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台澎海底電纜之規劃

The Planning of Taiwan-Penghu Submarine Cable

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摘 要

澎湖地區早期為一獨立運轉之電力系統，由尖山電廠之 12 部柴油發電機供應全島用電。本檢討係依據台電長期負載預測，平行檢討以海底電纜連接澎湖~台灣之供電可行性與原訂之擴建柴油機之電源開發方案做經濟性比較，以確立未來 20 年澎湖電力發展的大方向。

本檢討針對海底電纜採行之供電方式、工程可行性、系統可行性及經濟分析比較等各方面加以研討，提供各方案之評估以做為未來整體決策之依據。

Abstract

In the early days, the Penghu area was an isolated power system, with 12 diesel generators from the Chienshan power plant supplying electricity to the entire island. Based on Taipower's long term load forecast, this study examines the feasibility of connecting Penghu to Taiwan power system with submarine cables and compares the economics of the original plan for expanding diesel engines to establish the general direction of Penghu's power development in the next 20 years. This review discusses various aspects such as the power supply method, engineering feasibility, economic analysis of the aforementioned submarine cables, and provides an evaluation of each option as a basis for future decision-making.

關鍵詞(Key Words)：海底電纜(Submarine Cable)、系統規劃(System Planning)、澎湖(Penghu)。

*台灣電力公司輸供電事業部系統規劃處

台澎海纜工程規劃介紹

Introduction to Taiwan-Penghu Submarine Cable Project

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摘 要

161kV 臺灣~澎湖海底電纜線路工程興建計畫主要目地為優化澎湖能源系統降低使用石化燃料，建構澎湖成為綠能低碳島外，並藉由把臺灣本島與澎湖兩地電網連結，提高澎湖地區供電穩定，將澎湖豐沛的風力所產生的電力經由海底電纜輸送至臺灣，成為輸出綠能的島嶼，可謂兼具能源轉型、民生經濟與環保等多重效益的電力建設。本工程為國內第 1 條輸電等級海底電纜，過去無相關工程經驗可遵循，本公司憑藉工程專業及施工團隊努力下克服重重關卡的考驗，最終讓本工程順利合聯運轉，祈透過本案例分享，未來作為各單位規劃設計時參考。

Abstract

The main purpose of the 161kV Taiwan-Penghu submarine cable construction project is to optimize the Penghu energy system to reduce the use of fossil fuels, turn Penghu into a green energy and low-carbon island, and connect the power grids of Taiwan and Penghu. In addition to improving the stability of the power supply in the Penghu area, the aforementioned project can also transport the electricity generated by Penghu's abundant wind power to Taiwan via the aforementioned submarine cable, turning Penghu into an island that exports green energy. In short, this power construction project combines multiple benefits such as energy transformation, improvement of people's livelihood, economy and environmental protection. This project is the first power transmission grpade submarine cable in Taiwan, and there is no relevant engineering experience in the past to follow. With the hard work of its engineering expertise and construction team, Taipower overcame many hurdles and finally made this project run smoothly. We hope that the experiences of this project may serve as a reference for all units in the company when planning and designing similar projects in the future.

關鍵詞(Key Words)：海底電纜(Submarine Cable)、綠能低碳島(Green Energy and Low-Carbon Island)、再生能源(Renewable Energy)。

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台澎海纜與陸纜送電容量計算方式之差異探討

The Differences in Calculation Methods of Power Transmission Capacity between the Taiwan-Penghu Submarine Cable and Land Cable

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摘　要

本文旨在探討台澎海纜及陸纜送電容量計算差異，藉由立約商 JPS/SC 提送海底電纜送電容量計算資料，探討海陸纜於內部結構、外部環境、排列方式等因素對送電容量造成影響及兩者計算流程的差異，未來如有規劃建置海底電纜方案時，對其送電容量計算原理及流程有初步的理解。

Abstract

This article uses the data provided by the contracted company JPS/SC to explore the differences in the calculation of power transmission capacity (ampacity) between the Taiwan-Penghu submarine cable and land cable, focusing on influential factors such as the internal structure, external environment, arrangement of the submarine and land cable on power transmission and the difference of the two calculation processes. The content of this article may serve as reference for understanding the calculation principles and processes of power transmission capacity (ampacity) when planning and constructing similar projects in the future.

