台電工程月刊891期(11月)目錄

邁向2050淨零排放之電網穩定因應措施　專輯
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非傳統機組參與電力交易平台輔助服務之技術規範設計研析

A Study on Technical Requirements for Non-conventional Power Resources Participating in Ancillary Service Market

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摘　要

台電公司於110年7月啟用電力交易平台，開拓了非傳統機組提供輔助服務交易之契機，使儲能系統、需量反應、及自用發電設備、再生能源等可以提供其可調度容量，並於日前輔助服務市場參與調頻、即時、補充備轉之交易。本文聚焦於前述非傳統機組進入日前市場參與輔助服務之機制研析，包含技術規範、能力要求與驗證、遙測通訊、以及註冊程序。本文之機制研析，期能使儲能業者、用戶群代表、自用發電設備設置者等法定可提供輔助服務之來源之技術參考，並參與電力交易平台之輔助服務交易。除了使國內相關業者可建立新興電力交易模式，並在再生能源高度發展之際，增加系統之調度彈性，使國內電網成為一永續且強韌之電力系統。

Abstract

The Electricity Trading Platform unveiled in July 2021 by Taiwan Power Company paves the way for non-conventional power resources, e.g., energy storage systems, demand response, co-generation and renewable energy, to trade their dispatchable capacity in the day-ahead ancillary service market (AS Market), which comprises three products, namely frequency regulation, spinning and supplemental reserves.

This study focuses on the technical and regulatory designs, including capability requirements, pre-qualification, metering and telemetry, and registration procedures, for non-conventional power resources to participate in AS Market. The regulatory study presented in this paper is expected to formulate a preliminary technical guidance for potential participants, such as owners of storage equipment, aggregators of demand response and entities of co-generation. Thus, the flexibility of Taiwan's power system can be further enhanced to cope with the rapid development of renewable energy.

關鍵詞(Key Words)：電力交易平台(Electricity Trading Platform)、輔助服務 (Ancillary Service)、儲能(Energy Storage System)、需量反應 (Demand Response)、自用發電設備(Co-generation)。

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電力系統慣量研究

A Research on Power System Inertia

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摘　要

隨著再生能源占比提升，電力系統等效慣量將逐步降低。因此未來電力系統將可能面臨頻率變化率增加、備轉容量降低、以及極端頻率變化的系統狀態。因此，未來的電力系統規劃與運轉需要考量系統慣量。本文主要依據台電公司委託計畫的完成報告，彙整並精簡相關的內容。本計畫的研究內容包含慣量估測的方法、研究影響系統頻率響應的重要參數、探討系統臨界慣量以及含慣量限制條件的機組調度策略、分析大量再生能源併入台電系統情境分析，並考慮不同再生能源占比與事故情境下的各種預測模型建立。在改善頻率響應策略部分，本計畫討論如何藉由再生能源的控制策略以及儲能系統來改善系統慣量，並進行等效模型建立與系統分析。本計畫最後建立程式介面的架構，進行台電系統PMU低頻事件記錄以及PSS/E模擬低頻事件之系統慣量估算等。

Abstract

As the proportion of renewable energy increases, the equivalent inertia of power systems will gradually decrease. Consequently, power systems will face situations of increasing ROCOF, decreasing reserve capacity, and drastic frequency variations. Therefore, power systems shall incorporate the factor of system inertia into the planning and operation considerations. The major contents of this paper is based on the research results of a project commissioned by Taipower, including estimation methods for inertia, important parameters that affect frequency response of a power system, critical inertia of a power system, unit scheduling strategies in line with inertia constraint limits, renewable energy integrated with the power system of Taipower, and the establishment of various prediction models by considering different accident scenarios and renewable power penetration. In terms of the strategies to improve frequency responses, this project discusses how to improve power system inertia

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through control strategies aiming at renewable energy and energy storage systems, along with conducting a equivalent model for the purposes of simulations and system analyses. In addition, a structure of the program interface for power system inertia has been established to record PMU low-frequency events of the power system of Taipower and to estimate/simulate the system inertia at the time of low-frequency events with the aid of PSS/E.

