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建立韌性指標及強化公私協作提升能源韌性

Establishing Resilience Metrics and Strengthening Public-Private Partnership to
Enhance Energy Resilience

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摘要

台灣被認為是未來高階晶片製造及 AI 資料中心重鎮，而發展 AI 的關鍵條件就是能源。因新興科技用電需求增加，且面對各種新型態威脅的挑戰，建構具備高韌性的電網已成為確保供電穩定的首要任務。電網脆弱性與人為或自然威脅具有甚大的關聯性，不可預測的地緣政治、天然災害、發電廠事故、鐵塔倒塌、電網設備故障和關鍵基礎設施老化及人為失誤，可能造成大災難及大範圍的停電。因此，事先須採取主動因應措施，防範於未來。增強電力系統的韌性應是一項集體責任，一個清晰、標準化並可應用於電力系統中普遍可接受的韌性指標，會有助於評估高衝擊低機率事件下的區域電網及整體發輸配電系統效能，並指引強化供電韌性所需的基礎設施和電網技術投資。社區可以在韌性規劃、基礎設施建設與緊急應變上，與電力公司進行合作，共同提升能源韌性。藉由加強溝通、資源共享和制定社區客製化解決方案，電力供應的脆弱性可以被緩解，共同創建一個穩定、可靠且具有韌性的電力供應系統。

Abstract

Taiwan is poised to become a global hub for high-end chip manufacturing and AI data centers, where energy serves as a critical enabler of AI development. With rising electricity demand driven by emerging technologies, and increasing exposure to new forms of threats, building a highly resilient power grid is a must to ensure reliable power supply for high-tech industry. Grid vulnerabilities are closely linked to both man-made and natural threats. Unpredictable geopolitical events, natural disasters, power plant fires, transmission tower collapses, equipment failures, aging critical infrastructure and human errors could lead to catastrophes and widespread power curtailments. Proactive measures are required to mitigate such risks in advance. Strengthening power system resilience should be viewed as a collective responsibility, and establishing resilience metrics is imperative. A clear, standardized, and broadly applicable set of resilience metrics could assist performance assessment of regional grid and overall generation, transmission, and distribution systems in high impact and low probability events, and guide infrastructure planning and technology investments to enhance grid resilience. Utilities and communities can collaborate in planning, infrastructure development, and emergency response to jointly improve energy resilience. By enhancing communication, sharing resources, and developing customized solutions for the community, the vulnerability of power supply can be mitigated to create a stable, reliable, and resilient power supply system.

關鍵詞(Key Words)：電網韌性(Grid Resilience)、公私協作(Public-Private Partnership)、電能資源適足性(Resource Adequacy)、變流式電能資源(Inverter-Based Resources, IBRs)、韌性指標(Resilience Metrics)。

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低碳時代下供電型態的變革與應對策略

Transformation of Power Supply and Response Strategies in the Low-Carbon Era

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摘要

本報告探討臺灣電網在高再生能源滲透、電力需求持續成長與極端氣候頻仍下所面臨的可靠度與韌性挑戰。為兼顧供電穩定與低碳轉型，本文說明多項制度與技術應對策略，包括強化備用與備轉評估能力、推動智慧電網與區域調度、完善多元資源市場化與監管機制、推進韌性工程及防災體系，並建立運轉資料標準化與可靠度檢視機制。隨著經濟部於 2023 年設立電力可靠與韌性推動管理辦公室(OERM)，我國電力監管正逐步邁向制度化與專業化，未來將持續結合技術創新、制度調整與國際接軌，形塑以資料治理為基礎、兼具前瞻性與韌性的電力監管體系，支撐淨零轉型與永續發展目標。

Abstract

This study examines the challenges faced by Taiwan's power grid in maintaining reliability and resilience under high renewable energy penetration, growing electricity demand, and the rising frequency of extreme weather events. To reconcile power supply stability with low-carbon transition objectives, it outlines a series of institutional and technical strategies, including strengthening the assessment of reserve and spinning capacity, advancing smart grid and regional dispatch systems, enhancing market liberalization and regulatory frameworks, improving grid resilience and disaster-prevention mechanisms, and establishing standardized operational data and reliability evaluation procedures.