關鍵詞(Key Words)：海底電纜(Submarine Cable)、送電容量(Ampacity)、熱阻抗(Thermal Resistance)。

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穿越海堤推管工程之探討-以台灣~澎湖海底電纜工程為例

Cross Seawall Pipe Jacking Project – Taking the Taiwan-Penghu Submarine Cable Construction Project as an Example

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摘　要

台灣西部沿海地區多為沖積層，屬於軟弱泥、砂等細粒料組成之複合地層，其地質特性為高孔隙比、強度低、易於壓縮變形等，又因本工程海纜台灣端上岸點位於雲林縣口湖鄉沿海堤防邊，高地下水位及軟弱砂質地層增加工程施工困難度。須選擇適用之工法克服當地地質條件。以本公司新建海底電纜工程為例，規劃設計之推管須穿越海堤下方，施工過程中對地面上結構物之擾動及位於海上作業中之安全極為重要。故本專案以「台灣~澎湖 161kV 線穿堤推管」為例，說明推管穿越海堤施工之困難克服，期能藉由本專案工程經驗作為日後類似推管施工時參考。

Abstract

Most of the coastal areas in western Taiwan are alluvial, which is a composite formation composed of soft mud, sand and other fine particles. Its geological characteristics are high void ratio, low strength, and easy to compress and deform. In addition, because the landing point of this project's submarine cable in Taiwan is located on the edge of the coastal embankment of Kouhu Township, Yunlin County, high groundwater levels and weak sandy strata increase the difficulty of project construction. Therefore, suitable construction methods must be selected to overcome local geological conditions. Taking this submarine cable project as an example, since the planned pipe jacking has to pass under the sea wall, during the construction process, it is very important to avoid disturbing the structures on the ground and to ensure safety during offshore operations. This article takes the "Taiwan-Penghu 161kV Line Cross Seawall Pipe Jacking" project as an example to illustrate how to overcome the difficulties in construction. It is hoped that the experience of this project may serve as a reference for similar projects in the future.

關鍵詞(Key Words)：泥水加壓工法 (Slurry Pressure Balance Method)、沉陷觀測點 (Settlement Point)、聚氨基膨脹樹脂 (Polyamino Expansible Resin)、引拔退管 (Pull Back Method)。

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台電離岸風力發電第一期計畫海纜工程規劃、設計及施工經驗之分享

The Planning, Design and Construction in Submarine Cable of Taipower's Offshore Wind Power Phase 1 Project

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摘　要

海底電纜早期用於國家或地區之間的電信傳輸，但隨著近年來技術的演進及調度需求，電力傳輸逐漸成為主要用途。囿於篇幅有限，本文僅針對離岸風力發電廠海纜之設計階段及施工階段的核心項目及特殊性加以說明，摘要其施工要領並強調設計內容，如太陽輻射下熱鄰近效應、所受應力不得超過其設計極限、風機基礎端引入與埋設等，確保其輸電系統可達到預期之全生命週期及安全目標，其中，海底電力電纜置入光纖後，其多功能性亦有效提升輸電的穩定度。

旨揭計畫建置共21 部風機，總裝置容量為109.2 MW，每年約可發出3.6 億度之綠電，約可提供8.5 萬家戶一整年的用電量，可減少約18 萬公噸碳排量，相當於462 座大安森林公園一年之減碳效益，本計畫除了達成離岸風電示範風場237.2 MW(本公司109.2 MW)之國家重要能源政策目標外，亦為後續離岸風電計畫奠定重要基礎，將彰化外海優質風場之風電輸送到臺灣，為擴大發展綠電帶來更多新的可能。

Abstract

Submarine cables were used for telecommunication among countries or regions in the early days. However, with the evolution of technology and dispatching needs in recent years, power transmission has gradually become the main purpose. Due to the length limit, this article only explains the core items and particularities of offshore wind power submarine cables in design and construction stages. In addition, we summarize relevant construction essentials, such as thermal proximity effect under solar radiation, cable laying considerations, wind turbine generator (WTG) foundation pull-in and trenching, etc. to ensure that the power transmission system can achieve the expected life cycle and safety goals. After the submarine cable is embedded with optical fibers, its multi-functionality also effectively improves the stability of power transmission.

