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先進能源技術之發展與應用 專輯
Special Issue：Development and Application of Advanced Energy Technology

我國綠電市場成長趨勢之研析

Research on the Growth Trend of Taiwan's Renewable Energy Market

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摘　要

我國近年政府積極推動再生能源發展及產業能源轉型，電業法修正案、用電大戶及RE100 等政策都將影響未來國內綠電市場發展。爰此，本研究透過數學規劃方式建立綠電市場供需模型，評估至 2030 年國內綠電市場潛在供給及需求的量能，以探討未來綠電市場可能發展之情況以及面臨之挑戰。研究結果顯示，綠電市場交易量至 2030 年將成長至 145.6 億度至 173.7 億度間；綠電市場供給則以離岸風電為綠電交易大宗。另市電價格、產業負載型態亦為影響綠電市場之重要因素，為後續研究精進方向。

Abstract

In recent years, the government has actively promoted the development of renewable energy and industrial energy transformation.Policies such as the amendment to the Electricity Act, obligations for energy-intensive consumers to utilize renewable energy, and initiatives of RE100 will affect the future development of the domestic renewable energy market. Therefore,this study uses mathematical programming to create a renewable energy market supply and demand model to evaluatethe potential supply and demand of the domestic green power market until 2030, in order to explore the possible development of the future renewable energy market and the challenges it faces.Research results show that the renewable energy market transaction volume will grow to between 14.56 billion kWhs and 17.37 billion kWhs by 2030, and the renewable energy market supply is dominated by offshore wind power as the bulk of renewable energy transactions. Furthermore,the regulated electricity tariff and industrial load patterns are also important factors affecting the renewable energy market, which are the direction for subsequent research.

關鍵詞(Key Words)：綠電市場(Renewable Energy Market)、用電大戶(Energy-Intensive Customers)、RE100(Renewable Energy 100)、躉購制度(Feed-In Tariff)、數學規劃(Mathematical Programming)。

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模組化風力發電預測系統開發

Development of a Modular Wind Power Generation Forecast System

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摘 要

近年來台灣風力發電發展快速，政府規劃的目標是在 2025 年建置完成 5.7GW 的離岸風機；由於離岸風機朝大型化發展，離岸風場具有單一場址規模大且集中特性，加上風力又屬間歇性能源，其併網易對電力系統的穩定性造成影響。台灣在完成 2 座示範風場後，2022 年起陸續有新建置的離岸風場加入系統營運；為使新建置的風場能在試運轉後儘早加入預測系統的行列，本研究擬使用模組化設計，開發建立新版的風力發電預測系統，由於模組化可使系統更具有擴充性，有利於未來新風場更快併入預測系統中，也將有利相關營運單位能更即時地掌握風力發電出力的現況。

Abstract

Taiwan’s wind power generationhas developed rapidlyin recent years to achieve the government’s policy goal of completing the construction of 5.7 GW offshore wind turbines by 2025. With the trend oflarge scaledevelopment of offshore wind turbines, asingle offshore wind farm has the characteristics of large scale and concentration. In addition, wind power is an intermittent energy source, and its connection to the power grid can easily affect the stability of the power system. After the completion of two demonstration wind farms, newly established offshore wind farms have been successively connected to the power grid since 2022. In order to enable new wind farms to join the ranks of power generation forecast as soon as possible after completing their trial operation, this study plans to employ modular design to develop and establish a new version of wind power generation forecast system. Modularization can make the forecast system more scalable, help new wind farms to join the power generation forecast system faster, and also help relevant operating units to grasp the current status of wind power output in a more real-time manner.

