Digital Twins for Structural Condition Assessment of Power Stations

DETAILS

SECTOR | Energy

STAGE | Operations and Maintenance

TECHNOLOGIES | Data Analytics, Digital Twins, IoT (an integrated system of sensors, communications and analytics), Sensors

SUMMARY

This case study was submitted jointly by the World Economic Forum (WEF) and technology company Akselos

In 2019, Irish electricity company ESB selected was seeking a solution to help them understand the structural health of a 47-year-old pumped storage station, to determine if the asset could continue to operate safely into the future. As Ireland's only pumped storage station, Turlough Hill generates up to 292MW into the Irish grid during peak demand periods. Approaching 47 years of operation, ESB started to ask fundamental questions about structural integrity and operational risk. ESB's structural engineers were looking for innovative ways to achieve this as well as to monitor its condition if it were to continue operating. The challenge was intensified due to the sparse analogue data that was available to digitize the asset and build out the complete 3D view of the structure. In addition, much of the actual hydro station is simply not accessible due to being buried into the mountain, and even the internal structure is hard to inspect.

The solution was to create a structural model - or digital twin - of the entire asset. The physics-based model represents its entire physical replica in absolute detail and accuracy. The model is set-up to be updated with loading conditions and inspection data on a regular basis, providing the ability to carry out structural assessments based on the near-real time condition. With the digital twin now deployed, the next stage is to connect the digital twin and real-life asset via sensors, to create a Digital Guardian that will give a constant, real-time picture of Turlough Hill's structural condition.

Top drivers for this project:

1. Environmental: Turlough hill generates up to 292MW of renewable energy into the Irish grid during peak demand periods and so is strategic to the operation of the national grid, a failure on this site has significant direct and indirect environmental consequences.
2. Technological: ESB has an ambition to lead the transition to a low-carbon future, with creative ideas, innovative thinking and new technologies. The company was actively looking for unique, innovative solutions to improve their management of the complex asset.
3. Economic: With limited site availability, the costs associated with replacing this kind of infrastructure would be unachievable, and as Ireland's only pumped storage station, Turlough Hill has a crucial role in the country's ongoing transition into renewable energy grid stabilization.

Desired outcome:

1. Provide ESB with the data they needed to support a decision to extend the asset's design life by 20 - 50% (14 - 35 years).
2. Reduction of inspection frequency by using the twin to focus inspections on areas of concern and reducing the need for costly 'drain-downs' of the asset. Overall increasing the uptime and reducing OPEX in the range of 10-20%.
3. Identify optimal cycles of operation: A traditional pumped station was designed for a daily cycle of production. In the renewable energy price-driven market cycles can be commercially advantageous at any point in time.

Top barriers:

1. Creating an accurate model itself was challenging because of the size of the asset. The asset is 584m in length and required a very detailed model to simulate the operating production cycles.
2. Getting access to all the key data from 1960's archives needed to understand the asset in all its structural detail to ensure it was simulation ready.
3. Complexity of operating conditions. Cycles of electricity generation are evolving and so are the demands on the existing systems; this requires an evolution in the existing measures of performance and monitoring

Given the commitment from ESB to put all the necessary resources into the pilot scheme we were able to have access to the right engineers and data to work through the initial challenges. A dedicated team of Akselos engineers worked through the original design documentation, mostly hand drawings, site plans and calculations to render a fully navigable 3D digital replica of the actual asset. To address the complexity of the operating conditions, ESB engineers worked with us to build out a method to assess different cycles of operation. This is still part of the ongoing challenge for the future operation of the asset, and we need to continue to evaluate the impact of the new cycles of operation and get an understanding of potential impact.