This project built a total of 21 wind turbines with a total installation capacity of 109.2 MW,

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which can generate approximately 360 million kilowatt-hours of renewable energy every year, which can provide approximately 85,000 households with electricity consumption for a whole year, and can reduce carbon dioxide emission by 180,000 metric tons, which is equivalent to the carbon reduction benefits of 462 Daan Forest Parks in one year. In addition to achieving the important national energy policy goal of 237.2 MW of offshore wind power demonstration wind farms (109.2 MW of Taipower), this project also laid an important foundation for subsequent offshore wind power projects and transported wind power from offshore Changhua's high-quality wind farms to Taiwan, bringing more new possibilities to expand the development of green power.

關鍵詞 (Key Words)：台電(Taiwan Power Company)、離岸風電(Offshore Wind Farm)、示範風場(Demonstration Wind Farm)、台澎海纜(Taiwan-Penghu Submarine Cable)。

台灣~澎湖 161kV 海底電纜第一回線 S、T 相受損修復案例分享

Case Study of Damage Repair of Taiwan-Penghu 161kV Submarine Power Cable No.2 (Phase S) and No.3 (Phase T)

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摘　要

海纜接續匣組立安裝，操作過程與陸纜最大差異處在於，海纜接續匣之保護蓋須與海纜鉛合金遮蔽層以鉛工熔接，於鉛工及防蝕作業完成後，再將回流導體接續於保護蓋外部，以熱縮套管防蝕處理。

海纜與架台放置於海床後，再以 8 噸重石袋(經日本建設審查核可，通過 8 噸船錨落下試驗及拖拉試驗，並證實可抵抗 10 節海流)堆砌保護。

Abstract

The biggest difference between the installation process of submarine cable and land cable joint is that the protective cover of the submarine cable's joint must be welded with the lead alloy shielding layer of the submarine cable. After the lead welding and anti-corrosion operation are completed, the return conductor is connected to the outside of the protective cover and treated with a heat shrink tube to prevent corrosion.

After the submarine cable and platform were placed on the seabed, they were then stacked with 8-ton heavy stone bags (approved by the Japan's construction review, passed the 8-ton anchor drop test and drag test, and were proven to withstand 10-knot ocean current) for protection.

關鍵詞(Key Words)：海底電纜(Submarine Power Cable)、受損(Damage)、修復(Repair)。

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台澎海纜防錨擊經驗分享

Anchor Strikes Prevention Experience of the Taiwan-Penghu Submarine Cable

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摘 要

台澎海纜穿越台澎間國際重要航道總長 58.8km，每日不分晝夜皆有來自四面八方的船舶經過，錨擊防範維護方式已超出既有陸纜防挖管控思維。本文章係以利用航港局之船舶自動辨識系統(AIS 2.0)建立台澎海纜監視系統，發展防範船舶錨擊的管控實務，針對台澎間海纜水域進行監視管控，透過平台可自行設定船舶之寬度及船舶之航速作為下錨風險船舶的告警判別，並建置信文自動發送之功能，達到嚇阻危害船舶遠離台澎海纜警戒區域的具體作為，目前已有實務防範案例驗證通報機制的可行性。

海底電纜之維護工作對供電單位而言，是全新領域亦是全新挑戰，嘉南供電區營運處本著維護供電安全之使命，突破既有思維開創務實的海纜防錨擊管控工作，本篇報告內容已寫下供電維護全新的頁章。

Abstract

The Taiwan-Penghu submarine cable runs through the important international waterway between Taiwan and Penghu, with a total length of 58.8 km. Ships from all over the world pass through this channel every day and night. Therefore, the prevention and maiatenance methods of submarine cables against anchor strikes far exceed the management and control requirements for land cables. This article uses the Ship Automatic Identification System (AIS 2.0) of the Harbor Bureau to establish a monitoring system to prevent ship anchor strikes, and monitor and control the waters of the submarine cable. The platform can identify the anchoring risk of the passing ships based on their width and speed and issue an alarm, and automatically send messages to deter hazardous ships from the warning area of Taiwan-Penghu submarine cable. There have been practical prevention cases to verify the feasibility of the notification mechanism.