With the establishment of the Office of Electricity Reliability and Resilience Management (OERM) by the Ministry of Economic Affairs in 2023, Taiwan's power governance is moving toward greater institutionalization and professionalization. Looking ahead, the power sector will continue to integrate technological innovation, regulatory refinement, and international alignment to build a data-driven, forward-looking, and resilient governance framework that underpins Taiwan's net-zero transition and long-term sustainable development goals.

關鍵詞(Key Words)：電網韌性(Grid Resilience)、供電可靠度(Power Reliability)、智慧電網(Smart Grid)、再生能源併網(Renewable Energy Integration)。

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以再生能源電能市場支援全時(24/7)使用再生能源作法 建議

Recommendations for Enabling Twenty-four Seven (24/7) Renewable Energy Utilization via the
Renewable Energy Market

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摘要

採購再生能源可協助企業減少其經濟活動所造成對環境影響，並且帶來穩定能源使用所需支付費用等利益，國內外許多企業已承諾百分之百使用再生能源。近年來我國開放再生能源電力市場，許多企業已透過向再生能源發電業或售電業簽署購售電合約或向自用再生能源設備採購等雙邊合約，搭配逐月發用電匹配結算方式取得再生能源憑證。聯合國能源機制(UN-Energy)推動企業發揮採購影響力，以全時無碳能源合約(24/7 Carbon-free Energy Compact)響應驅動全球經濟快速去碳化迫切需要，藉由推進全時無碳能源(24/7 CFE)，加速電網去碳化。本研究提出支持 24/7 全時再生能源電能市場構想，以期在兼顧「完善再生能源市場發展」與「電力事業運作架構」下，設計綠電媒合與交易機制、定位台電公司於綠電交易市場角色，以更完善市場機制為多元低碳能源組合、24/7 全時使用無碳電力及實踐淨零碳排目標布局。

Abstract

Procuring renewable energy allows enterprises to mitigate the environmental impact of their economic activities while providing benefits such as stabilizing energy costs. Consequently, many domestic and international companies have committed to 100% renewable energy usage.

With the liberalization of Taiwan's renewable energy market in recent years, many enterprises have secured Renewable Energy Certificates (RECs) through bilateral contracts, such as signing Power Purchase Agreements (PPAs) with renewable generators or retailers, or purchasing from self-consumption renewable installations, utilizing a monthly generation-consumption matching and settlement mechanism.

The United Nations Energy (UN-Energy) initiative encourages enterprises to leverage their procurement influence to address the urgent need for rapid global economic decarbonization through the 24/7 Carbon-free Energy Compact. By promoting continuous, round-the-clock carbon-free energy, this initiative seeks to accelerate grid decarbonization.

This study proposes a market framework to support 24/7 renewable energy utilization. It outlines mechanisms for green power matching and trading while defining Taipower's role within the market, aiming to strengthen market operations, facilitate a diversified low-carbon energy mix, enable continuous 24/7 carbon-free electricity usage, and support the achievement of net-zero carbon emission targets.

關鍵詞(Key Words): 再生能源電能市場(Renewable Energy Market)、溫室氣體盤查(Greenhouse Gas Inventory)、時間匹配(Time Matching)、電業法(The Electricity Act)、一天 24 小時、一週 7 天(24/7)。

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國際淨零轉型趨勢與策略

International Trends and Strategies for Net-Zero Transition

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摘要

在全球氣候變遷日益嚴峻的背景下，淨零排放已成為各國能源轉型與產業升級的核心戰略。本文綜整歐盟、美國、日本與韓國等主要經濟體之淨零政策與行動，指出國際趨勢正由技術導向轉向制度整合與跨部門協作。歐盟以《歐洲氣候法》及「Fit for 55」方案建立完整法制架構，美國藉《降低通膨法案》推動清潔能源投資，日本以「綠色成長戰略」強調氫能與核能創新，韓國則採「核能+再生能源」雙核心模式，同時各國透過碳定價、綠色金融及能源科技創新強化減碳效益，推動產業與電力系統同步轉型。臺灣在此國際趨勢下，亦積極推動能源結構重塑與電網現代化，強化地熱、氫能與儲能布局，並以《氣候變遷因應法》作為長期政策推動基礎。未來應持續強化跨部門治理、技術創新與社會共識，以實現經濟成長與淨零轉型並行，最終打造具韌性且永續的能源體系，迎向 2050 淨零新時代。