關鍵詞(Key Words)：再生能源(Renewable Energy)、等效慣量(Equivalent Inertia)、備轉容量(Spinning Reserve)、機組調度(Unit Commitment)、情境分析(Scenario Analysis)、頻率響應(Frequency Response)、程式介面(Programming Interface)。

國內電動載具充電設施之合宜運作模式

Operation Mode Applicable to Domestic Electric Vehicle Charging Facilities

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摘 要

隨著政府推動電動載具相關政策目標的推動，國內電動載具充電設施之電力需求及設置數量將大幅成長。面對未來電動載具所需之充電設施供電線路佈設及資通訊規範等需求，台電公司須針對不同環境所需之電動車電力佈線建置案例、對充電運營商之電能管理策略、符合國際標準之電動載具充電設施之資料模型及通訊模式等議題進一步研究。

本文研擬符合國內電業之運作案例，提出了充電站管理系統(CSMS)之架構規劃，並開發電動車充電排程及最佳化演算法，依所提架構完成CSMS、DRMS及ELMO三系統整合模擬展示，並分別建構使用者操作介面系統平台。此外，本文於示範場域-台灣電力公司台北市區營業處地下一樓，完成充電樁裝設及Busway電力佈線建置之示範系統展示。

Abstract

Accompanied with government policy related to electric vehicles (EV), the electricity demand for domestic electric vehicle (EV) charging facilities and the number of installations are expected to grow significantly. Due to the future needs for infrastructures and communication standards of EV charging facilities, issues such as power line deployment of EV charging facilities, energy management strategies of charging point operators (CPO), and international communication standards of EV charging facilities should be further investigated to serve as reference for Taiwan Power Company.

This paper aims to introduce the basic architecture of charging station management system (CSMS) and the EV charging power scheduling optimization algorithm developed in this study. Based on the proposed architecture, we have accomplished three integrated simulation/demonstration of three systems, namely CSMS, demand response management system (DRMS) and electricity load management optimizer (ELMO), along with user interface platforms for each of the three systems, and a demonstration site of charging piles and busway power wiring in the basement of Taipower's Taipei City District Office.

關鍵詞(Key Words)：充電站管理系統 (Charging Station Management System)、電力負載管理優化器 (Electricity Load Management Optimizer)、需量反應管理系統 (Demand Response Management System)。

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太陽能發電案場輸出平滑化控制與成本效益研究

Output Smoothing and Cost-effectiveness Analysis of Solar Photovoltaic Farms

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摘 要

再生能源被視為減碳與發展永續環境不可或缺之重要技術，然而目前最被廣泛應用的太陽能與風力發電，均易受天候因素影響，若遭遇短期天氣變化可能導致輸出功率驟升或驟降而衝擊電網。儲能系統為現有平滑輸出功率研究中最常見的解決方案，再生能源業者雖具平穩輸出之責任，然而額外建置儲能之成本可能縮減業者獲利，故在制定相關法規前仍須進一步研析。本文以台灣能源政策規劃中綠能占比最高的太陽能發電為例，開發其出力平滑化之儲能調度演算法，並依據台灣北、中、南區之歷史發電數據，同時考量不同的代金費率、採用棄光策略與否及跨區域之太陽能案場共用儲能等情境下，求出滿足平滑化限制之最佳儲能系統裝置容量。相關研究結果可供太陽能業者用以投資規劃，或供政府機關作為法規制定之參考。

Abstract

Renewable energy (RE) is regarded as an important technology-indispensable for carbon reduction and the development of a sustainable environment. However, two most widely used technologies, namely solar and wind power generation, are both susceptible to weather factors. Short-term weather changes may cause drastic power output fluctuation and cause consequential effects to the power grid. Energy storage system (ESS) is the most common output smoothing solution among the others. Although owners of RE facilities are responsible for stabilizing their own power output, additional costs of ESS may nevertheless reduce their earnings. Therefore, further research is needy before formulating relevant regulations.

This article takes solar photovoltaic (PV), accounting for the highest RE penetration in the energy policy planning of Taiwan, as an example to develop ESS scheduling algorithm for the purpose of RE output smoothing. Based on historical regional power generation data, including northern, central, and southern Taiwan, an optimal installed capacity of ESS may thus be determined, along with considering the influences of different penalty rates, PV power curtailment strategies, and sharing ESS capacity amid PV farms in different regions. The results of this study may serve as a reference for solar energy companies and government agencies to draft their investment plans or regulations.

