

General comments

The paper discusses the use of digital twin tools in Industry 4.0 and their possible application in offshore wind farms. Improvement of digital twin technologies is important for development of the wind energy industry and for sure there is potential to use tools developed in other industrial fields. Research about digital twins falls in the topic of condition monitoring, which is in the scope of WES.

General Comments		
No.	Comments	Answers
1.	After having read this article, I don't think it is suitable for publication. The first part is a review of digital twin technologies that were used in the manufacturing industry or in the wind energy field.	We appreciate your feedback. Our primary aim in submitting our article to the WES journal, as opposed to ICT-type journals, is to draw the attention of both industry and academia professionals in the wind energy sector towards the incorporation of ICT (Information and Communication Technology) into wind energy implementation. By highlighting the successes of digital twin technology in the manufacturing industry, we seek to persuade the wind energy community to explore and adopt digital twin applications in their field. We have also made an addition to the introduction section, emphasizing the critical need for Industry 4.0 implementation in wind energy. A key challenge encountered in implementing digital twins in the wind industry pertains to standardization. Standardization is of paramount importance and is endorsed by professional organizations such as the Digital Twin Consortium ¹ and the Industrial Digital Twins Association ² . While the manufacturing industry has embraced the industrial digital twin approach rooted in Industry 4.0 since its inception, the wind industry lags behind in this regard. Consequently, we initially delve into the adoption of digital twin technology in the manufacturing sector, laying the groundwork for its potential integration into the wind industry.

¹ <https://www.digitaltwinconsortium.org/>

² <https://industrialdigitaltwin.org/en/>

2.	<p>In this review the authors do not explain clearly how to apply the technologies they analyze to the operation of wind farms.</p>	<p>Thank you for the comment. We have revised the introduction section (2nd paragraph) by clearly explaining how to apply digital twin technology into the operation of wind farms in general.</p> <p>“... For the offshore wind industry, digital twin technology can be applied to remotely monitor and control wind turbines during operation, through (near) real-time digital information instead of direct observation. Sensor data from SCADA is connected to the digital twin. These data are read and stored through digital twins of the wind turbines. Engineers can invoke a specific timespan of the time-series data stored in internal, external, and cloud databases through digital twins. Combined with machine learning technology, these time-series data can be analyzed to estimate power output, predict potential failures, optimize inspection schedules, and improve future products...”</p>
3.	<p>Moreover, the article uses a lot of jargon not common in the wind energy field that makes it difficult to read for a member of the wind energy community.</p>	<p>Thank you for the comment. We believe that the reviewer referred to the terms of industry 4.0, digital twin, framework and interoperability, therefore, we have revised introduction section to address this comment.</p> <p>“...In 2011, industry 4.0 was first introduced at the Hanover Fair, as a program of the German government (Xu et al., 2021). Industry 4.0 is driven by Industrial Internet of Things (IIoT) and cyber-physical system (CPS) that utilize computer-based algorithms to control and monitor physical devices like vehicles, robots, machines, etc...”</p> <p>“...Basically, digital twin is a virtual representation of a physical object with two-way communication and reflects the real-time data of the physical object...”</p>

		<p>“...The application of digital twin technology requires a framework which is a communication architecture/platform to connect digital assets and physical assets. The framework is also critical in ensuring connectivity between the various companies involved in the development and operation of offshore wind farms....”</p> <p>“...there is a growing demand for all companies involved in one project to communicate in a similar and standard "language" in order to integrate automatically without human intervention. This ability is called interoperability where the computer systems or programs can exchange the correct information with each other and carry out the functions...”</p>
4.	<p>The second part of the article presents a case study of a digital twin of a new floating offshore wind farm. This second part of the article is not effective because the information given to the reader is not enough to construct a digital twin, but it is not even a literature review study because authors present just their work and do not give a broad perspective on condition monitoring of floating wind farms.</p>	<p>Thank you for the comment. Yes, the second part of the article is not a literature review study, it is our case study, as we mentioned on the introduction section: “...3. to conceptually apply the solution framework for offshore wind farms in the case study...”.</p> <p>We believe through the case study applying the solution framework we discovered from our literature review, we provide a solid solution to convince researchers working in the wind energy community to apply digital twin technology in this regard.</p>
5.	<p>In view of this issue, I don't think the article is suitable for publication in its current state. I think the authors should clarify the scope of their article, improve the writing, and make the article more appealing and easier to understand for the</p>	<p>Thank you for the comment. Our paper consists of literature review study on 2 related topics, namely (i) the digital twin concept in terms of offshore wind farms, and (ii) the digital twin frameworks on manufacturing and offshore wind farm sectors.</p> <p>Based on the result from those literature review studies, we provided a case study</p>