Abstract

Amid increasingly severe global climate change, achieving net-zero emissions has become a central strategic objective for energy transition and industrial transformation worldwide. This study synthesizes the net-zero policies and implementation pathways of major economies, including the European Union (EU), the United States, Japan, and South Korea, and observes a transition in international trends from technology-driven approaches toward institutional integration and cross-sector collaboration.

The EU has established a comprehensive legal framework through the European Climate Law and the “Fit for 55” package. The United States promotes large-scale clean energy investment under the Inflation Reduction Act. Japan advances its Green Growth Strategy with a focus on hydrogen development and nuclear innovation, while South Korea adopts a dual-core strategy integrating nuclear power and renewable energy. In addition, these economies reinforce decarbonization effectiveness through carbon pricing mechanisms, green finance instruments, and energy technology innovation, thereby facilitating synchronized transformation of industry and power systems.

In response to these global developments, Taiwan is actively restructuring its energy mix and modernizing its power grid, while strengthening the deployment of geothermal energy, hydrogen technologies, and energy storage systems. The Climate Change Response Act serves as the institutional foundation for long-term policy implementation. Moving forward, enhanced cross-sector governance, continued technological innovation, and broader social consensus will be essential to achieving parallel progress in economic growth and net-zero transition, ultimately building a resilient and sustainable energy system toward the 2050 net-zero target.

關鍵詞(Key Words): 氣候變遷(Climate Change)、淨零排放(Net Zero)、碳定價(Carbon Pricing)、能源轉型(Energy Transition)、跨部門協作(Cross-Sector Collaboration)。

配電系統之韌性提升

Enhancing the Resilience of Power Distribution Systems

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摘要

本文概述電網韌性之意涵，並聚焦於配電系統在整體韌性中所扮演的關鍵角色。透過歐美日等國家的經驗，說明其提升配電系統韌性的政策方向與技術發展趨勢。相較於其他國家，我國配電系統之韌性表現並不遜色；然而，隨著營運環境日益複雜，配電系統可靠度的進一步改善已逐漸面臨瓶頸。面對極端氣候的挑戰，除持續精進事故應變與復電作業外，亦須思考配電網的演進。本文分別就電力轉換設備、數位化與智慧化、資源整合與微電網，以及系統管理與優化等面向，探討未來可能的發展方向，並介紹工研院在相關領域的階段性成果，期能拋磚引玉，促進各界對配電系統韌性議題的關注與投入，共同推動我國配電系統韌性的提升。

Abstract

This paper reviews the concept of power system resilience, with a particular focus on the critical role of distribution systems. Drawing on experiences from Europe, the United States, and Japan, it outlines policy directions and technological trends for enhancing distribution system resilience. While Taiwan's distribution system exhibits resilience performance comparable to international benchmarks, increasing operational complexity and rising renewable energy penetration have constrained further reliability improvements.

To address challenges posed by extreme climate events, efforts must extend beyond refining emergency response and service restoration practices to include the evolution of distribution network architectures. This paper explores prospective development directions in power electronic technologies, digitalization and smart grid solutions, resource integration and microgrids, and system operation and management enhanced by artificial intelligence. Selected phased achievements by the Industrial Technology Research Institute (ITRI) are also presented, aiming to stimulate interest and investment in distribution system resilience and support Taiwan's continued advancement in this critical area.