關鍵詞(Key Words)：太陽能出力平滑化 (PV Power Output Smoothing)、儲能系統 (Energy Storage System)、容量最佳化 (Capacity Optimization)、棄光 (Power Curtailment)。

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2030 台電前瞻電力趨勢研究

A Study of 2030 TPC Electric Technology Foresight

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摘 要

為提供台電因應政府能源轉型與電力市場改革等政策之參考，本研究透過德菲法問卷及層級分析法(AHP)問卷，參考國際能源署(IEA)公布之能源技術路徑圖，對各項電力前瞻技術進行篩選及排序。本研究之成果，有助針對前瞻電力技術，建立組織內部共識，提升資源之使用效率及效度。本研究依據2種設想情境，4個技術分群需要，臚列11項前瞻技術，供台電後續進行研發布局之參考。

Abstract

To serve as reference for Taipower to cope with government policies, e.g., energy transformation and electricity market reform, this study uses the methods of Delphi Questionnaire and Analytic Hierarchy Process (AHP) Questionnaire, on review of an energy technology roadmap made public by the International Energy Agency (IEA), to analyze various electric technologies through the measures of screening and ranking. The results of this study may help establish an internal consensus within the organization, on the topic of 2030 TPC Foresight Electric Technologies, so as to improve the efficiency and effectiveness of resource utilization. Based on two scenarios and four technology grouping, we list eleven foresight technologies for Taipower' to carry out the follow-up R&D configuration.

關鍵詞(Key Words)：前瞻電力技術(Electric Technology Foresight)、低碳轉型(Decarbonization)、層級分析法(Analytic Hierarchy Process, AHP)、技術預測(Method Technology Forecast)。

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高再生能源占比下之備轉容量需求評估方式探討

Methods to Evaluate the Operating Reserve Requirements under High Renewable Penetration Scenario

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摘　要

2021年11月，台灣電力公司所設立之輔助服務交易平台已正式上線營運，並透過調頻備轉、即時備轉及補充備轉三種不同的頻控類輔助服務，協助系統頻率能在正常與事故異常情況，保持穩定與安全，亦稱備轉容量。依據國內目標，2025年太陽能發電裝置容量將達到20GW、離岸風電為5.6GW，屆時系統慣量將會降低，系頻率擾動也會因再生能源特性而有所增加，若要維持系統強韌性與因應事故，上述三項輔助服務需求量必須謹慎評估。

有鑒於此，本文針對美國ERCOT、PJM、澳洲AEMO、英國NGESO、愛爾蘭EirGrid以及日本OCCTO等國際具高再生能源占比之單位於頻控輔助服務需求評估方式進行探討，並研析需求評估之關鍵條件，相關研究成果可供未來再生能源發展目標下之備轉容量需求量評估之參考。

Abstract

The ancillary service (A.S.) market platform, developed by Taiwan Power Company (TPC) and commercialized in November 2021, includes three submarkets-ancillary services Regulation Reserve (RR), Instantaneous Reserve (IR) and Supplemental Reserve (SupR). The mission of A.S. is to maintain frequency stability and security of the power system under normal and abnormal conditions-also known as operating reserves. According to the government's set goal to boost renewable energy (RE), installed capacities of photovoltaic and offshore wind power shall respectively reach 20GW and 5.6GW in 2025. Consequently, system inertia will decrease due to high RE penetration and result in significant frequency fluctuations. To maintain reliability and resiliency of the power system, it is necessary to quantify the aforementioned A.S. in a prudent way.

This paper introduces the market rules regarding A.S. of the areas of high RE penetration, e.g., ERCOT, PJM, AEMO, NGESO, EirGrid and OCCTO, to serve as reference for TPC to quantify the requirements of Operating Reserve.

關鍵詞(Key Words)：輔助服務(Ancillary Service)、備轉容量(Operating Reserves)、再生能源(Renewable Energy)。

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基於天氣模式分類的日前太陽光電發電預測

Day-ahead Solar Power Forecasting Based on Weather Classification

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摘　要

太陽光電預測技術包含資料處理程序和預測模型的建立。由於發電量與照度存在高度相關性，若能準確預測照度，將可大幅提高預測的精確度。然而目前照度預測因數值天氣預報的限制仍有改進空間，因此如何改善相關資料的處理技術來提高預測精確度非常重要。根據文獻，天氣型態分類是資料前處理的重要手段之一，若能將不同天氣型態進行分類並分別建立預測模型，應可有效提高預測的精確度。本文嘗試建立各種不同的天氣模式分類方式，包含考量一般數據集群分類、依季節分類、依上下午時段分類，以及依據資料大小與差異的方式分類等。研究結果顯示，基於不同天氣模式分類的方法都可提高日前預測的精確度，且隨著天氣分類方式的改善以及照度預測精確度的提高。

