IEEE International Conference on Industrial Electronics for Sustainable Energy Systems (IESES 2023)

Tutorial Proposal

- **Tutorial Title: AI driven offshore wind farm management**

- **Presenter(s):** Senior Researcher, Dr., Junyong You, Norwegian Research Centre, Norway

- **Brief description:**
Offshore wind energy is an increasingly important source of sustainable energy. Wind energy is a clean and renewable source of energy; thus it does not produce harmful pollutants or greenhouse gas emissions obstructing sustainable development. This makes it a key contributor to reducing carbon emissions and mitigating the impacts of climate change. Wind energy also helps to diversify the energy mix, reducing reliance on fossil fuels and increasing energy security. This is particularly important in countries (e.g., China) that might be heavily dependent on imported energy sources. Furthermore, wind energy can be generated locally, reducing the need for long-distance transmission lines and associated losses. This can improve the reliability and stability of the power grid, particularly in remote or rural areas. On the other hand, the cost of wind energy has been steadily decreasing, making it increasingly competitive with traditional fossil fuel sources. This trend is expected to continue as technology improves and economies of scale are achieved. Therefore, wind energy is a key component of sustainable development, providing clean, renewable energy that promotes energy security, economic growth, and local energy generation, while also reducing carbon emissions and mitigating the impacts of climate change.

  However, there are quite some challenges in the industry of wind energy, especially offshore wind farm management. Offshore wind farms can have environmental impacts on marine wildlife, including disruption of migration patterns and potential harm to marine mammals and birds. Offshore wind turbines are exposed to harsh weather conditions such as storms, high winds, and waves, which can damage or destroy the turbines and increase maintenance costs. In addition, offshore wind farm management is a complicated problem encountering challenges frequently, e.g., the maintenance of wind energy can be challenging due to the harsh and remote environments of offshore wind farms.

  To address the challenges in the industry of offshore wind energy, deep learning driven artificial intelligence (AI) technologies can be applied to improve the efficiency and reliability of offshore wind farms. The typical applications include.

  - Predictive maintenance: AI can be used to analyze data from sensors on offshore wind turbines to detect potential equipment failures before they occur. This allows for proactive maintenance and repair, reducing downtime and maintenance costs.

  - Performance optimization: AI can analyze data from turbines and weather forecasts to optimize turbine performance based on changing wind conditions. This can improve energy production and reduce wear and tear on equipment.

- Environmental monitoring: AI can be used to monitor the environmental impacts of offshore wind farms on marine wildlife, allowing for early detection of any harmful effects and enabling mitigation strategies to be put in place.

- Supply chain management: AI can be used to optimize supply chain management for offshore wind farm maintenance and operations, reducing costs and improving efficiency.

- Safety management: AI can help improve safety management on offshore wind farms by analyzing data on worker behavior and identifying potential safety hazards.

- Intelligent farm management: AI can provide decision support for automatic operations in wind farm management based on environmental conditions, e.g., reinforcement learning technique can be used to decide the optimal operations in wind farm management.

In summary, AI can provide valuable insights and improve the efficiency and effectiveness of offshore wind farm management. However, effective implementation of AI requires careful planning and management, including data management, software development, AI modelling, etc. This tutorial expects to provide the audience with fundamental knowledge about deep learning, AI and their practical applications in offshore wind farm management with hands-on project experience.

- **Duration:** 2 hours

- **Outline:**
The tutorial will include four parts: 1) General introduction to AI and deep learning technologies; 2) Deep learning models that are relevant to wind farm management; 3) Practical applications of deep learning and AI in wind farm management; and 4) Hands-on experience from projects of wind farm management.

1) General introduction to AI and deep learning technologies (20 minutes). This part will focus on a general introduction about AI technology in the era of deep learning. The basic concept about AI and deep learning models will be presented, e.g., classical machine learning models, supervised, self-supervised and unsupervised learning, reinforcement learning.

2) Deep learning models that are relevant to wind farm management (30 minutes). This part includes popular deep learning models that can be employed in wind farm management. For example, predictive tasks such as sensor maintenance and environmental condition prediction can be formulated as time-series problems. Subsequently, recurrent neural networks, Transformer models, temporal convolution networks can be very useful in these time-series problems. The basic knowledge about these deep learning models will be presented.

3) Practical applications of deep learning and AI in wind farm management (30 minutes). In this part, a practical scenario of offshore wind farm will be set and example problems will be defined, e.g., a typical problem can be smartly schedule the next operation in farm control based on the wind forecast. In this case, two problems should be modelled. The first is to perform a short-term prediction of wind profile, e.g., wind speed and direction in the next hour. The second problem is to optimize the operations in order to achieve a predefined goal, e.g., energy saving. Details in the problem formulation will be explained and the relevant mathematical and engineering approaches will be presented.

4) Hands-on experience from projects of wind farm management (30 minutes). In this part, experience from own previous projects will be analyzed and shared. For example, in a previous project on using deep learning models for wind prediction and reinforcement learning for operation optimization in an offshore wind farm will be discussed, including the implementation of deep learning models and reinforcement learning models. Hands-on experience to solve the encountered challenges will be discussed.

Finally, a 10-minute wrap-up will be presented to summarize the tutorial.