關鍵詞(Key Words)：配電系統(Distribution System)、韌性(Resilience)、電力轉換器(Power Conversion System)、電網數位化(Power Grid Digitization)、智慧電表系統(Advanced Metering Infrastructure)、先進配電管理系統(Advanced Distribution Management System)。

臺灣離岸風電的前景與挑戰

Prospects and Challenges of Offshore Wind Development in Taiwan

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摘要

本文整合政府統計、產業報告與學術研究，回顧自 2012 年以來風力發電的三階段制度演進，並盤點建置與投融资進度。統計結果顯示，截至 2025 年累計併網容量為 4.4 GW，與規劃目標 5.6GW 存在差距，因此推動時程進行滾動式調整。後續政策藍圖以 2035 年 18.4 GW 與深水開發為核心，預期導入浮式示範、數位化監測與智慧運維以擴大可開發海域。臺灣離岸風電的主要挑戰集中於區域電網承載、政策不確定性、颱風造成的施工限制、專業人才缺口、地質條件與港口承載限制，以及利率與通膨所造成的融資壓力。若藉由動態線路容量、預先資格授權、發展權保護、強化人才培育與海床感知監測等措施克服上述挑戰面，臺灣將於 2035 年前逐步具備建立具國際競爭力之離岸風電產業鏈的條件。

Abstract

This study synthesizes government statistics, industry reports, and academic research to review the three-stage institutional evolution of Taiwan's offshore wind power development since 2012 and to examine progress in project construction and financing. The findings indicate that, as of 2025, cumulative grid-connected capacity has reached 4.4 GW, falling short of the planned target of 5.6 GW. Consequently, the implementation timeline has undergone rolling adjustments.

The subsequent policy roadmap centers on achieving 18.4 GW by 2035, with a strategic emphasis on deep-water development. Future expansion is expected to incorporate floating wind demonstration projects, digitalized monitoring systems, and intelligent operation and maintenance (O&M) technologies to extend development into deeper and more technically challenging offshore areas.

Taiwan's offshore wind sector faces several major challenges, including regional grid capacity constraints, policy uncertainty, construction disruptions caused by typhoons, shortages of skilled professionals, complex geotechnical conditions, port capacity limitations, and financing pressures arising from inflation and elevated interest rates. If these challenges are addressed through measures such as dynamic line rating, pre-qualification and site authorization mechanisms, protection of development rights, strengthened workforce development, and advanced seabed sensing and monitoring technologies, Taiwan could progressively establish the foundations of a globally competitive offshore wind industry by 2035.

關鍵詞(Key Words)：離岸風電(Offshore Wind Energy)、再生能源治理(Renewable Energy Governance)、技術創新與在地化(Technological Innovation and Localization)、產業金融與投資機制(Industrial Finance and Investment)、環境與基礎條件適應(Environmental and Site Condition Adaptation)、離岸風電發展政策(Offshore Wind Development Policy)。

如何緩解再生能源的衝突及僵局

Mitigating Conflict and Policy Deadlock in Renewable Energy Development

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摘要

因應氣候變遷及極端氣候的情況，發展再生能源已為全球主流趨勢，世界各國皆積極發展各類型再生能源。然而，我國當前卻因資訊不對稱、缺乏利害關係人對話和參與機制等導致衝突加劇及社會信任度降低的困境，進而也使再生能源的發展受到阻礙。本文透過日本營農型光電與我國漁電共生的成功案例說明再生能源(尤其光電)成功關鍵在於「以原產業為本，光電僅為加值」，並需要更透明的資訊、讓利害關係人參與討論與決策的平台以及利益共享的機制。我國能源轉型 2.0 應以台灣民主韌性為基石，以發展現地現用的區域電網為目標，來維持地方電網的韌性與達到穩定供電的目標。此外，政府積極推動的社會溝通更應從「政策說明」轉向「民眾參與及賦權」，將能源轉型視為重建社會信任的工程，持續推進氣候與民主韌性。

Abstract

In response to climate change and increasingly frequent extreme weather events, the expansion of renewable energy has become a dominant global trend. Many countries are actively promoting diverse forms of renewable energy. In Taiwan, however, development has been hindered by escalating social conflict and declining public trust, largely stemming from information asymmetry and the absence of effective stakeholder dialogue and participation mechanisms.