Abstract

Solar power forecasting technology basically includes procedures of data processing and establishment of forecasting models. There is close correlation between power generation and solar irradiance. Correspondingly, when solar irradiance can be predicted accurately, the accuracy of solar power generation forecast can be significantly improved. However, there is still a lot of room for improving solar irradiance forecasting due to the limitation of numerical weather prediction (NWP). Therefore, it is important to improve the accuracy of related forecast technologies, such as data processing. According to literature review, classification of weather patterns is an important method for data preprocessing among others. When different weather patterns can be classified, the corresponding prediction models can be established, and the forecasting accuracy can be improved effectively. This paper attempts to establish a variety of methods to classify weather patterns. The aforesaid methods include typical clustering classification, season-based classification, time-based classification (morning or afternoon), and the classification according to data's amplitude and variance. The research results demonstrate that forecasting methods based on weather classification can improve the accuracy of day-ahead forecasts.

關鍵詞(Key Words)：太陽光電(Solar Photovoltaic)、預測(Forecasting)、資料處理(Data Processing)、數值天氣預報(Numerical Weather Prediction, NWP)、天氣分類(Weather Classification)。

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風機調頻技術應用於台電系統的研究

A Study on Wind Turbine Frequency Regulation Technologies Applicable to TPC Power System

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摘 要

台灣離岸風力發電將於近幾年內大幅增加，未來如何維持可靠的系統頻率穩定度將是重要的議題。本文探討風力發電機的各部分模型以及各種主流的風機頻率控制技術，包含下垂控制、慣量控制、步階慣量控制以及快速功率備轉控制，並將這些控制器寫入PSS/E自建模型中，用以模擬實際台電系統的頻率響應。經由模擬結果顯示，慣量控制技術可以獲得較佳的頻率改善效果。本研究的成果可供台電公司參考，用以規劃或設計未來風機頻率控制的模式與機制。

Abstract

The generation of offshore wind power in Taiwan will significantly increase in the coming years. How to maintain the frequency stability of power system has become an important issue. This paper discusses in details the structure of wind turbines and main frequency control technologies, e.g., droop control, inertia control, step inertia control and fast power reserve control, which will be written into user-defined PSS/E models to simulate the actual frequency responses of TPC power system. The simulation results demonstrate that the use of inertia control technologies may help achieve frequency improvement related to increasing transient frequency nadir. The results of this research may serve as a reference for Taipower to plan and design the frequency control mode and mechanism of wind turbines.

關鍵詞(Key Words)：風力發電(Wind Power Generation)、頻率穩定度(Frequency Stability)、頻率控制(Frequency Control)、下垂控制(Droop Control)、慣量控制(Inertia Control)、步階慣量控制(Step Inertia Control)、快速功率備轉控制(Fast Power Reserve Control)。

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電網故障信息辨識與優化處理方案

Power Grid Fault Information Identification and Processing Scheme Optimization

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摘　要

台中供電區營運處所屬台中區域調度中心負責台中、彰化、南投地區161kV以下輸電網路及相關變電所運轉、調度。工作內容包括電網設備故障引起之警報、電網設備故障處理、通報各種停電工作及復電操作、保護電驛動作與故障原因的認知及示波器顯示之電壓、電流波形、振幅、斷路器動作時序與設備故障，本文研究電網設備故障產生之各種信息，參考實務經驗，希望在面對能源轉型，供電裕度低下之際，精進運轉、調度技術，穩定供電。

Abstract

Taichung Area Dispatch Control Center (TADCC), a division of Taichung Power Supply Department, is responsible for the operation and dispatch of the transmission network and related substations with voltage below 161 kV within Taichung, Changhua, and Nantou. The work content of TADCC includes alarms triggered by equipment failures, power grid equipment failure handling, notification of various power outages and power restoration operations, recognizing the actions of protection relay and fault causes, and figures such as voltage, current waveform, amplitude, circuit breaker action sequence, and equipment failure displayed on the oscilloscope screen. This paper studies various information generated by power grid equipment failures and seeks to utilize practical experience to improve the operation and scheduling of power grid.

關鍵詞(Key Words)：台中區域調度中心(Taichung Area Dispatching Control Center)、保護區間(Protection Zone)、協調時間(Coordination Time Interval, CTI)、故障測距設備(Fault Locator)、滙流排(Bus)、斷路器失靈保護電驛(Breaker Failure Protection Relay, 50BF)、匯流排保護電驛(Bus Protective Relay, 87B)、斷路器遮斷容量(Interrupting Capacity, IC)。

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