The maintenance of submarine cables is a new field and a new challenge for Taipower. To keep in line with the mission of maintaining power supply safety, the Jia-Nan Power Supply Operation District of Taipower broke through the existing thinking and initiated pragmatic anti-anchor strike management and control work for submarine cables. The content of this article has written a new chapter in power supply maintenance.

關鍵詞(Key Words)：船舶自動辨識系統(Automatic Identification System 2.0，AIS 2.0)、台澎海纜監視系統(Taiwan-Penghu Cable Monitoring System)、信文自動發送(Automatically Send Messages)。

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台澎海纜監測系統概述

Overview of Taiwan-Penghu Submarine Cable Monitoring System

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摘　要

台灣-澎湖 161kV 海底電纜是連結台灣本島與澎湖離島特高壓海底電纜，於 111 年 2 月 11 日正式運轉，因無法以人力方式巡檢，故設計海纜內部建置 12 芯光纖進行 3 項海纜運轉監視，隨時掌握運轉狀況。此外海纜敷設在海床上，為避免受到船隻錨擊等外部機械力的破壞，藉由介接航港局船舶自動辨識系統廣播驅離海纜區域上方船隻，降低海纜故障的風險，確保台灣與澎湖間電力傳輸的穩定性及可靠性。

Abstract

The Taiwan-Penghu 161kV submarine cable is an ultra-high voltage (UHV) submarine cable that connects the main island of Taiwan and the outlying islands of Penghu. It was officially put into operation on February 11, 2022. Since it is impossible to conduct manual inspections, a 12-core optical fiber was built inside the submarine cable to carry out the tasks of cable operation monitoring and status tracking at any time. Furthermore, the cable is laid on the seabed to avoid damage from external mechanical forces such as ship anchor strikes. By interfacing with the Maritime Port Bureau's automatic interfacing system (AIS), the ships cruising in waters above the submarine cable can be driven away using broadcasts to reduce the risk of submarine cable failure and ensure the stability and reliability of power transmission between Penghu and Taiwan.

關鍵詞(Key Words)：海底電纜(Submarine Cable)、光纖(Fiber Optic)、監測(Monitor)、自動辨識系統(Automatic Identification System)。

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台澎海纜於電力通信之應用與效益

Application and Benefits of Taiwan-Penghu Submarine Cable in Utility Communication

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摘 要

本公司建置台澎海纜連接台灣本島與澎湖地區，整合澎湖風力發電系統至本島電網，可促進再生能源發展，增進能源多元化，提供優質、充裕且安全的電力，此外海纜內嵌光纖芯線建置通訊系統支援澎湖地區電力系統的保護、監控、資料傳輸和電力調度，確保電網穩定可靠。同時透過出租多餘的光纖芯線給通信業者，創造了業外營收機會，進一步促進業務多元化和當地通信服務的發展。此計畫有助於實現能源多元化，改善澎湖離島供電系統，並為未來用電需求做好準備。

Abstract

Integrating the Penghu wind power system with the power grid of Taiwan main island can promote the development of renewable energy, enhance energy diversification, and provide high-quality and abundant power supply, Taipower hence planned to build the Taiwan-Penghu submarine cable. Additionally, the submarine cable is embedded with an optical fiber communication system, which can support the protection, monitoring, data transmission and power dispatching of Penghu's power system, as well as the stability and reliability of the area's power supply. Furthermore, by leasing excess optical fiber core lines to telecommunication service providers, the company can create additional revenue and further promote business diversification and the development of local communication services. In summary, this project will not only help diversify energy sources, but also improve the power supply system of Penghu, helping the company to prepare for future electricity demand.

