BAHRAIN WORLD TRADE CENTER, BAHRAIN

First Ever Integration of Large-Scale Commercial Wind Turbines into a Building

The reliably strong and directional sea breeze from the Arabian Gulf allowed the possibility of integrating large-scale, commercially-available wind turbines into a building. Similar attempts by others had usually failed because of the high costs for adapting the building and the R&D for custom turbines. The premise of this project was to therefore use commercially-available wind turbines and to develop a building form sympathetic to receiving them, for less than 3% of the project value. The Bahrain World Trade Centre became two 50-storey office towers tapering to a height of 240m and supporting three commercially-available, 29m diameter, horizontal-axis, fixed wind turbines.

Most studies for integrating horizontal axis turbines into buildings use fixed turbines. Vertical axis turbines benefit from bring truly omni-directional and their development is encouraging but, at the time of design development, no large-scale ones had been proven for building applications. Fixed horizontal-axis turbines have the drawback of operating only with wind coming from within a limited azimuth, assuming that problems of blade deflection and stress through excessive skew flow have been overcome. They were.

First of all, the buildings face the dominant direction of the prevailing wind. The symmetrical and elliptical shapes in horizontal section funnel the onshore breeze and also act as aerofoils to create a leeward negative pressure. These two effects combine to increase the wind speed at the turbines by up to 30%. The tapering profile of the paired buildings means this increase is greatest at ground level where the velocity is least, and least at high level where the velocity is greatest. The relative wind velocities and energy outputs of the bottom, middle and top turbines are nearly equal at 93%, 100% and 109%, respectively. Achieving this was a key factor in successfully integrating the turbines. Wind tunnel testing and later CFD modeling confirmed that the shape and positioning of the towers create an ideal “S” flow where the centre of the wind stream remains within the wind-skew tolerance of the turbine for directions between 270°~360°. The turbines enter “standstill” mode outside the cautiously narrower range of 285°~345°.

Each of the turbines has a nacelle, a rotor, a bridge, control monitoring and safety systems, and an electrical interface with the building. The nacelle is the cowling containing gearbox, generator, cooling system and associated control systems. They are mounted on top of the bridges only to display the functionality of the turbine. Their conventional design was enhanced to suit desert application and their structural safety increased to “High Safety” in line with the Danish code followed by their manufacturers. Each nacelle operates independently.

The cut-out wind speed of 20m/s (down from the usual 25 m/s) is achieved through stall control. With this passive method of limiting turbine power when the wind speed is too high, turbulence on the leeward side of the blades prevents lift and stabilizes output to maximum. Full power of about 225kW is achieved at 15 to 20m/s, depending on air density. At extremely high wind speeds, centrifugal force extends the tips of the blades and rotates them to exert a governing drag force.

A key part of the design was determining the loads on the rotor as these would be transferred through the nacelle and bridge and onto the buildings. Structures were then analyzed for strength and fatigue. Some 199 different load cases were modelled for each turbine and validating calculations or operational processes theoretically demonstrated the absence of excessive fatigue for either turbine or bridge. This analysis has since been validated and appropriate adjustments to the operating regime have been made.

The bridges have elliptical sections for aerodynamic reasons and at one end have maintenance-free bearings to absorb up to 0.5m of relative movement between the towers. The bridges span 31.7m and support a nacelle weighing 11 tonnes at their midpoints. They have been designed to withstand and absorb wind-induced vibration and that induced by the turbines in either operating or standstill mode. Their natural frequency does not conflict with the frequency of its exciting vibrations or those of the building, but design precautions allow them to be further damped if necessary. The bridges have a slight (173 º) V-shape in plan to guarantee a clearance of 1.12m during conditions of extreme blade deflection and extended blade tips. This is merely precautionary as blade position is monitored by laser and excessive deflection will set the turbines to standstill.

