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達成綠能發電高佔比與穩定供電雙贏目標之策略　專輯

考慮再生能源高滲透率下之抽蓄水力電廠最佳機組排程研究

Investigation of the Optimal Scheduling of Pumped Hydro Storage under the Scenario of High Renewable Energy Penetration

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摘 要

台灣政府近期規劃新的能源政策，訂定 2025 年的再生能源發電占比將為全系統發電量的 20%；然而，在高滲透率的再生能源下，傳統需量下的負載曲線則被重塑為一鴨子曲線，電力系統運轉因而面臨更多挑戰。為了因應大量間歇再生能源注入下的挑戰，考慮調度抽蓄水力儲能系統為一有效且可行之方案，因其具有快速反應能力與大裝置容量的抽蓄水力儲能系統可提供有效的調頻備轉能力，能及時填補供電需求。本研究擬採用開源軟體 MATPOWER 中的最佳機組排程工具 MOST，模擬分析在高滲透率的再生能源下，考慮台電兩抽蓄水力電廠之台電系統最佳機組排程，模擬情境將考慮多個再生能源滲透等級與系統負載度程度。由分析結果可知，現有台電抽蓄水力電廠可在高滲透率的再生能源下，適應地提供機組排程，因應鴨子負載曲線下的發電供需平衡。

Abstract

According to the energy transformation target set by the government, 20 percent of the total electricity will be generated by renewable energy sources (RESs) by 2025. High RES penetration however reshapes the load curves, e.g. the Duck Curve, and complicates power system operation. Owning the advantages of short/quick response time and large-scale generation capacity, pumped hydro storage (PHS) may very well serve as the operating reserve necessary for frequency regulation in case of unexpected generator tripping. This study aims to conduct the optimal scheduling of two PHS power plants under the scenarios of various RES penetration and load levels, applying an optimal scheduling tool named MOST MATPOWER. The results of this study confirm that PHS is helpful for the power system to deal with high RES penetration and the Duck Curve.

關鍵詞 (Key Words)：再生能源 (Renewable Energy)、高滲透(High Penetration)、鴨子曲線(Duck Curve)、抽蓄水力儲能(Pumped Hydro Storage)、短期排程(Short-Term Scheduling)、調頻備轉(Frequency Regulating Reserve)。

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風力發電機慣量與頻率控制技術研究

Research on the Inertia and Frequency Control Technologies Related to Wind Turbines

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摘 要

當系統發生事故，諸如大型機組跳機，可能導致系統的頻率產生變化。為了維持系統的穩定性，需要盡速提升在線機組的出力以達到供需平衡。一般的同步發電機內部有調速機進行頻率調節，因此過去電力系統的頻率響應大部分取決於調速機的特性。然而大量再生能源併網後，再生能源也必須共同負擔電網頻率調節的責任。實際上，再生能源電力轉換器可以提供更多彈性的控制模式，對於電力系統的電壓與頻率穩定有相當大的助益。本文的目的是探討風力發電機的慣量與頻率調節控制技術，在閱讀相關的文獻後，整理和歸納出幾種控制的方法，包含下垂控制、動態下垂控制、慣量控制、步階慣量控制、快速備轉控制、以及降載控制技術等。接著本研究利用 PSCAD 建立這些控制方法的模型，並應用於一個六匯流排的測試系統。研究過程中嘗試改變各種控制模式的參數並觀察對系統的影響，最後根據模擬分析的結果歸納出各種控制模式的優缺點。本文的研究結果可以供未來風機慣量與頻率控制技術的研發參考，並可以做為風機併網規範的重要依據。

Abstract

Power system contingencies such as unexpected tripping of large generators usually cause volatility of system frequency. To maintain system stability, it is necessary to increase/decrease the output of online generators to balance generation and load. In the past, frequency response depended on the characteristics of the speed governors of synchronous generators. Along with the government's energy transition policy, more and more renewable energy sources (RESs) expectedly will connect with the power system. It is inevitable for RESs to undertake the responsibility of frequency regulation. In fact, power converters of RERs may very well provide various flexible control modes to help stabilize the voltage and frequency of the power system. This study aims to explore the inertia and frequency control technologies related to wind turbines. The contents of this study includes (1) identify a number of control methods (through literature review), e.g. droop, dynamic droop, inertia, step inertia, fast power reserve and de-loading controls, (2) apply the aforesaid control modes to a six-bus testing system for model analysis by using PSCAD, (3) intentionally alter the parameters of control modes to observe the corresponding effects on the power system. Based on the simulation outcomes, advantages and disadvantages of the control modes were accordingly recorded and summarized. The results of this study may serve as a reference for further inertia and frequency control technologies study of wind turbines, and an important basis for enacting technical regulations for wind turbines connected to the power system.