關鍵詞(Key Words)：台澎海纜(Taiwan-Penghu Submarine Cable)、光纖(Optical Fiber)、電力通信(Utility Communication)。

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台澎海纜合聯之模擬與量測分析

Simulation and Measurement Analysis of the Taiwan-Penghu Submarine Cable

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摘 要

連接台灣及澎湖之台澎海底電纜經過十數年興建後，於 110 年 10 月經過加壓 168 小時後併入系統，正式使台灣和澎湖成為同一系統。為使台澎海纜順利上線運轉，相關測試工作皆不得馬虎，本文說明藉由 RTDS 其具備電磁暫態模擬及多　頻率系統的強項，分析交流變頻耐壓、電抗器操作及合聯條件，並根據分析結果提出可行的方案。最後於海纜實際上線運轉之際，實測系統現象，不僅提供營運單位後續運轉維護的依據，更紀錄了台灣電力的里程碑。

Abstract

After more than ten years of construction, the Taiwan-Penghu submarine cable after 168 hours of energization in October 2021 officially made Taiwan and Penghu one system. To ensure the cable go online smoothly, the relevant test work must not be sloppy. This article not only explains that RTDS has the strengths of electromagnetic transient simulation and multi-frequency system, analyzes the AC variable frequency withstand voltage, reactor operation and connection conditions, but also proposes feasible schemes based on the analysis results. Finally, when the submarine cable was actually in operation, the measured system conditions not only provided the operating unit with a basis for subsequent operation and maintenance, but also recorded a milestone for Taipower.

關鍵詞(Key Words)：電力系統模擬(Power System Simulation)、即時數位模擬系統(Real Time Digital Simulator)、海底電纜(Submarine Cable)。

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台澎海底電纜合聯後澎湖地區電力系統現況與挑戰

The Current Situation and Challenges of the Power System in Penghu Area after the Integration of Taiwan-Penghu Submarine Cable

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摘　要

本研究旨在探討台澎海纜合聯對澎湖地區電力系統的影響，透過分析海纜合聯的裝置容量變化、發電量比較、電力潮流輸送及尖山電廠受調度情況等關鍵數據，闡述澎湖電力系統的現況與願景。研究發現，台澎海纜合聯對澎湖地區的電力系統產生了重要影響，其中包含能源結構的變化、供電穩定性的提高及綠能的極大化。具體而言，火力發電在能源結構中的占比降低，而再生能源的併網裝置容量提高。此外，也為澎湖地區提供更穩定之電力來源。然而，研究也發現併入台灣系統從「網外變網內」，尖山電廠定位角色的轉變，其柴油發電機組在短時間內快速啟停及快速反應的能力，足以因應電力供需急遽波動，並在再生能源高占比之電力系統中扮演著關鍵角色。

Abstract

This study aims to explore the impact of the Taiwan-Penghu submarine cable joint on the power system in the Penghu area. By analyzing key data such as changes in device capacity of the submarine cable joint, comparison of power generation, power flow transmission, and dispatching conditions of Chienshan Power Plant, the current situation and vision of the Penghu power system are explained. The study found that the Taiwan-Penghu cable joint has had an important impact on the power system in the Penghu region, including changes in the energy structure, improvement of power supply stability, and maximization of green energy. Specifically, the proportion of thermal power generation in the energy structure decreases, while the capacity of grid-connected devices for renewable energy increases. In addition, it also provides a more stable power source for the Penghu area. However, the study also found that the integration into Taiwan's system has changed the positioning role of the Chienshan Power Plant from "outside the grid to inside the grid". Its diesel generators' rapid start-stop ability is sufficient to cope with sudden fluctuations in power supply and demand. It plays a key role in power systems with a high proportion of renewable energy.

關鍵詞(Key Words)：電力系統(Power System)、海纜合聯(Submarine Cable Joint)、綠能極大化(Green Energy Maximization)、快速起停(Rapid Start-stop)、再生能源(Renewable Energy)。

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台澎海纜對離島再生能源發展之效益

The Benefits of Taiwan-Penghu Submarine Cable to Penghu's RE Development

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摘　要

本效益分析建立於台澎海纜加入系統後，澎湖地區再生能源併網能力有顯著提升，配合中央政策，持續推動再生能源發展，逐步實踐澎湖地區成為台灣第一座低碳島。

Abstract

This benefit analysis is based on the fact that after the joining of Taiwan-Penghu submarine cable, the renewable energy (RE) grid connection capability in Penghu has been significantly improved. To keep in line with government policies, Taipower will continue to promote the RE development of in Penghu and turn it into Taiwan's first low-carbon island.

關鍵詞(Key Words)：再生能源(Renewable Energy)、微電網(Microgrid)、海纜(Submarine Cable)。

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