Towards autonomous inspection

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Turbines have traditionally been inspected visually, often by a servicing company. But in recent times, due to the exponential progress in drone technology, these inspections are made by flying drones equipped with high-resolution cameras. Aero Enterprise takes a look at how this latest technology is being used for faster turnaround times.

In light of recent world events, the development and use of sustainable, renewable, climate-friendly and politically independent sources of energy are not only needed but are a key component for a safe future. One such source is wind power produced by wind turbines.

Over the past decades, there has been rapid and continuous progress in wind power, which will now undoubtedly accelerate even more. But to operate properly and efficiently, wind turbines need to be regularly maintained and repaired. This is especially important with the new generation of wind turbines, where rotor diameters can exceed more than 200 metres and damage to such turbines could lead to the loss of millions of euros.

Austrian-based company Aero Enterprise offers a full cycle of inspection with professional drones, from the inspection itself to the generation of strict industry-grade reporting. Currently, it provides inspection services, either using professional consumer drones, such as the DJI M300, or the specially developed SensorCopter© a helicopter-type UAV, which is able to inspect onshore and offshore turbines, in difficult weather conditions on a 'one turbine, one flight,' basis.

As part of its innovation and drone portfolio expansion, it has developed a universal Flight Intelligence module that turns almost any Pixhawk/Ardupilot or DJI-based drone into a fast turn-around on-site wind turbine inspection drone. In this article, we will dive a little deeper into this module and the inspection of wind turbines with drones.

Nowadays, a lot of companies produce drones. Some of them have custom-made flight control systems designed for special use cases, but the biggest part belongs to general-purpose drones. These are based either on Pixhawk/Ardupilot autopilot that supports telemetry and control over the Mavlink protocol, or DJI-based with support of DJI OSDK library. Both systems basically provide manual control from the transmitter and automatic flight over a predefined flight path that can be uploaded to the drone from ground control software prior to the flight.

Of course, with systems for visual inspection, we should consider drones that are capable of carrying additional payloads, like a camera with a good enough resolution (you can read in further detail about the required image quality and data evaluation processes in our previous article 'Challenges in Evaluating Drone Data' in PES Wind, issue 2, 2021) and with enough flight time and flight stability. So, when considering a drone, our target is one that is able to carry around 1 kg of additional payload and has a flight time of at least 15 minutes, i.e. the DJI M300 class of drone.

Now we are going to consider the limitations of conventional inspection methodology with drones that are already available on the market, which will allow us to explain the idea behind the development and benefits of using the Aero Enterprise Flight Intelligence system.

As mentioned, each drone is able to fly manually, but in the case of wind turbine inspection, the pilot needs to be experienced and have all the required permissions to operate and fly around the turbine, a process which can be very challenging, especially for offshore operations. More often than not, wind turbine servicing companies do not have such pilots in their work-force.

Another way that we can look at this is to use the capabilities of the drone to fly automatically, by a predefined flight path. At first, you might think this type of flight could be carried out by an inexperienced pilot. But predefining a flight path that will match the real shape of the wind turbine in advance is not possible, even if there is software that is capable of calculating such a flight path based on a theoretical wind turbine model. This is because turbine blades usually bend due to gravity in some arbitrary way.

We must also take into account that prior to the flight, the turbine must be stopped in an orientation best suited for inspection, which is impossible to exactly predict. The situation

From left to right: Aero Enterprise Flight Intelligence equipment; Ground Station radio module, Flight Intelligence air module: DJI M300 version; Flight Intelligence Lidar gimbal: DJI M300 version becomes more difficult with the inspection of floating offshore turbines, as these cannot be rigidly fixed in a particular position and can move, drift and undulate during the inspection flight. Therefore, any flight with a precalculated flight path could fail with a drone impacting the turbine.

To avoid this, the flight path must be created based on the real-world turbine shape on-site and automatically corrected in real-time during the flight. Considering all of this and the limitations encountered with conventional methods, we developed a universal solution that could be installed on consumer drones. With this equipment, for example, a less experienced pilot employed by a wind turbine servicing company, could carry out a turbine inspection with the required quality autonomously.