關鍵詞 (Key Words)：頻率調節(Frequency Regulation)、慣量(Inertia)、下垂控制(Droop Control)、風機(Wind Turbine)、再生能源(Renewable Energy)、快速備轉(Fast Power Reserve)。

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電力系統慣量研究回顧

Literature Review of Power System Inertia

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摘　要

台灣再生能源的裝置容量逐年增加，包含大型離岸風場以及大規模太陽光電系統的併網。隨著再生能源發電的增加以及傳統同步發電機比例降低，將對於電力系統頻率穩定度產生極大的挑戰。未來系統若發生大幅度的擾動，頻率的變動將會大幅增加，因此將可能增加機組排程、低頻卸載策略、快速頻率調節、以及保護電驛設定的困難度。本文彙整國外重要文獻的報導，針對再生能源併入系統後對於慣量的影響以及因應策略進行探討。本文重要的內容包含電力系統頻率變化率的趨勢與要求、影響慣量的主要因素、因應低慣量的解決方法、慣量估算的方式，以及臨界慣量的定義。由研究調查的結果可知，未來台灣電力系統極可能出現大幅度的頻率變化率，因此系統慣量的估算、臨界慣量的定義、以及提供快速頻率調節的能力將更加重要。

Abstract

The installed capacity of renewable energy sources (RESs) in Taiwan has continued to increase in recent years. The increase of RE generation nevertheless reduce the ratio of traditional synchronous generators and therefore cause great challenges to the stability of power system frequency. In the foreseeable future, when a large disturbance occurs for some reason, e.g. large scale offshore wind farms and photovoltaic systems connected to the power system, the frequency of power system will fluctuate dramatically, and cause difficulties to scheduling, low-frequency load-shedding strategy, rapid frequency regulation, and relay protection setting, etc. The contents of this study include (1) literature review and summarization of system inertia and corresponding strategies, (2) the trend and requirements for rate of change of frequency (ROCOF), retrieved from cases of worldwide power systems, (3) main factors that may affect system inertia, (4) solutions to low system inertia, (5) methods of inertia estimation, and (6) definition of critical inertia. As the results of this study indicates, the power system in Taiwan will appear large ROCOF in the near future, and the issues such as estimation of power system inertia, definition of critical inertia, and the ability of providing rapid frequency regulation will become more and more imperative.

關鍵詞 (Key Words)：再生能源(Renewable Energy)、頻率穩定度(Frequency Stability)、頻率變化率(Rate of Change of Frequency)、慣量估計(Inertia Estimation)、臨界慣量(Critical Inertia)。

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台灣能源轉型下的線路壅塞管理

Transmission Congestion Management under the Energy Transition Policy

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摘 要

本文主旨在研究 2025 年台灣能源轉型的系統條件下潛在的易壅塞線路，並透過設置內燃機與儲能系統，以及對風場或太陽光電案場進行降載以紓解易壅塞線路的過載情形。本研究考量台電實際的系統參數、負載資訊、大量再生能源的併入情境、以及進行機組排程。本研究藉由計算易壅塞線路的敏感因子以及 N-1 事故模擬分析，提出內燃機與儲能系統的可能適當位置以及裝置容量，並探討必要時可能需要降載的再生能源場域地點以及適當的容量。模擬結果指出，大潭電廠及南火電廠可以適度增設內燃機組以紓解北部與南部易壅塞線路之壅塞情形；星元與星彰電廠可適度增設儲能系統以紓解中部線路壅塞。在風場降載策略上，必要時北部離岸風場的降載方式對於紓解線路壅塞之效果顯著。在太陽能降載策略上，若是能平均分散至各區域併接點，且於樹德、南崁、出西、北港、四湖、虎菁、虎科、斗六等併接點的容量不會過大的情形下，太陽光電出力並不會加劇壅塞線路的壅塞情形，因此不需要對太陽光電進行降載策略。