關鍵詞(Key Words)：風力發電(Wind Power Generation)、模組化(Modular)、再生能源預測(Renewable Energy Forecast)。

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基於衛星雲圖之日射量估計與預測技術開發

Development of Solar Irradiance Estimation and Forecast Technology Based on Super-pixel Segmented Satellite Cloud Images

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摘　要

隨著太陽光電系統的滲透率逐漸增加，其發電出力的間歇性與不穩定性，對區域電網操作將帶來極大的挑戰。解決太陽光電對電網的衝擊，除了光儲系統，發展太陽光電發電出力預測，亦是因應能源轉型過程降低對電網衝擊的關鍵技術。太陽光電發電出力情況與雲層變化息息相關，因此本文建立一個基於超像素分割衛星雲圖進行短期日射量的估計與預測的技術，分析衛星雲圖並萃取其雲層特徵，採用光流法，分析雲層移動，生成預測的衛星雲圖。分析方法係先採用線性迭代聚類方法對衛星雲層進行分割得到多塊影像，進行改良的紅藍比例法取得雲層特徵，接著使用光流法來預測未來雲層影像，然後利用這些雲層特徵來估計和預測日射量。最後並透過實驗設計，以平均絕對誤差(MAE)、均方根誤差(RMSE)以及相關係數(R^2)等指標，來驗證所提出方法的性能。

Abstract

As the penetration rate of solar photovoltaic (PV) systems gradually increases, the intermittency and instablility of its power generation will bring great challenges to the operation of regional power grids. In addition to PV storage systems, the development of PV power generation forecast is also a key technology to minimize the impact of PV systems on the power grid in response to the energy transformation process. The output of solar power generation is closely related to the changes in clouds. Therefore, this study establishes a technology for estimating and forecasting short-term solar irradiance based on super-pixel segmentation of satellite cloud images. It analyzes satellite cloud images and extracts their cloud characteristics, and uses the optical flow method to analyze cloud movement and generate forecasted satellite cloud images. The analysis method is to first use the linear iterative clustering method to segment satellite clouds to obtain multiple images, and then use the improved red-blue ratio method to obtain cloud characteristics. After that, the optical flow method is used to forecast future cloud images, and the cloud characteristics are used to estimate and forecast solar irradiance. Finally, through experimental design, the performance of the proposed method is verified with indicators such as the mean absolute error (MAE), root mean square error (RMSE), and correlation coefficient (R^2).

關鍵詞(Key Words)：日射量(Solar Irradiance)、衛星雲圖(Satellite Cloud Images)、超像素分割(Super-pixel Segmentation)、光流法(Optical Flow Method)。

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儲能系統參與電力市場之應用、挑戰與展望

Applications, Challenges and Prospects of Energy Storage Systems in Electricity Market

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摘　要

隨著大量再生能源的併網，雖然可以實現淨零排放，但也使得維持電力系統的安全可靠度變成一項艱鉅的挑戰。若現有發電資源缺乏調度彈性，很容易造成電網輸電壅塞甚至導致再生能源受削減，進而嚴重地增加電力系統營運成本。為了推動再生能源發展以實現淨零排放的目標，電池儲能逐漸被認為扮演著一個很重要的關鍵角色。本文將探討電池儲能系統(BESS)於再生能源的應用案例，包含轉移多餘的再生能源以降低壅塞或削減問題，電池儲能的快速反應和靈活調度彈性可滿足日益增長的輔助服務需求，可取代即將退役的火力發電源備足充分的備用容量，提供高效率的虛擬容量而減少輸電線路擴充或擴建的昂貴成本，在極端氣候下可提高電力系統的韌性與可靠度等方面。藉由 BESS 的成功案例，為臺灣實現淨零排放提供經驗和借鑒。

Abstract

The integration of large amounts of renewable energy into the grid can help achieve net-zero emissions, but it also makes maintaining the safety and reliability of the power system a difficult challenge. If the existing power generation resources lack dispatch flexibility, it will easily cause transmission congestion and even lead to a reduction in renewable energy generation, which will seriously increase the operating costs of the power system. In order to promote the development of renewable energy and achieve the goal of net-zero emissions, battery energy storage system (BESS) is gradually considered to play an important role. This article will explore the application cases of BESS in renewable energy, including transferring excess renewable energy to reduce congestion or curtailment. The rapid response and dispatch flexibility of BESS can meet the growing demand for ancillary services, replace retiring thermal power generation sources with sufficient reserve capacity, provide high-efficiency virtual capacity, reduce the expensive cost of transmission line expansion, and in extreme cases improve the resilience and reliability of the power system under extreme climate conditions. The introduction to successful BESS cases in this article may serve as a reference for Taiwan to achieve net-zero emissions.