Drawing on successful experiences from Japanese agrivoltaics and Taiwan's fishery-electricity symbiosis projects, this paper argues that the key to renewable energy development, particularly solar photovoltaics, lies in prioritizing the continuity of primary industries, with photovoltaic installations serving as value-added components rather than replacements. Essential conditions for success include greater information transparency, institutionalized platforms for stakeholder participation in deliberation and decision-making, and equitable benefit-sharing arrangements.

Taiwan's "Energy Transition 2.0" should be grounded in democratic resilience and oriented toward the development of localized grids that support on-site generation and consumption. Such an approach would enhance local grid resilience while maintaining supply stability. Moreover, government-led social communication must evolve from one-way policy dissemination to participatory engagement and citizen empowerment. Energy transition should therefore be conceived not merely as a technological or industrial transformation, but as a long-term process of rebuilding social trust and reinforcing both climate resilience and democratic resilience.

關鍵詞(Key Words)：能源轉型(Energy Transition)、利害關係人參與(Stakeholder Engagement)、民主韌性(Democratic Resilience)、利益共享(Benefit Sharing)。

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**台灣尼阿斯資深經濟顧問

採用 Stackelberg 賽局理論之儲能共享最佳容量規劃與定價策略

Optimal Capacity Planning and Pricing Strategies for Shared Energy Storage Based on a Stackelberg Game Theory Framework

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摘要

隨著再生能源技術的進步，儲能系統在促進能源轉型等方面扮演著關鍵角色。共享儲能為一種新興的儲能應用模式，能夠有效降低建置及維護成本，提升資源利用率。本研究旨在研究社區型微電網後儲能共享方案暨容量規劃方法，並提出基於 Stackelberg 賽局理論的雙層兩階段最佳化模型，決策儲能系統建置容量及租賃定價，實現最小化用戶用電成本和最大化營運商利潤。下層模型採兩階段混合整數非線性規劃，模擬用戶充放電調度並決定總建置容量與契約容量；上層模型則利用差分進化演算法優化租賃價格。案例分析顯示，共享儲能相比用戶自行建置可節省更多成本，營運商投資報酬率在用戶參與及未參與即時備轉下分別為 13.1% 與 10.6%。儲能價格下降可降低租賃價格並吸引更多用戶參與，即時備轉容量結算價格則顯著影響用戶成本節約。

Abstract

With the advancement of renewable energy technologies, energy storage systems (ESS) have become essential for facilitating the energy transition. Shared energy storage has emerged as an innovative deployment model that reduces installation and maintenance costs while enhancing resource utilization efficiency. This study investigates a behind-the-meter shared ESS scheme for community microgrids and proposes a bi-level, two-stage optimization model based on Stackelberg game theory to determine optimal storage capacity and leasing prices, aiming to minimize users' electricity costs while maximizing operator profits.

The lower-level model is formulated as a two-stage mixed-integer nonlinear programming (MINLP) problem to simulate user charging and discharging operations and to determine the total installed capacity and contracted capacity. The upper-level model employs a differential evolution algorithm to optimize leasing prices.

Case study results demonstrate that the shared ESS model achieves greater cost savings compared with individually owned storage systems. The operator's return on investment (ROI) reaches 13.1% and 10.6% under scenarios with and without participation in real-time spinning reserve markets, respectively. Sensitivity analysis further indicates that declining ESS capital costs lead to lower leasing prices and increased user participation, while settlement prices for real-time reserve capacity significantly influence users' cost savings.

關鍵詞(Key Words)：微電網 (Microgrid)、共享儲能 (Shared Energy Storage)、輔助服務 (Ancillary Service)、Stackelberg 賽局理論 (Stackelberg Game Theory)、非線性規劃 (Nonlinear Programming)、差分進化演算法 (Differential Evolution Algorithm)。

