Application of Artificial Intelligence in Renewable Energy and Decarbonization

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Received: 1 October 2021; Accepted: 12 October 2021.

Article type: Research article.

1. Renewable energy and decarbonization

At a high level, renewable energy is created by renewable sources such as wind, solar and energy resources that can be refreshed continually, which is generally and almost exclusively carbon free.^[1-3] By year 2050, the International Energy Agency projects that the society needs to be in a zero-carbon system.^[4] Among those energy, electricity is the easiest to decarbonize because of the renewable energy. In the next 30 years, electricity needs to be decarbonized as much as possible. Besides, activities that utilize fossil-based resources today need to be electrified so that they can also use the decarbonized electricity.

Renewable energy is extremely important because it aligns with the decarbonized energy sector in the future. Today most of the grid energy are generated from the synchronous generators such as steam and gas turbines, which are very reliable and stable. When the renewable energy such as solar and wind are added to the grid, the behavior of the grid will be different. The renewable energies added to the grid change rapidly and are volatile. To achieve the zero-carbon target, about 90% of today's electricity needs to from renewables. Artificial intelligence (AI) plays an important role in the generation, transformation, and distribution of the renewable energies.^[5-7] We will exemplify this idea using the wind energy.

2. Applications of AI in renewable energy

It is important to realize that the demand for electricity generated by wind has increased dramatically.^[8,9] The wind turbines work under extremely complex and challenging environment and AI has been applied to a wide variety of areas such as engineering, design, manufacturing, and servicing. When using AI to identify the defects in the wind turbines, it is very challenging to build a reliable AI model because of the small dataset. The model is trained on the flaws of the

materials during manufacturing, which is only a small percentage. Overfitting will be a problem because the dataset is very small. To implement this anomaly detection model, several techniques can be applied.

To help increase the volume of the dataset, synthetic data generation and data augmentation can be applied to significantly increase the amount of training data.^[10-12] The model can be built with a much higher accuracy compared to that solely relying on the factory data. Generative neural networks are used to fabricate new dataset that could mimic the original data. The workflow can also start with pre-trained models to evaluate different architectures. Pre-trained models are cost effective components in building successful AI workflows. Fig. 1 shows the complete deep learning software stack from NVIDIA for researchers and software developers to build high performance GPU-accelerated applications.

In addition to manufacturing, artificial intelligence can help with inspections. Computer vision can be used to examine thousands of images of turbine blades to check if they have been damaged by harsh conditions such as lighting and storms.

3. Future opportunities and challenges

In the future, AI could be combined with grid formation control to help determine how energy is being uploaded to the grid. Currently, the system is based on a synchronous generator design, and by using converters and inverters, AI can maintain grid voltage and frequency, the two really important factors. AI creates the ability to form rather than follow the grid. Today, most of the wind and solar energy on the grid is in a following mode. In this new paradigm, AI will help improve the grid around it. The second topic AI can help with is demand response. Because more and more renewables on the grid are volatile, facilities are being overbuilt to accommodate lighter wind and solar conditions. One way to deal with this overcapacity problem is to use AI to dial down demand where it causes less inconvenience. The next frontier in how AI can be applied to the renewable sector revolves

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Fig. 1 NVIDIA complete deep learning software stack to build high performance GPU-accelerated applications.

around the resources themselves. For example, better models of wind turbulence in highly computationally intensive environments can be used to operate farms more efficiently, but obtaining this information is very challenging.

Conflict of Interest

There is no conflict of interest.

Supporting Information

Not Applicable.

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