Abstract

This study aims to investigate the transmission lines apt to be congested under the influence of the energy transition policy (20% generation from renewable energy by 2025) and to propose the countermeasures to relieve the aforesaid congestions, e.g. installing internal combustion engines (ICEs), energy storage systems and wind/solar curtailment. The factors taken into consideration in our simulations include the actual power system parameters provided by Taiwan Power Company (TPC), load data, scenario of mass renewable energy generation and scheduling/unit commitment. The major results of this study include (1) recommendations of the locations and installed capacity of ICEs and/or energy storage systems, through the sensitivity factor and N-1 contingency analyses, (2) investigations of the appropriate locations and capacity of renewable energy needed to be curtailed when necessary, (3) simulation results indicate that the installation of ICEs at Da-Tan power plant and Nan-Pu power plant can relieve the transmission line congestion in northern and southern Taiwan, while the installation of energy storage systems at Xing-Yuan power plant and Xing-Chang power plant can relieve the congested transmission lines in central Taiwan, (4) the effect of curtailing offshore wind farms in northern Taiwan is remarkable, and under the premises of (a) solar power plants are distributed in a wide area and (b) the capacity of solar power connected to Shu-De, Nan-Kan, Tai-Si, Bei-Gang, Sih-Hu, Hu-Jing, Hu-Ke and Dou-Liou are not overloaded, solar power plant will not become a cause of transmission line congestion, so no solar curtailment is necessary.

關鍵詞 (Key Words)：壅塞(Congestion)、內燃機(Internal Combustion Engine)、儲能(Energy Storage)、敏感因子(Sensitivity Factor)、風場(Wind Farm)、太陽光電(Solar Photovoltaic)。

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台灣電力系統因應再生能源高占比議題之儲能設備應用研究

Application of Energy Storage System for High Proportion of Renewable Energy in Taiwan Power System

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摘　要

因應全球暖化的影響，台灣近幾年以風力和太陽能作為主要發展方向，目標為逐年增加再生能源的占比率，於 2025 年再生能源占比率達 20%。然而，風力和太陽能有間歇性發電的問題，隨著再生能源的占比上升，其對電力系統的穩定度將會有嚴重的影響。有鑑於此，本研究通過蒐集國內外有關儲能系統實際投入至電網系統中應用之相關文獻與軟體模擬，分析臺灣本島電網在再生能源發展的各階段下，儲能系統投入的必要性以及需求。經模擬分析後，建議臺灣電力公司：(1) 在 2025 年時，快速反應負載資源(FRR)輔助服務預計採購量 300MW 下，儲能自動頻率控制(AFC)調頻輔助服務採購容量應達 550MW 以上。(2) 再生能源出力變化率應至少限制在每分鐘 15%內。以加強台灣電力系統的安全性及穩定性。

Abstract

To cope with global warming, Taiwan has vigorously promoted wind power and solar energy in recent years. The policy goal is to elevate the proportion of renewable energy (RE) generation to 20% by 2025. However, the RE generation such as wind and solar are intermittent. The increase of RE proportion will cause negative effects to the stability of power system. This study therefore aims to analyze the necessity and required capacity of energy storage system (ESS), through literature review and software simulation, at different stages from the perspective of power grid. The results of this study include (1) when the ancillary service purchase capacity of Fast Response Resource (FRR) in 2025 is set at 300MW, the purchase capacity of Auto Frequency Control (AFC) shall be equal or above 550MW, (2) The ramp rate of RE shall be limited to below 15% per minute.

關鍵詞 (Key Words)：高占比再生能源(High Proportion of Renewable Energy)、電池儲能系統(Battery Energy Storage System)、頻率響應(Frequency Response)、系統慣量(System Inertia)、穩定度(Stability)。

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輸電級再生能源發電設備併聯審查

Review of Renewable Energy Facility Connected to Transmission System

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摘 要

配合政府再生能源發展政策，能源局 2017 年 8 月公告再生能源開發目標，預定 2025 年達到 27.423GW 再生能源裝置容量，其中太陽光電 20GW，風力發電 4.2GW 等。面對未來大量再生能源併聯，須配合電網相關管理機制及先進電網控制技術等，以確保供電穩定。本文針對現行管理機制之再生能源併聯審查作業流程及檢討項目進行說明，藉由各審查階段預先掌握再生能源併聯後，對系統帶來之衝擊。文中亦針對併網審查檢討指標說明，也依再生能源併聯審查案件類型態樣、併接方式、開發區域等不同之情境及審查方式等進行詳細介紹。藉由再生能源併聯審查，系統可穩定供電及創造全民、業者、台電三贏局面，共同迎向綠能低碳電網的新世代。

