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BWTC scores world first

The kingdom's most innovative building yet has crossed a significant milestone with the successful operation of its three turbines last month. *Gulf Construction* speaks to the people who have made the feat possible.

BAHRAIN World Trade Center (BWTC), the world's first commercial building to integrate large-scale wind turbines, crossed a significant milestone with the successful trial run of its three turbines early last month.

Situated in Manama, Bahrain, the project has three massive turbines, measuring 29 m in diameter, supported by bridges situated at heights of 60 m, 96 m and 132 m, respectively.

The successful rotation of the blades involved collaboration between Atkins, which designed the BWTC, Ramboll, the specialist bridge designer and turbine specialist Norwin, who were in Bahrain for the milestone event.

"The results from the trial runs have been very encouraging," says Ole Sangill, director and managing partner of Norwin, which is responsible for the design, manufacture, installation and maintenance of the turbines.

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FROM TOP: The various stages of the assembly of the turbine blades and its final attachment to the nacelle on the bridges of the BWTC. The work was overseen by engineers from bridge designer Ramboll turbine specialist Norwin and architect Atkins.
BELOW: LytheRao ... capping a milestone in the kingdom.

"Through the initial testing in November and December 2007, the turbines were run as individual units to determine that they were performing within their prescribed performance and safety standards under varying wind speeds. Over five days early last month (April), they were then tested in parallel for a sustained period. The trials were carried out under Norwin's direct supervision. These tests will continue and include ongoing data collection and assessment. Complete automation of the turbines will not take place until integration of the turbine controls with the building systems has been fully tested, commissioned and validated. This is expected to take up to two years," he says.

"In a period of 14 hours, spread over a four-day period, the three turbines have successfully generated a combined output of 1424 kWh within wind speeds ranging from 3 to 9 m/s. The turbines will continue to run intermittently as testing and commissioning continues. After full commissioning. the turbines are expected to run around 50 per cent of the time. Their ability to turn will be affected by a number of factors including wind availability, ongoing maintenance to the building façade adjacent to the turbines and the building's need for the power generated," Sangill adds.

Expanding on the last constraint, he mentions that there is no provision for power storage. The expectation is ultimately that the public supply authority Electricity Distribution Directorate (EDD) will in the

Sangill ... happy with the turbine tests.
RIGHT: Engineers check the blade tips which can act as a mechanical fail-safe brake in case of an emergency.

future approve the principle of accepting excess power from the turbines being injected back into the main electricity grid. At present, this is not an acceptable option but future improvements to the mains supply infrastructure may make it possible.

Once fully functional, the power generated by the turbines will serve as an additional source, and over a year is estimated to be from 11 to 15 per cent of the towers' overall power requirement. Each turbine can generate a maximum output of 225 kW, while operating between optimal wind speeds of 16 m per second (mps) to 20 mps depending on air density.

Over a year, the turbines are capable of generating 1,100 to 1,300 MWh, which is equal to powering approximately 250 homes for a year. This is expected to eliminate the equivalent of 55,000 kgC of carbon emissions annually.

Overcoming challenges

"One of the challenges we have had to overcome was the integration of the power and control systems for the towers and the turbines," says Simha LytheRao, senior project manager at Atkins, who has been associated with the project since early 2005. "It has been a learning curve for everybody. The first issue was how to get the power from the turbines into the building without affecting the power quality within the building. Several studies were conducted to show how the power systems would seamlessly integrate. Also, we had to assure the local authorities that we were doing nothing that would cause problems to the main power supply. As mentioned, the ministry had made it very clear that there would be no allowance for any feedback into the grid.

"Power integration was only one aspect of the set of recent challenges, the other being integration of controls," explains LytheRao. "We have the building management system, the fire alarm system, building cleaning unit controls and the security/access control system, all of which interact directly or indirectly with the turbine control system. Decisions need to be made automatically to ensure that the turbines and building systems do what they are supposed to do under the full range of likely conditions. In order to validate the connectivity necessary to achieve this functionality, we have to run through numerous tests to ensure that all components interface appropriately."

Safety focus

"We have set up equipment on the towers that will ascertain factors such as wind speed, direction, and building power consumption," says Sangill. "A dedicated control system is integrated with the turbines and the building management system through a bundle of fibre optic cables that run the entire length of the towers. The data generated from this equipment and the turbine controllers is used to establish the proper functioning of the turbines and is also accessible via the internet at our headquarters in Denmark."

Although the turbines used on the BWTC are based on standard turbines that are found in wind farms, they have been modified to build in additional safety measures due to the proximity of the turbines to the bridges, the towers and the urban environment in general.

"Safety has been one of our main concerns in the redesign of these turbines for this project and a number of features and redundant systems not normally found in state-of-the-art turbines have been put in," says Sangill. "As a part of the initial study, a safety and risk analysis was carried out by Ramboll that found that the safety of the turbines placed on this particular place was satisfactory."

The turbines operate fully automatically and generate power within a cut-in wind speed of 4 mps and a cut-out wind speed of 20 mps. The entire turbine is also strengthened to withstand wind speeds up to 70 mps in any direction, which is much higher than the equivalent wind speed of a class IV hurricane (>69 mps).