- **Motivation and Focus:**
An important theme of IESES 2023 sustainable energy systems. Offshore wind is an important component of sustainable energy systems for several reasons:

- Abundant and reliable: Offshore wind has the potential to generate a significant amount of electricity. Wind speeds are generally higher and more consistent offshore, which means that offshore wind turbines can generate more electricity than their onshore counterparts.
- Low-carbon: Offshore wind is a low-carbon source of energy that does not emit greenhouse gases or other air pollutants during operation. This makes it an important tool in reducing carbon emissions and mitigating climate change.
- Space-efficient: Offshore wind turbines can be placed in areas where there is little competition for space, such as in the middle of oceans or seas. This means that they can generate electricity without taking up valuable land that could be used for other purposes.
- Less disruptive: Offshore wind turbines are often located far from shore, which means they are less visible and less disruptive to local communities than onshore wind farms.
- Economic benefits: Offshore wind can also provide economic benefits to communities and countries that invest in it. For example, it can create jobs in construction, manufacturing, and maintenance, and it can help to reduce reliance on imported fossil fuels.

On the other hand, AI technology is playing more and more important role in sustainable energy and offshore wind systems. For example, AI can be very useful in the following aspects of energy systems.
i) Predictive Maintenance: AI can help predict when maintenance is required on energy systems by analyzing real-time data on their performance. This can help to reduce downtime and maintenance costs, while improving system reliability and extending its lifespan.
ii) Performance Optimization: AI can analyze large amounts of data on energy system performance and environmental conditions to optimize their operation. This can help to increase the efficiency of electricity generation, reduce costs, and ensure that the systems operate safely.
iii) Energy Management: AI can help to manage energy systems by optimizing the use of renewable energy sources, storage solutions, and energy consumption. This can help to reduce energy waste, minimize costs, and ensure that energy systems operate efficiently.
iv) Safety: AI can help to improve safety by monitoring offshore wind turbines and alerting operators to potential hazards. This can help to reduce the risk of accidents and ensure that workers are safe.
v) Decision-making: AI can help make faster and more informed decisions by providing insights into complex data sets. This can help to optimize energy systems, detect and diagnose faults, and monitor environmental conditions.

Therefore, we believe that the topic of AI, especially driven by deep learning, is crucial and relevant for IESES 2023. The proposed tutorial is expected to provide the audience with basic concepts and knowledge about AI, deep learning, and the applications in offshore wind energy systems, and also in other energy related industry.

The target audience of this tutorial includes: graduate students from AI and energy systems, and engineers from energy industries.

The main learning objectives for the audience include:

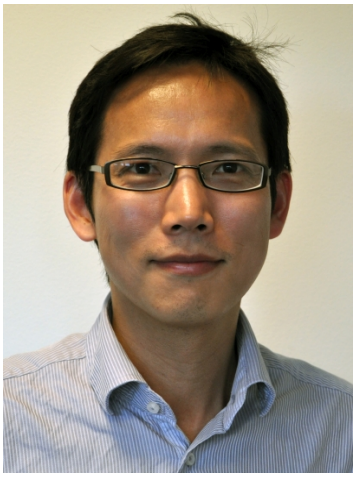
1) To understand basics about AI technology, e.g., classical machine learning, deep learning, supervised / self-supervised / unsupervised learning, reinforcement learning.

2) To gain knowledge about relevant deep learning models and how to implement them by programming.

3) To understand when and how to apply deep learning driven AI in energy systems, including from problem formulation to solution definition, and finally product development.

4) To understand the practical challenges of applying AI / deep learning in energy system and how to handle the challenges.

- **Brief CV:** Photo, name, email, and short resume (relevant to the proposal).



Dr. Junyong You (email: juyo@norceresearch.no) is a Senior Researcher at the Norwegian Research Centre (NORCE). He is also a Research Coordinator of AI projects at NORCE. Dr. You received the Bachelor and Master degrees in the Department of Computational Mathematics in 1998 and 2001, respectively, and the Ph.D degree from the Department of Information and Communication Engineering in 2007, both from Xi'an Jiaotong University in China. Dr. You has over 20 years of research experience in AI, machine learning modelling (classical learning, deep learning), data analysis, and applications in different areas such as energy, transportation, aquaculture. Dr. You is the author or co-author of over 70 publications in premium journals and conferences. He has been in charge of over 20 research projects in the relevant fields. For example, Dr. You is in charge of a Chinese-Norwegian collaboration project (Research on smart operation control technologies for offshore wind farms); He is a contact person for a research center "Smart Ocean" (Flexible and cost-effective monitoring for management of a productive and healthy ocean) at NORCE; Dr. You is a Work Package leader on reinforcement learning for

offshore wind platform optimization. Dr. You is also the coordinator of two national AI infrastructure projects: EuroCC2 (National Competence Centres in the framework of EuroHPC) and NAIC (Norwegian Artificial Intelligence Cloud). Dr. You has also been invited to give talks about AI and deep learning technologies and applications in several national events (e.g., at the Norwegian Cognitive Center https://norwegiancognitivecenter.com/blog/ai-inspire-redefining-workflow-with-ai-assisted-tools-94jls).

- **Relevant publications:**
  https://scholar.google.com/citations?hl=en&user=QUbrswsAAAAJ&view_op=list_works&sortby=pubdate

  1) J You, J Korhonen. “Attention integrated hierarchical networks for no-reference image quality assessment,” Journal of Visual Communication and Image Representation, 2022.
  2) J You, et al. “A set of web-based public decision support tools for integrated planning and management in aquaculture,” MethodsX, 2022.
  3) J. You, “Long short-term convolutional transformer for no-reference video quality assessment,” Proceedings of the 29th ACM International Conference on Multimedia, 2021.
  4) F. Chen, J. You, et al., “Ultra-short-term wind power forecasting based on attention mechanism”, 10th Renewable Power Generation Conference, 2021.
  5) J. You, “Weather data integrated mask R-CNN for automatic road surface condition monitoring,” IEEE Visual Communications and Image Processing (VCIP), 2019.