Abstract

To comply with the government's energy policy, the Bureau of Energy, MOEA in October 2017 declared that domestic installed capacity will reach the target of 27.423GW by 2025- 20GW PV and 4.2GW wind energy. In the face of more and more renewable energy (RE) connected with the power system, Taiwan Power Company (TPC) has to deploy advanced grid control technologies, under brand new grid management mechanisms, to ensure stable power system operation. The main focus of this study is to fully understand the review procedures of RE facilities connected to the power system, and the impacts of RE at each review stage, including review items (power flow, fault current, transient stability, voltage fluctuation, flicker, power factor, harmonic, LVRT/HVRT), review types, connecting types, development districts, etc. Through the RE review mechanism, we look forward to safer and more stable power system and win-win situation for the public, market participants of RE and TPC.

關鍵詞 (Key Words)：再生能源(Renewable Energy)、併聯審查(Connecting Review)、審查流程(Review Procedure)。

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再生能源加入於系統輔助服務需求評估之研析：以北美與歐洲為例

Review of the Ancillary Reserve Requirements Coping with Mass Renewable Energy- Take North America and Europe for Example

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摘 要

隨著環保意識抬頭以及對核電安全的疑慮促使國際間逐漸開始重視再生能源發展，然而再生能源的間歇與不穩定特性已成為電力系統所需面臨的挑戰，有鑒於國內近年來再生能源發展快速，如何確保既有電力調度機制可於再生能源於系統占比增加下仍可保持系統供電穩定便成為相當重要的課題，特別是維持系統頻率穩定與用電安全的備轉容量方面。由於歐美地區對於再生能源發展有著豐富的應用經驗，可供我國對於備轉容量相關評估機制上的參考。本文針對美國德州、愛爾蘭、美國夏威夷以及加拿大等四個北美與歐洲地區於再生能源加入後之系統備轉容量中的各項輔助服務需求評估方式進行探討，並特別著重於再生能源不確定性與變化性對系統可能造成的影響進行分析，上述研究成果可供我國評估未來再生能源發展目標下之輔助服務因應對策制定的重要參考。

Abstract

Due to the rise of public awareness of environment and the safety of nuclear energy, renewable energy sources (RES) have earned emphasis and created challenges to the operation of power system. Therefore, how to ensure stable power system operation to cope with mass RES integration has become an issue of utmost importance, e.g. maintaining sufficient operating reserve to balance power supply and demand. Since North America and Europe have accumulated considerable experience in the aforesaid aspect, related cases may provide useful reference for us to evaluate the mechanism of operating reserve. This study aims to explore the requirements of ancillary services (AS) of Texas, Ireland, Hawaii and Canada. focusing on the impacts caused by the uncertainty and variability of RES generation. The results of this study may serve as reference for enacting AS strategies and operating reserve requirements in Taiwan.

關鍵詞 (Key Words)：再生能源併網(Integrated Renewable Energy)、輔助服務(Ancillary Reserve)、電力調度(Power Dispatch)。

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回頁首

風力發電量推估與尾流模式分析-以離岸一期為例

Wind Energy Production Estimation and Wake Model Analysis - A Case Study of TPC Offshore Phase 1 Project

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摘　要

臺灣自 2000 年起積極推動風力發電，累計裝置容量已逾 71.1 萬瓩，成果豐碩，惟因臺灣地狹人稠，陸域風力場址大多數已設置，未來開發將有難度。反之，臺灣四面環海，尤其在西側風能豐沛；在海域之風速穩定、亂流較少，是現在世界各地再生能源的發展新星。本公司目前已完成離岸風力一期工程發包，預定 109 年底完成本公司第一座離岸風場，目前承商提審之風況及風能分析報告書已核定，本文將依承商提送之風機及布置資料，實際驗證期風能估算結果並為往後風場開發規劃提供估算方法；另分析風能分析軟體新增之尾流模型在實際估算上之結果。

Abstract

The installed capacity of wind power in Taiwan has substantially increased since year 2000, currently over 711MW. When sites suitable for onshore windfarms have mostly been developed, the sites suitable for offshore windfarms remain undeveloped, especially the western Taiwan waters. The offshore phase 1 project of Taiwan Power Company is expected to be completed by 2020. The focuses of this study include (1) to verify the wind energy estimation methods for the project, (2) empirical analysis by applying the newly modified WAsP wake model .

