

Vibration based condition monitoring systems on the drive train, gearbox and generator are common, however many other types are also available. Generic costs have been anonymised and averaged from an array of vendors.

When multiple CM systems that observe different properties are added to the same sub-system the chance of fault detection increases. These have been modelled as parallel systems. This is shown below.

\[ R_p = 1 - \prod R_i \]

\( R_p \) is the probability of not having a fault at time \( T \).

Results

A vibration CM system offers potential lifetime savings of over £4m. The addition of either oil sensors or an AE system reduce the lifetime savings. This indicates that the additional O&M cost reductions found from adding CM systems are outstripped by the cost of the CM systems themselves. This may diminish as the turbines increase in size and the financial implications of failures increase.

A CM system was specified to include: a vibration drive train CMS, a tower vibration SHM and a vibration monitoring foundation system. The efficacy (detection rate) of the two SHM systems was varied and the effect on savings is shown below.

Costs for both a PM and CBM are calculated from the subsystem failures.

\[ C_{CBM} = C_{SPP} + C_{LP} + C_{CMSPP} + C_{FA} + C_{CM} \]