關鍵詞(Key Words)：電池儲能系統(Battery Energy Storage System, BESS)、備轉容量(Operating Reserve)、備用容量(Planned Reserve)、壅塞(Congestion)、共置儲能(Co-location Energy Storage)、混合電源(Hybrid Resource)、儲能為輸電資產(Storage as Transmission Asset, SATA)。

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天然氣混燒氫能之燃燒特性研究

Research on Combustion Characteristic of Hydrogen Blended Natural Gas

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摘 要

鑒於全球氣候危機，淨零碳排議題在各大國之間同時以商業競爭和環保意識衍生出許多國際法規政策以及研發投注。2023 年 4 月 17 至 18 日於日本北海道舉辦的七大工業國組織(G7)氣候、能源及環境政策會議，跨國企業正集結力量於發展氫能、增加再生能源和整合型能源發電廠，以此過渡到零碳排發電。

本研究從專對天然氣混燒氫氣的敏感度分析若干文獻和反應資料庫中，提取適用本案的化學動力模型，並將其用於混氫燃燒行為趨勢分析，最後與實驗數據相互驗證。從結果可推估實際機構與火焰行為和燃料與空氣參數相互影響，如研究發現當維持固定熱釋放率時，混氫比例達 30%vol. 所產生的明顯流場變化對 NOx 和火焰溫度分布的影響，如火焰熱區尺度、壁面二次流…等等。研究過程的經驗結果可作為未來機組混氫燃燒和購置時有所參考，以此建立台電研究所於國際重要議題之技術能量。

Abstract

In view of the global climate crisis, the issue of net-zero carbon emissions has generated many international regulations, policies, and R&D investments among major countries based on business competition and environmental awareness. Following the Group of Seven Major Industrial Countries (G7) Climate, Energy and Environmental Policy Conference held in Hokkaido, Japan, from April 17 to 18, 2023, multinational companies are gathering strength to develop hydrogen energy, increase renewable energy and integrated energy power plants to gradually achieve zero-carbon emission power generation.

This research extracts a chemical kinetic model suitable for this project from several literature and reaction databases which dedicated to sensitivity analysis of natural gas mixed combustion with hydrogen, and uses it to analyze the trend of hydrogen blended natural gas combustion, and finally validated with experimental data. For example, research results have found that when a fixed heat release rate is maintained and the hydrogen mixing ratio reaches 30% vol., the resulting flow field changes have an impact on NOx and flame temperature distribution, such as the dimension of the flame hot zone, wall secondary flow, etc. The empirical results of the research process can serve as a reference for future hydrogen blended natural gas combustion engineering and gas turbine procurement for units under TPC.

關鍵詞(Key Words)：乾式低氮排放 (Dry Low Emission)、氮氧化物(NOx)、燃燒器(Combustor)、氣渦輪機(Gas Turbine)、模擬分析(Simulation Analysis)、GRI mech 3.0、氫能(Hydrogen Energy)、混氫燃燒(Hydrogen Blended Fuel Combustion)、零碳排(Net Zero Carbon Emission)。

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海水電解產氫技術發展現況

Current Development Status of Seawater Electrolysis Hydrogen Production Technology