If the wind speed was to rise above 20 mps, which is considered to be the maximum speed for turbine operation on the project (less than for a turbine in free-field), the blade tips would extend, owing to the centrifugal force, and rotate to act as a self-regulating governing brake, through the exertion of a drag force.

The blade tips will either, as for the mechanical brake, be activated by the turbine controller's first or a second level emergency system, or, in the extreme rare case of a fault in both these systems by a "burst" valve due to pressure rise – when the uncontrolled rotor goes into an "overspeed" – which is the most critical situation for a wind turbine.

The turbines include a "fail-safe" mechanical disc brake on the high-speed side of the gearbox and a calliper-type mechanical brake directly on the low speed rotor side, which will be used in special situations.

Furthermore, the turbine blades are fixed to the hub at a fixed angle using zinc-coated stainless steel bolts (which help minimise the effect of corrosion). The profile helps to ensure that the moment the wind speed becomes too high, turbulence is created on the leeward side of the rotor blade and prevents lift, thereby stalling the blade so that the power output stabilises at a maximum output.

Periodic maintenance

Sangill also says that a comprehensive and intensive maintenance regime will be in place soon. This would include daily monitoring and weekly inspections by the local team of operators, which will comprise checks for stressing of the blades, flaking of coatings, change in noise pattern and any other anomalies that could arise. These daily inspections will be supplemented by detailed inspections by a team from Norwin, Denmark, four times a year to ensure the flawless functioning and high safety of the turbines.

Low noise and vibration

"Through the four days of operations of the turbines, the noise and vibrations levels caused by the turbines have been well below what was expected," says Sangill. "This is because a series of studies had been done right from the inception of the project with the aim of minimising noise and vibration.

"Much of the dampening of the noise and vibration has been achieved because of the overall way the project has been conceived," says LytheRao. "The 68-tonne steel bridges provide a massive dampening effect. They in turn rest on a number of types of bearings all separated by elastomeric interfaces which absorb much of the residual vibration. The bridges are supported off the main core of each tower taking out any other structural-borne vibration. Similarly, the orientation of occupied areas, away from noise generation of the turbines, and the acoustic performance of the glazing has resulted in no noise from the turbines being discernable within the office space, as proven during testing."

The design of the bridges by Ramboll has been done in close co-ordination with the turbine manufacturer and was also based on the data received from local wind conditions, wind tunnel tests and the 199 different load cases that were modelled for each turbine, taking the bridge dynamics into consideration.

The aerodynamically efficient bridges are ovoid in cross-section and incorporate maintenance-free bearings where they connect to the buildings to allow the towers to move up to 0.5 m relative to each other. In addition, the bridges that span 31.7 m and support each nacelle, weighing in at 11 tonnes, have been designed to withstand and absorb wind-induced vibration and the dynamic loads induced by both an operating and an idling turbine, explains LytheRao.


The three turbines in tandem generated 1,424 kWH of power over a 14-hour period.

"Although there is a slight movement in the bridges when the turbines are subjected to an emergency shut down (to be used only in extreme conditions), this response is well within design allowances," he adds.

Effective wind capture

The idea to integrate the turbines was considered from the initial design stages of the BWTC. It has therefore been possible for all involved – including the architect, the contractor, the bridge designer and the turbine manufacturer – to achieve turbine integration in tandem with the overall building design and construction process.

However the concept of using the building form to harness the unobstructed prevailing onshore breeze from the adjacent Gulf coast in order to provide a renewable source of energy for the project has remained a core principle. Incoming wind is funnelled between the towers, amplifying wind speeds around the turbines by up to 20 per cent. Furthermore, the elliptical-shaped towers act as aerofoils, equally distributing the wind velocity vertically, LytheRao explains. The reduced funnelling effect as the towers rise up balances the wind velocities at each turbine, allowing the design of the bridges and turbines to be standardised. Estimated energy yields are 109 per cent at the top turbine, 100 per cent for the middle turbine and 93 per cent for the bottom turbine.

The BWTC project has pioneered the large-scale integration of turbines into a major building and this has already been noticed by several developers in the region who are looking to integrate turbines and other renewable energy technologies into their developments in various configurations. "There has been great interest, including in Dubai, to construct towers that work towards minimising the impact on the environment, by including the integration of renewable energy generation technologies, including turbines and, or photo-voltaics," says LytheRao.

He adds: "The use of established technologies on the BWTC, including type-tested turbines with minimal modifications have ensured that the additional cost incurred by incorporating turbines into the project was reduced to around 3.5 to 4 per cent of the overall project value, making it not only environmentally responsible but also a financially viable venture. This is also the reason why we opted for the horizontal axis turbine as opposed to vertical axis turbines that are now being proposed in some of the projects across the globe. This philosophy of not being radical, but being innovative in terms of combining existing technologies, has helped us keep costs down and kept the engineering straightforward while at the same time creating a project that has the potential to be a global landmark."