基於電池式儲能系統之電力系統慣量估測方法

Power System Inertia Estimation Method Based on Battery Energy Storage Systems

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摘要

隨著再生能源占比提高，電力系統的旋轉慣量逐漸減少，使傳統依賴系統發生事故進行慣量推估的方法，難以滿足即時性與可靠度的需求。本研究提出一套整合儲能系統主動提供小擾動、雙階段訊號平滑，以及頻率變化率分析的慣量估測方法，可在無需等待重大故障事件的情況下，持續監測電網慣量變化。透過儲能系統作為擾動來源，並搭配雜訊抑制與滑動視窗演算法，所提出方法能在高雜訊與多種再生能源滲透率條件下維持穩定與準確的估測結果。其估測趨勢亦與再生能源滲透率所造成的理論慣量下降相一致，驗證了本方法的可行性與可靠度。

Abstract

With the increasing penetration of renewable energy, the rotational inertia of power systems has gradually declined, rendering traditional inertia estimation approaches, primarily based on large disturbance events, insufficient to meet real-time monitoring and reliability requirements.

This study proposes an inertia estimation method that integrates battery energy storage systems (BESS) for active small-signal perturbation, a two-stage signal smoothing process, and rate-of-change-of-frequency (RoCoF) analysis. The proposed framework enables continuous monitoring of system inertia without the need to wait for major fault events. By employing BESS as a controllable disturbance source and incorporating noise suppression techniques together with a sliding-window algorithm, the method maintains stable and accurate estimation performance under high-noise conditions and varying levels of renewable energy penetration.

The estimated inertia trends are consistent with the theoretical reduction in system inertia associated with increasing renewable penetration, thereby validating the feasibility and reliability of the proposed approach.

關鍵詞(Key Words): 電池式儲能系統 (Battery Energy Storage System, BESS)、慣量估測(Inertia Estimation)、再生能源(Renewable Energy)、頻率變化率(Rate of Change of Frequency, RoCoF)。

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海底地熱資源之探勘與開發潛能評估—以基隆海底火山為例

Exploration and Assessment of Submarine Geothermal Resource Potential : A Case Study of the Keelung Submarine Volcano

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摘要

基隆海底火山位在台灣北部萬里近海，介於野柳岬與基隆嶼之間，直徑可達 5 km，有高溫熱液並伴隨廣泛海底噴氣柱分布，應具有地熱資源開發潛能。本研究整合既有海域地質、地球物理與地球化學調查成果，說明基隆海底火山之地熱資源特性與分布情形，並評估其地熱資源之開發潛能。除了可以用傳統地熱資源開發模式以鑽探取熱發電外，更可能利用海底噴氣柱的流體動能或改良式海洋溫差來驅動渦輪發電機，作為未來相關技術研發與示範評估之參考。這裡分別探索野柳斷層帶及基隆嶼 2 處鑽探取熱發電潛能場址，及野柳斷層、火山區及凹陷區等 3 處可能噴氣柱流體動能潛能場址。由於我國自然地質條件，才有此國際上的獨特優勢，具有海底火山地熱資源開發的潛能，基隆海底火山地熱資源的調查與開發可以是我國一個重要的綠能來源，並成為國際海底火山地熱資源開發之先驅。

Abstract

The Keelung Submarine Volcano (KSV), located offshore Wanli in northern Taiwan between Yehliu Cape and Keelung Islet, has a diameter of approximately 5 km and exhibits high-temperature hydrothermal activity accompanied by extensive submarine gas flares. These characteristics indicate considerable potential for geothermal resource development.

This study integrates existing marine geological, geophysical, and geochemical survey data to characterize the geothermal features and spatial distribution of resources associated with the KSV, and to evaluate their development potential. In addition to conventional geothermal power generation through drilling and heat extraction, alternative energy utilization approaches are proposed, including harnessing the kinetic energy of submarine gas-flare fluids and applying modified ocean thermal energy conversion (OTEC) systems to drive turbine generators. These concepts may provide innovative directions for future technological development and demonstration projects.

Two potential sites, the Yehliu Fault Zone and the vicinity of Keelung Islet, are identified for heat-extraction-based geothermal power generation. In addition, three locations, the Yehliu Fault Zone, the volcanic edifice, and the adjacent depression area, are recognized as prospective sites for utilizing gas-flare fluid kinetic energy.