	wind energy community that reads this journal.	<p>which we believe that instead of causing this paper not suitable to be published in its current state, the case study can improve the paper quality by presenting the solid solution.</p> <p>We believe that we clarified the scope of our article through three objectives we mentioned on introduction section (4th paragraph), and the research approach diagram in Figure 1.</p>
6.	Apart from these general comments, I have specific comments and suggestions for technical corrections that I hope can be useful to improve the article. Specific comments are reported below, while technical corrections are in the attached document.	Thank you for all your comments; general, specific, and technical ones. Your inputs have helped improve our article in one way and another. We really appreciate it. Hopefully the revised manuscript will be clearer and more understandable for wind energy community.
Specific comments		
7.	In the abstract, you should avoid using Industry 4.0, or explain the meaning of this concept in plain words. The same applies to the introduction, where Industry 4.0 appears as the first word.	<p>Thank you for the input, we have addressed this comment on the comment no.3 above. It can be found on 1st paragraph of introduction section.</p> <p>“...Energy industry has been moving forward by involving intelligent technology following the industry revolution in its application. In 2011, industry 4.0 was first introduced at the Hanover Fair, as a program of the German government (Xu et al., 2021). Industry 4.0 is driven by the Industrial Internet of Things (IIoT) and cyber-physical system (CPS) that utilize computer-based algorithms to control and monitor physical devices like vehicles, robots, machines, etc. Wind farm industry requires a fast change towards industry 4.0, powered by smart technology such as machine learning, big data, the internet of things, and digital twins in order to achieve the monitoring, automation and analysis of supply chains ...”</p>

8.	Line 6 “advanced technologies”: can you name some of them?	Thank you for the input, we named two of them on the revised abstract; “...Motivated by the advanced technologies such as cyber-physical systems and Industrial Internet of Things in the context of Industry 4.0 implemented in the manufacturing sector, ...”
9.	Section 1 – Introduction. I would use the first section of the article to introduce terms of the Industry 4.0 word that are not familiar to people of the wind energy community. Later you use a lot of jargon and acronyms, and many papers are related to scenarios a lot different from the wind energy field.	Thank you for the input, we have addressed this comment on the comment no.3 above. We hope it becomes clearer for people of the wind energy community. Regarding the acronyms of many papers we reviewed, we argued that we wrote down the original jargon and acronyms mentioned in those papers.
10.	Section 2. I think that before moving to the review of digital twin technologies, it would be beneficial to explain in plain simple words what is a digital twin concept and a digital twin framework.	Thank you for the input. As we addressed the comment no.3, we have explicitly mentioned the definition of digital twin and the framework on the introduction section.
11.	Figure 1 is not useful and can be removed. All information inside the figure is already described in the text.	Thank you for the comment, however, we believe that figure 1 provides a clearer outlook of how we conducted our research. We argue that through the visualization of red and blue circles, we specify the scope of the selected articles.
12.	Section 2. This section is not very useful, and I think it can be removed. This is the description of the literature review process which is normally done in any study and review article. I think it would be better to re-write this section, merging it with section 3, and cite the most important	Thank you for the comment, however, we believe that it is important and necessary to inform the readers how we conducted our research on the methodology section. We argue that by explaining our research methodology we also specify the scope of our research.

	papers in the literature, mention their findings and how they can be used in the research of this paper.	
Technical corrections		
13.	See attached document. There are many sentences that are a bit obscure and difficult to understand. I have highlighted them and commented with "rephrase".	Thank you for the input, we have revised the manuscript to address this comment.