VALUE CREATED

Firstly, and most importantly, increase the overall confidence of the operations teams in understanding the level of safety and boundaries for safe operations for this mature asset. Asset Life extension: in the absence of the Akselos technology ESB would have to resort to conventional engineering techniques to assess impacts and risks. These methods require a number of detailed assessments followed by a number of structural work programs that typically cost 10 to 100 million Euros. In the worst case it could entail a complete refurbishment of the main water distribution system which would be in the 100 million plus price range. These costs were avoided by using a structural digital twin. Inspection scopes will be reduced by 30 - 40% compared to sectorial, prescriptive inspection methodologies. This will result in saving 100-200K Euros on each inspection.

ESB has proof via an isolated project that millions can be saved per asset each year with a structural digital twin. When scaled to a portfolio of critical assets, the economic benefits are significant. A critical part of Ireland's renewable energy infrastructure is now resilient for a number of decades, allowing for time to consider the best options as the world transitions to a low carbon economy.

POLICY TOOLS AND LEVERS

Funding and financing

The project materialized as part of the Free Electrons Accelerator Programme of which ESB is a founding member. The programme is designed to support start-ups who are working to transform the energy market with next-generation ideas. ESB and nine other global utilities work with each of the start-ups to refine and test their products with the potential to reach 80 million customers in more than 40 countries. Free Electron is a Utility ecosystem that is helping this very traditional sector adapt in the face of the energy transition to low carbon, renewable energy. Akselos won a place among 400+ companies to compete with a selected few to run pilots within the Free Electron programme. Without it, penetration of a company like ESB would have been unlikely at this stage.

IMPLEMENTATION

Ease of Implementation

Despite the challenges the digital twin pilot was implemented in a matter of weeks once the challenge of asset digitization was overcome.

Cost

The pilot project was implemented for circa 120K Euros including operator and Akselos staff commitments.

There were little operations cost as the pilot was implemented using CAPEX and was handed over to the operations teams. Running costs is estimated at less that 50K per annum.

Country Readiness

Technology innovation has been a central pillar to Irelands’ economic recovery over the years and as such the country has a good policy framework. ESB is a state-owned company and it is a founding member of the Free Electrons programme.

Technological Maturity

The technology is breakthrough in nature but is the result of 15 years’ research in MIT’s mechanical engineering lab, funded by the US Department of Defence. It has been validated by hundreds of academic papers and by all of the main standards organisations.

Scalability

Scalability is one of the USP’s of Akselos’ software. The technology allows for simulations to take place in minutes rather than months. It was developed with scalability in mind and can be applied to protect unlimited assets at the speed required for the energy transition. In addition to technical scalability, as a cloud-based solution it is well placed to scale across companies and the wider energy ecosystem.

RISKS AND MITIGATIONS

Implementation risk

There were no major risks identified for the implementation of the pilot scheme. Implementation risks were minimal and by design as the potential issues were de-bugged in the implementation stage. Also, the Akselos team is experienced in addressing the sorts of engineering challenges that the hydro plant represented. Mitigation strategies included: - a rigorous delivery process - cross references to recognize engineering standards for validation of each stage of the digital twin delivery.

Economic risk

The technology aims for a high ROI and rapid delivery, typically covering its own cost within one business cycle. In terms of human capital and ecosystem, our technology has been designed to empower engineers with a better understanding of the challenges they face, to improve the way they work. Structural digital twins won't replace the need for engineers to interpret the data and make critical decisions, they simply aid the decision-making process with accurate, real-time information.

Social risk

Structural Digital Twins are disruptive in nature and allow for the integration of new technologies, and processes such as edge computing, AI and machine learning to mention a few. The societal risks for these emerging technologies are latent, and the digital twin gives the players in the ecosystem the possibility of adopting new business models based on higher value-added services.

Safety and (Cyber)security risk

The technology will support customers to lower their carbon footprint by: - Improving design of critical assets and reducing materials required for manufacturing - Remote access and monitoring resulting in reduced deployment of people to the assets - Increased sustainability of critical assets. Increasing the operating envelope of a wind turbine for example from 25 years to up to 50, mitigating issues with recycling blade materials - Avoiding stranded assets for hydrocarbon industries by extending the life of old assets rather than building new ones as the world transitions to a low carbon economy.