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新及再生能源：
NEW AND RENEWABLE ENERGY :

電力系統：
POWER SYSTEM :

環境與永續：
ENVIRONMENT AND SUSTAINABILITY :

核能：
NUCLEAR ENERGY :

應用於高再生能源占比之電網型變流器控制與設計

Control and Design of Grid-Connected Inverters for Power Grids with High Renewable Energy Penetration

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摘 要

隨著再生能源占比逐漸提升，變流器作為再生能源發電系統的核心元件，其主要功能是將發電裝置產生的直流電轉換為符合電網標準的交流電。然而，隨著電網中再生能源滲透率的增加，變流器需具備更先進的功能以維持電網穩定。依據與電網的互動特性，變流器可以分為電網追隨型變流器(Grid Following Inverter, GFLI)和電網形成型變流器(Grid Forming Inverter, GFMI)。因此，為了更加瞭解變流器的演進與轉運特性，本研究探討變流器的基本原理與拓樸結構，並分析高再生能源占比下，傳統變流器所面臨的問題，例如電壓與頻率不穩定、電網慣量減少等問題。同時，藉由模擬分析來探討單台 GFLI 和 GFMI 以及並聯運轉的特性。

Abstract

As the proportion of renewable energy in power grids continuously increases, inverters have emerged as the core components of renewable energy generation systems, primarily functioning to convert direct current (DC) into grid-compliant alternating current (AC). However, with increasing renewable energy penetration, inverters need more advanced functionalities to maintain grid stability. Based on their grid-interaction characteristics, inverters are generally categorized into grid-following inverters (GFLIs) and grid-forming inverters (GFMIs). To elucidate the evolution and operational characteristics of these devices, this study explores the fundamental principles and topological structures of inverters. Furthermore, it analyzes the technical challenges confronting conventional inverters under high renewable energy penetration, such as voltage and frequency instability, and reduced grid inertia. Finally, simulation analyses are performed to investigate the operational characteristics of individual GFLIs and GFMIs, as well as their performance during parallel operation.

關鍵詞(Key Words)：再生能源(Renewable Energy)、變流器(Inverter)、電網慣量(Grid Inertia)。

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台電公司銷售備用容量之合理定價研析

An Analysis of Reasonable Pricing for Reserve Capacity Sales by Taiwan Power Company

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摘　要

《備用供電容量管理辦法》於 114 年 1 月 8 日修正施行，明確規範再生能源發電業及售電業的合規容量來源，並允許其向台電公司採購。隨著民間再生能源業者直供銷量逐年增加，其備用供電容量義務量擴大，故台電公司需及早研析其在備用容量市場中的未來角色及合理銷售策略。本文將著眼於國外先進電網容量市場運作、資源認定及合理價格定價方式，作為國內交易之借鏡。同時，依循管理辦法規定，考量利害關係人定位，具體規劃台電公司銷售供電容量的交易模式與合理定價。

Abstract

The Regulations Governing the Management of Reserve Capacity, amended and implemented on January 8, 2025, clearly defines compliant capacity sources for renewable energy generation and electricity retailing entities, and permits them to procure the aforementioned capacity from Taiwan Power Company (Taipower). Driven by the annual increase in direct supply and wheeling volumes from private renewable energy operators, their mandatory reserve capacity obligations have expanded. Consequently, Taipower must promptly analyze its future role and reasonable sales strategies within the reserve capacity market. This study examines international advanced capacity market operations, resource accreditation, and pricing mechanisms to serve as a benchmark for domestic transactions. Furthermore, aligned with the regulatory provisions and taking into account stakeholder positioning, this paper formulates specific transaction modes and reasonable pricing mechanisms for Taipower's reserve capacity sales.

關鍵詞(Key Words)：電力市場(Electricity Market)、備用容量(Reserve Margin)、合理定價(Reasonable Pricing)、容量價值(Capacity Value or Capacity Credit)。

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以深度學習提升電力負載預測準確度：SARIMA、RNN、LSTM 與 Transformer 之比較

Improving Power Load Forecasting Accuracy with Deep Learning：A Comparison of SARIMA, RNN, LSTM, and Transformer

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摘　要

雖然傳統時間序列方法具理論穩健性，但在面對電力負載的非線性與高波動特徵時，預測能力仍顯不足。近年來，深度學習模型因其強大的特徵提取與序列建模能力，為負載預測開闢新的途徑。本研究以台灣電力公司實際歷史負載數據為基礎，分別建立並訓練季節性自我迴歸差分移動平均數(SARIMA)模型、循環類神經網路(RNN)、長短期記憶網路(LSTM)模型與 Transformer 模型，並以平均絕對百分比誤差(MAPE)與均方根誤差(RMSE)作為主要評估指標。實證結果顯示，深度學習模型整體表現優於傳統 SARIMA 模型，其中 LSTM 在捕捉長期依賴與複雜模式上表現尤為突出，其預測平均絕對誤差百分比為 2.37%。