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摘　要

在全球淨零發展過程中，電解綠氫扮演舉足輕重的角色，電解綠氫的進展取決於綠電以及水資源的管理，為了避免發展電解綠氫可能導致與民爭水的議題爭議，海水電解產氫技術近年來備受注目。本研究已就海水電解產氫技術與國際相關進展進行分析，並說明發展海水電解產氫技術之應用優勢與技術挑戰。在本研究中，首先就海水電解產氫技術之發展背景、發展現況與發展方向進行分析，其次就電解水產氫與海水電解產氫之基本原理進行探討，此外，亦就國際上目前於觸媒材料的發展現況以及相關示範計畫進行說明與探討。全球各國因應淨零發展，正處能源轉型之階段，台灣四面環海，其海洋資源充足與豐富的離岸風場之條件，發展海水電解產氫技術或許為加速淨零轉型的關鍵之一。

Abstract

In the global net-zero emissions development process, electrolytic green hydrogen plays a pivotal role. The progress of electrolytic green hydrogen depends on the management of green electricity and water resources. To avoid the development of electrolytic green hydrogen that may lead to disputes with the public over water, seawater electrolysis has attracted much attention in recent years. This study analyzes the related international progress of seawater electrolysis and explains the application advantages and technical challenges of developing seawater electrolysis hydrogen production technology. In this study we first analyze the technical development background, current situation and future development direction of hydrogen production by seawater electrolysis, and then discuss the basic principles of hydrogen production by electrolysis of water and seawater electrolysis. Moreover, the current international development status of catalytic materials and related demonstration projects are also explained and discussed. Countries around the world are in the stage of energy transformation in response to net-zero development. Taiwan is surrounded by sea and has excellent offshore wind field conditions. The development of seawater electrolysis hydrogen production technology may be one of the keys to accelerating the net-zero transformation.

關鍵詞(Key Words)：海水電解(Seawater Electrolysis)、綠氫(Green Hydrogen)、淨零排放(Net-Zero Emission)、水資源(Water Resources)。

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水電解產氫觸媒電極與技術應用現況

Current Status of Catalyst Electrodes and Technology Applications for Hydrogen Production through Water Electrolysis

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摘要

電解水是以電化學方式將水分解為氫氣與氧氣，為簡單高效的產綠氫方式，因其低汙染和生產高純度氫氣而引起廣泛關注。在電解水的析氫析氧過程中，有許多參數會影響觸媒電極的催化活性，觸媒的性能、離聚物的種類與含量都會導致不同的催化活性。本文藉由四種不同濃度的離聚物測試，進行陰極電極的評估。透過固定負荷量觸媒 Pt/C 進行析氫反應的 LSV 測試，分析不同離聚物濃度在析氫反應中的催化活性，評估離聚物濃度對於產氫觸媒的影響。實驗分析結果中顯示隨著離聚物濃度的提升，觸媒漸漸被離聚物包覆住，觸媒活化位點無法裸露而導致電阻增加，因而使電極催化活性性能下降。性能下降代表水無法順利地分解為氫氣與氧氣，因而在相同電壓下，其氫氣生產的產量與效率預期會降低。

Abstract

Water electrolysis is the electrochemical decomposition of water into hydrogen and oxygen. It is a simple and efficient way to produce green hydrogen, which has attracted widespread attention because of its low pollution and production of high-purity hydrogen. In the process of electrolysis, there are many parameters, such as the performance of the catalyst, the type and content of the ionomers, etc., which will lead to different catalytic activities. This article evaluates the cathode electrode by testing four different concentrations of ionomers. The LSV test was carried out using a fixed load catalyst Pt/C to analyze the catalytic activity of different ionomer concentrations in hydrogen evolution reaction and evaluate the impact of the ionomer concentration on the hydrogen production catalyst. Experimental analysis results show that as the ionomer concentration increases, the catalyst is gradually coated by the ionomer, and the catalyst activation sites cannot be exposed, resulting in an increase in resistance, thus reducing the catalytic activity of the electrode. The performance degradation means that water cannot be decomposed into hydrogen and oxygen smoothly, so the yield and efficiency of hydrogen production are expected to be reduced at the same voltage.