So where are we now? At Aero Enterprise, we have developed a Flight Intelligence control system consisting of two main parts. The first part is an airborne system that consists of a lightweight Lidar and Flight Intelligence Module (FIM) that communicates with the drone autopilot on one side and with the ground control system on the other.

For DJI-based systems, a Lidar is mounted on a separate gimbal and for Pixhawk-based systems, it can be mounted on a gimbal with a camera. The Flight Intelligence module for the DJI M300 drone has mechanical spring-lock connectors for easy mounting without any screws and two electrical connectors: one for connecting the module to the DJI OSDK port, and another for connecting to the Lidar.

The flat module design allows for easy storage of the DJI M300 in a fully equipped configuration with FIM and double-mounted gimbals in the HPRC2800W transportation box, which can be separately purchased from HPRC. This provides a fast turn-around on-site, with no additional equipment mounting/dismounting needed before the flight. Just take the drone from the storage box and fly.

The installation of the Lidar on a separate gimbal for DJI-based systems allows standard cameras like the H20 etc., to be used independently from the Flight Intelligence equipment. For Pixhawk-based systems, the communication with autopilot goes over the standard UART port. The power rating for the whole air system is 24V/2A.

The ground part consists of the Flight Intelligence Ground Control Software (FI GCS) that can be installed on Windows or Linux-based computers and a USB-connected radio module for communication with the airborne unit. FI GCS provides the functionality needed to communicate with FIM to perform wind turbine inspections and can be customised upon request. The FIM can communicate with the FI GCS over Wi-Fi or over a radio channel. Due to Wi-Fi distance limitations, main communication goes over the radio channel.

The Flight Intelligence module software is based on modular architecture and can also be customised. In standard configuration, the software is intended for automatic turbine inspection with minimal effort from the user, i.e. by utilising the data from the Lidar and drone navigation system.

During the automatic calibration flight, the software algorithms determine all turbine parameters needed for the in-flight building of the flight path, corresponding to the current position and orientation of the turbine, without any preliminary information about the turbine. As soon as the turbine parameters are estimated, and the preliminary flight plan has been built, it is automatically loaded into FI GCS for verification by the user.

After verification, the flight path is displayed on the FI GCS map window and the automatic inspection flight can be started with one click. During the inspection flight, the intelligent control algorithm continuously processes Lidar data to update the flight

path and adaptively moves the drone and gimbal with the camera in such a way that it keeps an optimal distance from the blade to capture high-quality images. The software also automatically builds a turbine point cloud model that is later used in the processing of images.

The user can take control of the drone manually at any time, by touching the control sticks on the transmitter. This is useful in any emergency situation and for drones with a low flight time, as after landing and changing the battery, if the drone allows a battery hot-swap, the inspection flight can be continued by invoking the 'continue interrupted flight' function in FI GCS.

The drone will then automatically return to the interrupted point and continue the inspection flight. This procedure can be repeated as necessary, until the inspection is complete. After finishing the inspection flight, the drone will stop and hover in front of the turbine nacelle. Then the user can take control and land the drone manually.

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How does the drone inspection, analysis and reporting work with Aero Enterprise?

The first step is the drone flight planning and the inspection on-site. When the customer is able to provide their own drone and pilot, Aero Enterprise supports them with a cooperative Partner Program, utilising our operational experience as well as hardware and software solutions.

The second step is the data evaluation. When the customer has the in-house capabilities to evaluate the acquired image data, Aero Enterprise processes the raw data into valuable information and provides specialised software for the damage evaluation.

The third and final step is providing a report for further maintenance and repair planning.

The inspection report can be provided online, via an interface, which can be implemented into a customer's ERP system, or downloaded as a simple PDF. If, however, you would like Aero-Enterprise to take over the entire process from the initial flight planning through to the detailed inspection reports, no problem!

Aero Enterprise is a full-service provider for the drone-based inspection of wind turbines, onshore and offshore, as well as developing hardware and software solutions ranging from intelligent, autonomous flight systems for drones to detailed data acquisition, post-processing and reporting that can be customised to our customer's needs.