台電工程月刊924期(8月)目錄

新及再生能源：
NEW AND RENEWABLE ENERGY :

電力系統：
POWER SYSTEM :

環境與永續：
ENVIRONMENT AND SUSTAINABILITY :

系統整合：
SYSTEM INTEGRATION :

構網型變流器之控制探討與國際規範蒐集

Control Methods and International Standards for Grid-forming Inverters

江文莊* 謝國聖* 賴凱右*
Jiang, Wen-Zhuang Hsieh, Kuo-Sheng Lai, Kai-You

摘 要

隨著再生能源與儲能系統快速的發展，以變流器為主的發電裝置(Inverter-based Resources, IBR)也越來越多。傳統的電力系統主要是由同步發電機來發電，然而，再生能源與儲能系統主要是透過變流器將直流電轉換成交流電再輸送到電網。再生能源發展的初期，其再生能源數量尚不多，主要的變流器控制方式為跟網型(Grid-following)，顧名思義為跟隨電網的電壓與頻率，並對電網提供實功率與虛功率。根據專家研究，如果持續使用跟網型變流器，其占比超過百分之三十時將出現電網不穩定的情形。因此，為了增加電網穩定度，構網型(Grid-forming)變流器的應用也逐漸受到重視。然而，Grid-forming Inverter 其包含不同的控制方式。瞭解各種控制法將有助於對 Grid-forming Inverter 特性的掌握。本研究針對 Grid-forming Inverter 的特性、模型參數探討與應用作一介紹。

Abstract

With the rapid development of renewable energy and energy storage systems, there are more and more power generation devices based on inverters, referred to as inverter-based resources (IBR). The traditional power system mainly generates electricity through synchronous generators. However, renewable energy and energy storage systems mainly convert direct current (DC) power into alternating current (AC) power through inverters and then transmit it to the grid. In the early stages of renewable energy development, the amount of renewable energy was still small, and the main inverter control method is grid-following, which, as the name implies, follows the voltage and frequency of the grid and provides active and reactive power to the grid. Research shows that if grid-following inverters are used continuously and their share exceeds 30%, grid instability will occur. Therefore, to increase the grid stability, the application of grid-forming inverters has gradually received attention. However, grid-forming inverters have different control methods. Understanding various control methods will help understand the characteristics of grid-forming inverters. This study introduces the characteristics, model parameters and applications of grid-forming inverters.

關鍵詞(Key Words)：再生能源(Renewable Energy)、跟網型變流器(Grid-following Inverter)、構網型變流器(Grid-forming Inverter)。

*台灣電力公司綜合研究所

龍潭儲能系統工程規劃興建實務

Planning and Construction Practice of the Longtan Energy Storage System Project

徐啟焜*
Shyu, Chii-Kuen

摘　要

本文簡介台電龍潭儲能系統統包工程興建案例，藉由本案說明儲能系統興建規畫過程與施工內容。

本工程的建置包含規劃設計、基礎結構、設備安裝、管線工程、設備檢測、調整測試、性能測試與驗證及可靠度試驗，依系統區分有併網設備(高壓氣體絕緣開關、變壓器)、儲能設備(電力轉換器、儲能貨櫃、空調箱、能源管理系統)、輔助電源設備(直流充電機、UPS、低壓配電盤)、緊急發電機、監視系統、消防防護設備等。建置完成後之教育訓練與竣工後之維護和保固，均含括於統包工程內。

Abstract

This article uses Taipower's Longtan Energy Storage System Turnkey Project as an example to illustrate the planning process and construction content of the energy storage system construction.

The project's engineering contents include: planning and design, infrastructure, equipment installation, pipeline engineering, equipment testing, adjustment testing, performance testing and verification, and reliability testing. If classified by system, they are grid-connected equipment (high-voltage gas-insulated switchgear, transformer), energy storage equipment (PCS, energy storage container, HVAC, energy management system), auxiliary power supply equipment (DC charger, UPS, low-voltage switchboard), emergency generator, surveillance system, fire protection equipment, etc. In addition to the above, the content of this project also includes education and training after completion, and maintenance and warranty after completion.