關鍵詞(Key Words)：電解水產氫(Hydrogen Production by Water Electrolysis)、陰極電極(Cathode Electrode)、觸媒(Catalyst)、離聚物(Ionomer)、連結劑(Binder)。

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AI 能源樞紐系統

Artificial Intelligence Energy Hub System

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摘 要

本研究是以國立虎尾科技大學的智慧綠能場域作為平台，結合場域太陽光電與風能系統所發的電力及中央氣象局虎尾觀測站的氣象資料，作為計算資料的來源。以隨機森林迴歸模式，針對本系統之時間序列資料，進行資料分類處理。長短期記憶(Long Short-Term Memory, LSTM)是一種時間循環神經網路(RNN)，以 LSTM 作為預測之訓練與模型之建立，將所搜集之資料進行運算。本系統已可以準確預測太陽光電的發電量，但對於短期預測上，因受限於氣象預報資料，無法得到精準的資料。而風能的預測方面，本系統風機較小，且場域附近之工程因素，以致於準確性較低。綜合而言，本研究所建立之 AI 能源預測系統，對於太陽光電的中長期有較佳之表現，可以作為未來能源樞紐的重要一環。

Abstract

This study uses the smart green energy field of National Formosa University as a platform, combining the electricity generated by the solar photovoltaic and wind energy systems in the field with meteorological data from the Central Weather Bureau's Huwei Station as sources of calculation data. The random forest regression model is employed to classify and process the time series data of this system. Long Short-Term Memory (LSTM), a type of recurrent neural network (RNN), is used for training and model building for predictions, and the collected data is computed accordingly. The system can accurately predict the power generation of solar photovoltaics, but due to the limitations of weather forecast data, precise data for short-term predictions cannot be obtained. In terms of wind energy prediction, the wind turbine of this system is relatively small, and engineering factors near the field result in lower accuracy. Overall, the AI energy forecast system established in this study performs better for medium to long-term solar photovoltaic forecasts and can serve as an important part of future energy hubs.

關鍵詞(Key Words)：能源樞紐(Energy Hub)、虛擬電廠(Virtual Power Plant)、人工智慧(Artificial Intelligence)、再生能源(Renewable Energy)、太陽能(Solar Energy)、風能(Wind Energy)。

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浮游式黑潮洋流發電機組發展概況

Overview of the Development of Floating Kuroshio Current Turbine

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摘　要

台灣能源僅 3.3%為自主能源，其餘皆仰賴進口能源，因此，海洋能源技術的發展與提升對於自主能源至關重要，尤其鄰近台灣東部的的黑潮蘊藏龐大的能量，且流速穩定適合作為能源利用，若能有效利用，將對台灣能源安全有重大意義，並有助於減少溫室氣體排放。洋流能發電機可根據系統架構分成不同形式，依據台灣地理環境，黑潮洋流發電機適合浮體支撐方式，藉此透過升降控制以降低颱風對機組的影響。本文介紹浮游式黑潮發電機組發展和其試驗的成果，雖已透過 1/5 縮尺模型驗證其發電能力，但未來應持續推動研究並攜手產業逐步商業化，期望透過黑潮能量緩解台灣能源供需壓力提升能源安全。

Abstract

Taiwan only has 3.3% of its own energy resources, and the rest relies on imports. Therefore, the development and improvement of marine energy technologies is crucial to improving independent energy. The Kuroshio Current near eastern Taiwan contains substantial energy and has a stable flow rate. If it can be used effectively, it will be of great significance to Taiwan's energy security and help reduce greenhouse gas emissions. Currently, ocean current energy turbinescan be divided into different forms according to their system architecture. Considering Taiwan’s geographical characteristics, the Kuroshio current generator is suitable for floating supportto reduce the impact of typhoons through lifting control. This article introduces the development of the floating Kuroshio current turbine and the results of its testing. Although the power generation capability for a 1/5 scale model has been verified, continuing to promote research and join hands with the industry to gradually commercialize it, hoping to use Kuroshio energy to alleviate Taiwan's energy supplyand demand pressure and enhance energy security.