Owing to Taiwan's unique geological setting, the KSV represents a rare opportunity for the development of submarine volcanic geothermal resources. Systematic investigation and future development of these resources could contribute significantly to Taiwan's renewable energy portfolio and position the region as a pioneer in submarine volcanic geothermal energy exploration.

關鍵詞(Key Words)：基隆海底火山(Keelung Submarine Volcano)、海底火山地熱資源(Submarine Volcano Geothermal Energy)、熱液活動(Hydrothermal Activity)、噴氣柱(Gas Flares)、動能發電(Kinetic-Energy Power Generation)、野柳斷層(Yehliu Fault)。

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物聯網在電力產業的新局面從「錦上添花」變成「不可或缺」

Internet of Things in the Electric Power Industry : From Supplementary Enhancement to Strategic Necessity

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摘要

物聯網(IoT)技術在電力產業長期陷入「試點—發布—停滯」的循環：隨著應用規模提升，裝置數量與資料種類激增，系統整合複雜度與資安風險同步攀升，導入門檻提高；再者，多數效益集中於長期營運與資產優化，難以在短期內量化收益，使商業模式模糊、短期回報難以量化，削弱持續投資誘因。生成式人工智慧(GenAI)正改寫局面。GenAI 對電力的龐大需求將資料中心電力消耗在短短四年內翻倍，迫使科技巨頭投資電力基礎設施，即時監測、預測性分析與動態調度成為電力系統必須具備的能力。使 IoT 從「錦上添花」轉變為「不可或缺」，IoT 不再僅是提升效率的輔助工具，而是支撐電網韌性、滿足高可靠度用電需求的關鍵。

電力公司若要突破制度性與組織性障礙，必須採取可落地的實務策略，包含：在既有組織架構外建立「附加組織(Add-on Organization)」以進行跨 IT/OT 的快速試驗與迭代；透過小型場域與微型試點(Micro-pilots)驗證物聯網在微電網等具體應用中的實際效益；並建立清楚的技术路徑圖，將成熟試點逐步整合回核心業務。得以將 IoT 從零散試驗轉化為可規模化部署的營運能力，並成為生成式 AI 進入電力系統的關鍵橋樑。

Abstract

The adoption of Internet of Things (IoT) technologies in the electric power sector has long been constrained by a recurring “pilot–deployment–stall” cycle. As application scale expands, rapid growth in device numbers and data diversity increases system integration complexity and cybersecurity risks, thereby raising implementation barriers. Moreover, most IoT-generated benefits are realized through long-term operational optimization and asset performance improvements, making short-term returns difficult to quantify and weakening incentives for sustained investment.

The rapid expansion of Generative Artificial Intelligence (GenAI) is reshaping this landscape. The surge in electricity demand driven by data centers supporting GenAI workloads has led to a near doubling of data center power consumption within a short period of approximately four years, prompting major technology firms to invest directly in power infrastructure. Under these conditions, capabilities such as real-time monitoring, predictive analytics, and dynamic dispatch are becoming essential requirements for power system operation rather than optional efficiency-enhancing tools. Consequently, IoT is transitioning from a value-adding supplement to an indispensable technological foundation for ensuring grid resilience and meeting high-reliability electricity demand.

To overcome institutional and organizational barriers, electric utilities must adopt practical and implementable strategies. These include establishing “add-on organizations” operating alongside existing structures to facilitate rapid cross-domain experimentation across IT and OT systems; deploying micro-pilots in controlled environments, such as microgrids, to validate tangible operational benefits; and formulating clear technological roadmaps to progressively reintegrate validated pilot projects into core business operations. Through these measures, IoT can evolve from fragmented experimentation into a scalable operational capability and serve as a critical bridge for the integration of GenAI into power systems.

關鍵詞(Key Words)：智慧電網(Smart Grid)、物聯網(Internet of Things, IoT)、生成式人工智慧(Generative Artificial Intelligence, GenAI)、人工智慧物聯網(Artificial Intelligence of Things, AIoT)、電網韌性(Grid Resilience)、數位轉型(Digital Transformation)、電力系統現代化(Power System Modernization)。