Abstract

Although traditional time-series methods are theoretically robust, their predictive capabilities are still insufficient when faced with the nonlinear and highly volatile characteristics of power loads. In recent years, deep learning models, leveraged for their powerful feature extraction and sequence modeling capabilities, have emerged as a promising approach to load forecasting. Utilizing actual historical load data from the Taiwan Power Company (TPC), this study develops and trains Seasonal Autoregressive Integrated Moving Average (SARIMA), Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM), and Transformer models, employing Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) as the primary evaluation metrics. Empirical results demonstrate that deep learning models consistently outperform traditional SARIMA models. Notably, the LSTM model excels in capturing long-term dependencies and complex patterns, achieving a MAPE of 2.37%.

關鍵詞(Key Words)：電力負載預測(Power Load Forecasting)、深度學習(Deep Learning)、季節性自我迴歸差分移動平均數(Seasonal Autoregressive Integrated Moving Average, SARIMA)、循環類神經網路(Recurrent Neural Network, RNN)、長短期記憶網路(Long Short-Term Memory, LSTM)、自注意力機制(Self-Attention)、電力系統調度(Power System Dispatch)。

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鹽寮沙灘岸線資料大數據運用模型探討

An Investigation into Big Data Application Models for Shoreline Analysis at Yanliao Beach

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摘　要

海域營力是形塑海岸地形的重要因素。鹽寮沙灘位於臺灣東北角，其地形長期受到多重海氣象因子的影響，其中以東北季風與颱風期間的潮汐變化、波浪、海流及風力對岸線變動最為顯著。隨著影像資料持續增加與機器學習技術的發展，本研究結合大數據與深度學習，探討岸線變遷及模型辨識精度。研究方法整合影像前處理、畫面品質篩選與 U-Net 模型，建立自動化影像辨識流程。測試成果顯示本研究模型具備高度辨識準確度，成功辨識岸線位置，足見大數據與深度學習於岸線監測之應用潛力，能提供即時且可靠的資訊，對海岸變遷研究與管理具有實務應用價值。

Abstract

Marine formative forces are critical drivers shaping coastal morphology. Located in northeastern Taiwan, Yanliao Beach experiences long-term morphological variations driven by multiple meteo-oceanographic factors, among which tidal fluctuations, waves, ocean currents, and wind forces during the northeast monsoon and typhoon seasons exert the most significant impacts on shoreline changes. Propelled by the continuous accumulation of imagery data and advancements in machine learning techniques, this study integrates big data and deep learning to investigate shoreline dynamics and model identification accuracy. The methodology integrates image preprocessing, image quality screening, and a U-Net model to establish an automated image recognition workflow. The results demonstrate that the proposed model achieves high identification accuracy and successfully identifies shoreline positions, yielding outcomes highly consistent with manual annotations. This study highlights the application potential of big data and deep learning in shoreline monitoring, delivering timely and reliable information that holds substantial practical value for coastal change research and management.

關鍵詞(Key Words)：大數據(Big Data)、深度學習(Deep Learning)、岸線變遷(Shoreline Dynamics)、影像辨識(Image Recognition)。

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核能電廠除役過渡階段前期風險評估廠內事件方法論之研究

A Study on Internal Events PRA Methodology for the Pre-Defuel Stage of Nuclear Power Plant Decommissioning

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摘 要

核能電廠運轉執照到期後，將進行除役作業。除役過渡階段前期始自反應爐永久停機，終於爐心的用過核子燃料挪移至用過燃料池存放。此階段之電廠風險組態，依據各類型電廠而不同，但是會類似一般大修停機燃料填換之風險組態。

本研究提出除役過渡階段前期(爐心有燃料)的風險評估方式，包含電廠組態、肇始事件的定義、事故序列的發展、成功準則、故障樹分析、人為可靠度分析與量化分析，建立一個完整的方法論來評估除役過渡階段前期之風險，可應用在核一、二廠。

Abstract

Following the expiration of a nuclear power plant's operating license, decommissioning activities are initiated. The pre-defuel stage begins with the permanent shutdown of the reactor and concludes once all spent nuclear fuel within the reactor core is transferred to the spent fuel pool. During this stage, the plant risk configurations vary depending on the specific reactor type; however, they generally resemble the risk configurations observed during standard refueling outages.