關鍵詞(Key Words)：海洋能源技術(Marine Energy Technology)、黑潮洋流(Kuroshio Current)、浮游式黑潮洋流發電機 (Floating Kuroshio Current Turbine)。

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鍋爐深度學習影像辨識模型之建立

Establishment of Boiler Deep Learning Image Recognition Model

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摘 要

大型燃煤電廠之鍋爐肩負著供應蒸汽予汽機發電之重要任務，倘若鍋爐爐管洩漏，就必須停機檢修，這至少會造成發電損失和增加替代電源成本等負面影響。根據調查 80%的電廠強迫停機與爐管破損有關，其中又以水牆管故障約 40%佔最大多數。水牆管高處因巡檢人員不易到達，常需搭設鷹架或搭乘吊籠等來進行檢測，這不僅成本高、耗時費力，亦易有工安之風險。鑒於無人機可提供範圍廣泛且即時之影像拍攝，以及人工智慧圖像辨識技術能快速且精確的進行故障辨識，本研究乃結合此兩者進行林口電廠爐管故障檢測。結果顯示：即時物件偵測能提供即時資訊予現場人員，快速發現爐管損傷，找出洩露所在，將不利影響與損失降至最低。

Abstract

The boilers of large coal-fired power plants shoulder the important task of supplying steam to turbines for power generation. If the boiler tube leaks, the unit must be shut down for maintenance, which will at least cause negative impacts such as loss of power generation and increased cost of alternative power sources. According to a survey, 80% of forced shutdowns of power plants are related to boiler tube damage, of which 40% are caused by water wall tube failures. Inspection personnel often need to set up scaffolding or ride in a hanging cage to conduct inspections at high places on water wall pipes, which is not only costly, time-consuming and labor-intensive, but also prone to industrial safety risks.Since unmanned aerial vehicles (UAV) can provide a wide range of real-time image capture, and artificial intelligence (AI) image recognition technology can quickly and accurately identify faults, this study combines the two to detect boiler tube faults atLinkou Power Plant. The results show that real-time object detection can provide real-time information to on-site personnel, helping themto quickly detect boiler tube damage, locate leaks and minimize adverse effects and losses.

關鍵詞(Key Words)：物件偵測(Object Detection)、錨框(Anchor)、非極大值抑制(Non-Maximum Suppression)、無人機(UAV)、鍋爐破管(Tube Failure)。

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應用聲學特徵與機器學習於風機葉片損傷檢測研究

Research on Wind Turbine Blade Damage Detection Using Acoustic Features and Machine Learning

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摘 要

本研究提出一種基於聲學特徵與機器學習的風機葉片損傷檢測方法，利用聲學感測器收集風機葉片運轉聲音，通過訊號處理擷取葉片損傷特徵，並結合機器學習技術建立損傷檢測模型。在數據收集方面，針對不同機型之風機葉片進行多次數據蒐集，並從風場維護人員取得標籤資訊，區分正常與異常風機樣本。研究中採用極限梯度提升(XGBoost)演算法進行模型訓練，並通過交叉驗證避免過度擬合。結果顯示，模型在準確率、召回率及精確度方面均表現優異。最後在實地場域驗證進一步確認了模型的有效性和可靠性。

Abstract

This study proposes a wind turbine blade damage detection method based on acoustic features and machine learning. Acoustic sensors are used to collect operational sounds from the wind turbine blades, and signal processing techniques are applied to extract damage features. These features are then used to develop a damage detection model using machine learning techniques. In this study, multiple data collections were conducted on wind turbine blades of different models, and label information was obtained from wind farm maintenance personnel to distinguish between normal and abnormal turbine samples. The study employs the Extreme Gradient Boosting (XGBoost) algorithm for model training and uses cross-validation to prevent overfitting. The results demonstrate that the model performs well in terms of accuracy, recall, and precision. Finally, field verification further confirmed the validity and reliability of the model.

關鍵詞(Key Words)：風機葉片損傷檢測(Wind Turbine Blade Damage Detection)、聲學特徵(Acoustic Features)、機器學習(Machine Learning)。

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