A Wind Turbine Control System allows authorized operators anywhere to access the operating data and control the turbines. It also has an independent safety system to monitor possible abnormalities in the turbine and its operating environment and to bring the turbine to a standstill if required. It also collects wind and turbine data and has tools for its analysis. An Extended Wind Turbine Monitoring System has additional sensors and monitors and calibrates the control system operational limits. In the event of a control system failure, it brings the turbine to standstill by the tip brake working in conjunction with a hydraulic brake and failsafe mechanism.

he turbines have been certified by the Bahrani government’s Electricity Distribution Directorate but exporting power to the grid is not yet approved. Their projected energy yield is 1,100 ~ 1,300 MWh per year which is approx. 11 ~ 15% of the office tower’s likely consumption. In carbon emission terms, this equates to an average of 55,000 kgC. These figures are conservative. The yield may be even higher as this is the first time wind turbines have been placed 160m above the ground and between buildings.

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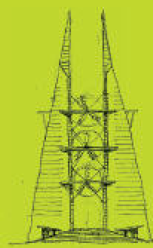
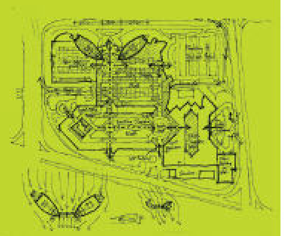
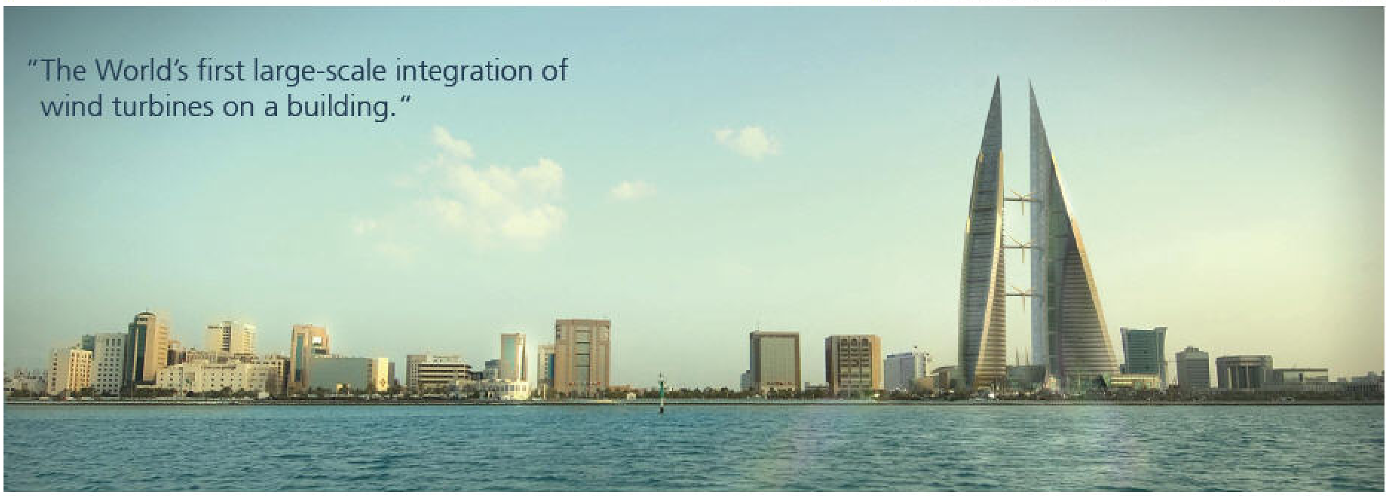
COMMERCIAL / MIXED-USE

ATKINS

Client: Confidential
Location: Manama, Bahrain
Building Type: Commercial
Status: Complete
Design Commencement: January 2003
Construction Commencement: June 2004
Construction Completion: April 2008
Total Area: 120,000m²
Total Height: 240 metres
Storeys: 42
Turbines: Three 29m diameter, horizontal axis 225kw each wind turbines.
Energy Yield: 11-15% of the energy requirements of the two towers.
Architect: Shaun Killa, Atkins







"The World's first large-scale integration of wind turbines on a building."