This study proposes a probabilistic risk assessment (PRA) methodology specifically tailored for the pre-defuel stage (with fuel remaining in the core). By integrating plant configuration characterization, initiating event identification, accident sequence development, success criteria determination, fault tree analysis, human reliability analysis, and quantitative evaluation, a comprehensive methodology is established to assess risks during the pre-defuel stage. This developed framework can be effectively applied to the Chinshan and Kuosheng Nuclear Power Plants.

關鍵詞(Key Words)：核能電廠除役(Nuclear Power Plant Decommissioning)、量化風險評估(Probabilistic Risk Assessment, PRA)、大修停機(Refueling Outage)。

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「濃度平均與封裝的分支技術指引」於我國低放廢棄物之處置分類運用

Application of the "Concentration Averaging and Encapsulation Branch Technical Position" to Low-Level Radioactive Waste Disposal Classification in Taiwan

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摘　要

美國核管會提出「濃度平均與封裝的分支技術指引」，作為低放廢棄物處置分類指引。該指引將放射性廢棄物分成可混合廢棄物和離散品項。可混合廢棄物採單一廢棄物流、多項廢棄物流或固化廢棄物方式進行濃度平均；離散品項採單一離散品項、混合離散品項或離散品項封裝方式進行濃度平均。韓國案例顯示，將廢樹脂混合盛裝於較大容器中，或大體積低濃度固化廢棄物與小體積高濃度固化廢棄物混合，除可滿足韓國低放處置場接收標準外，並符合處置安全。我國案例顯示，原 B 類或 C 類廢樹脂於處置時，若與 A 類廢樹脂混合後，總廢樹脂可歸為 A 類廢棄物；將廢射源依射源活度分開封裝時，將產生 1 桶 A 類廢棄物及 1 桶超 C 類廢棄物，最節省處置成本。韓國與我國案例顯示，濃度平均方式不僅可達到處置場接收所有廢棄物的目的，亦在確保處置安全的條件下，有效降低處置成本。

Abstract

The U.S. Nuclear Regulatory Commission (NRC) has issued the "Concentration Averaging and Encapsulation Branch Technical Position" (CA BTP) to serve as guidance for the disposal classification of low-level radioactive waste (LLW). This guidance categorizes radioactive waste into blendable waste and discrete items. For blendable waste, concentration averaging is performed using a single waste stream, multiple waste streams, or solidified waste methods. For discrete items, concentration averaging is conducted via single discrete item, mixed discrete items, or discrete item encapsulation approaches. Case studies from South Korea indicate that blending spent resins into larger containers, or mixing large volumes of low-concentration solidified waste with small volumes of high-concentration solidified waste, not only satisfies national repository acceptance criteria but also ensures disposal safety. In Taiwan's context, if Class B or Class C spent resins are blended with Class A spent resins during disposal, the total bulk of spent resins can be reclassified as Class A waste. Furthermore, encapsulating spent sealed sources separately based on source activity generates one drum of Class A waste and one drum of Greater-Than-Class-C (GTCC) waste, thereby minimizing disposal costs. These cases demonstrate that the concentration averaging approach enables repositories to achieve the goal of accepting all waste types while effectively reducing disposal costs under the premise of ensuring disposal safety.

關鍵詞(Key Words)：分支技術指引(Branch Technical Position, BTP)、低放廢棄物(Low-Level Radioactive Waste, LLW)、廢樹脂(Spent Resin)、廢射源(Spent Sealed Source)。

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ASME 法規案例 N-513-5 介紹與應用

Overview and Applications of ASME Code Case N-513-5

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摘 要

本文目的在介紹 ASME 法規案例 N-513-5，針對核能電廠的 2 或 3 級中能(Moderate Energy)管路與管件(肘管、彎管、漸縮管、擴張管、T 型管、閘閥體端等)發生瑕疵時，提供暫行接受的評估方法及準則，劣化情況的檢查和監測要求，以避免不必要的停機檢修/換管。此外，利用美國核能電廠的劣化管路安全評估案例，幫助讀者進一步了解 N-513-5 的管路瑕疵評估流程。

Abstract

This article presents an overview of ASME Code Case N-513-5, which establishes evaluation methodologies and criteria for the temporary acceptance of flaws in Class 2 or 3 moderate energy piping and fittings, including elbows, bent pipe, reducers, expanders, branch tees, and gate valve bady ends. Additionally, the code case specifies inspection and monitoring requirements for degraded components to mitigate unnecessary shutdowns or pipe replacements in nuclear power plants. Furthermore, a case study involving a degraded piping safety assessment from a U.S. nuclear power plant is utilized to provide readers with a deeper understanding of the N-513-5 flaw evaluation framework.

關鍵詞(Key Words)：安全評估(Safety Evaluation)、中能管路(Moderate Energy Piping)、平面瑕疵(Planar Flaw)、非平面瑕疵(Nonplanar Flaw)。

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