關鍵詞 (Key Words)：風力發電(Wind Power)、離岸風力(Offshore Windfarm)、發電量評估(Power Production Estimation)、尾流模型(Wake Model)、風能分析(Wind Energy Analysis)。

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同步發電機調速器與穩定器對系統頻率響應之影響

The Impact of Synchronous Generators' Speed Governors and Power System Stabilizers on the Frequency of the Power System

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摘　要

為落實能源轉型，政府規劃再生能源發電佔比將於民國 114 年達總發電量之 20%。由於再生能源(風機和太陽光電)的慣量要比傳統機組的慣量小很多，當這些機組取代傳統機組，系統發生跳機事故時，因系統慣量減少導致頻率響應變差，而造成系統穩定度問題。然而，要因應大量再生能源併網後，在不同情形下可能對系統造成的衝擊，進而研擬出控制對策，有賴準確的模型。本文將以台電所建置的 PSS/E 模型為藍本，先對其進行敏感度分析(Sensitivity Analysis)，找出各個參數對系統的慣量響應(Inertia Response)及初級頻率響應(Primary Frequency Response)的影響。接著，本文將系統參數進行微調，以符合 PMU 所量測的資料。

Abstract

To fulfill its energy transition policy, the government sets a target of 20% renewable energy (RE) generation mix by 2025. The increase of RE ratio has a downward influence on the inertia of power system which is the capability to quickly respond to unexpected outages such as generator tripping and usually causes problems of power system stability. Therefore, it is important to apply proper models to analyze/predict the impact of high RE penetration. This study utilizes the PSS/E model provided by Taiwan Power Company to perform sensitivity analyses to identify the influences of each parameter on the inertia response and the primary frequency response. The results of this study may be used to fine tune the parameters of the PSS/E model to ensure the parameters in line with the measurements recorded by PMUs.

關鍵詞 (Key Words)：發電機 (Generator)、調速機(Governor)、穩定器(Stabilizer)、慣量(Inertia)、頻率響應(Frequency Response)、發電機解連(Generation Loss)，頻率最低點(Frequency Nadir)。

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除役太陽光電模組回收循環利用處理方案之探討

An Exploration of the Recycling Process for Decommissioned Photovoltaic Modules

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摘 要

我國能源政策對於太陽光電至 2025 年裝置容量的目標值為 20GW，為實現此目標，本公司近年來也加快速度安裝，而這帶來新的挑戰：除役太陽光電模組該如何處理?。因此，本報告蒐集與分析國內外太陽光電模組在廢棄量預測、回收循環經濟潛力、回收技術發展趨勢與回收管理制度方面的資訊與報告。本報告並採用專利探勘工具，系統化分析太陽光電模組回收再利用技術領域在 1995 至 2018 年間之發展趨勢，結果顯示 2015 年至 2018 年間專利權人數、專利件數呈現衰退。本報告專利分析所產出之管理面、技術面數據與資料，可提供產業界作為評估技術開發或商業化之參考。

環保署 2019 年公佈廢棄太陽光電模組回收服務管理資訊系統，本報告模擬包括拆下打包模組、儲存模組、運輸模組至環保署指定暫存點之處理機制，協助提昇國內太陽光電模組再利用成效，也為國內推動循環經濟盡一份心力。

Abstract

Solar photovoltaic (PV) is a key renewable energy industry in the world. The ROC government’s renewable energy deployment plan aims to increase the share of PV module installation to 20GW by 2025. To achieve this goal, TPC has also accelerated the rate of PV installation in the recent years. However, this energy transition creates a new challenge: PV modules wastes. This report reviews and analyses relevant literature to examine the evaluation of PV modules waste-volume growth, the potential of the circular economy derived from the already known recycling PV modules waste technologies, the recycling technologies trend for the End-of-life (EOL) PV modules, the PV modules recycling regulation and collection systems in the world.

This report also uses patent analysis tools to explore the development trend of PV module recycling technology from 1995 to 2018. The results show that the number of assignees and the number of patents had been declining from 2015 to 2018. The management and technical data produced by the patent analysis in this study may serve as a reference for evaluating technology development or commercialization for the industry.

The Environmental Protection Administration, Executive Yuan announced the Service Management Information System on the Recycling of Photovoltaic Module Waste in 2019. This simulation of the PV module waste recycling process in this study is in accordance with the System, to properly solve the problem of PV module waste and make contribution to the domestic promotion of circular economy.

關鍵詞 (Key Words)：太陽光電模組(Photovoltaic Module)、廢棄物(Waste) 、循環經濟(Circular Economy)、回收循環利用程序(Recycling Processes)、專利分析(Patent Analysis)。

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