關鍵詞(Key Words)：電力轉換系統(Power Conversion System, PCS)、儲能管理系統(Energy Storage Management System, ESMS)、水霧滅火系統(Water Mist Fire Extinguishing System)。

*台灣電力公司輸變電工程處北區施工處

備用容量市場運作機制對供電穩定之探討與展望

The Impact of Reserve Capacity Market Operation Mechanism on Power Supply Stability

蔣佳佑* 呂昭麟** 陳冠彰** 鄒宏楷***
Chiang, Jia-Yo Lu, Chao-Lin Chen, Kuan-Chang Tzou, Hong-Kai

翁郁棋* 許涵甄* 王建凱***
Weng, Yu-Ci Hsu, Han-Chen Wang, Chien-Kai

摘 要

隨著全球再生能源併網容量和發電量的占比持續大幅增長，也帶給電力市場調度及供電穩定度前所未有的挑戰，在不斷以較低備用容量的再生能源取代傳統發電源之下，導致備用容量嚴重不足，進而影響供電的穩定度。有鑑於此，各國相繼提出許多應變措施，其中備用容量市場機制的改革已成為矚目的焦點。由於再生能源備用容量的貢獻度，會依其滲透率的成長逐漸的降低，這亦是近年來各國電力交易市場因備用容量成本的持續高漲，造成系統整體電價攀升的一大主因。本研究分析比較各國採用之可靠度標準，探討各國家制定備用容量目標的考量與準則，以及發電源可提供合格備用容量的認定標準，佐以備用容量成本與交易價格的實例分析，更進一步，剖析國際間容量市場機制與交易運作方式的利弊得失，及備用容量交易之合理定價，最後研析國際間備用容量市場機制的精進做法，以做為國內建立備用容量市場機制之參考。

Abstract

The substantial growth in the generation capacity of grid-connected renewable energy and the proportion of this power generation has not only led to a serious shortage of reserve capacity, but also brought unprecedented challenges to power dispatching and stability of power supply. In view of this, many countries have proposed various countermeasures, among which the reform of the market mechanism of reserve capacity (i.e. capacity market) has become the focus of attention. Since the contribution of renewable energy to reserve capacity will gradually decrease as its penetration rate grows, the costs of reserve capacity and overall electricity prices in foreign power markets have continued to rise in recent years. This study aims to analyze and compares the reliability standards, considerations and criteria for setting reserve capacity targets in various countries, and examines the criteria for determining whether a power generation source can provide qualified reserve capacity. With the help of case analysis of the costs and transaction prices of reserve capacity, the paper further analyzes the advantages and disadvantages of international capacity market mechanisms and operation modes of market transaction, as well as the reasonable pricing of reserve capacity transaction to serve as reference for establishing the market mechanism of reserve capacity in Taiwan.

關鍵詞(Key Words)：容量市場(Capacity Market)、備轉容量(Operating Reserve Capacity)、備用容量(Reserve Capacity)、容量價值(Capacity Value or Capacity Credit)、規劃備用容量標準(Planning Reserve Margin, PRM)、充足備用容量(Resource Adequacy Capacity, RA)、預期缺電時間(Loss of Load Expectation, LOLE)。

---

*德瀚資訊有限公司電力市場顧問服務
**工業技術研究院產業科技國際策略發展所
*** Fluence Energy Taiwan Ltd.

極端事故之電力調度實務-以 2024 年 403 地震為例

Power System Operation Practice under Extreme Accidents - Taking the 403 Earthquake in 2024 as an Example

郭允哲* 蔡文達* 林昭琦* 周芳正*
Kuo, Yun-Che Tsai, Wen-Ta Lin, Chao-Chi Chou, Fang-Cheng

摘 要

2024 年 4 月 3 日早晨 7:58 於花蓮外海發生規模 7.2 強震(此後通稱 403 大地震)，造成數座電廠總計共 324 萬瓩之機組接續跳脫，致使系統頻率降低至最低 59.46Hz，造成低頻卸載電驛第一段動作，使抽水中之抽蓄機組自動跳機。遠在台灣海峽海上的離岸風機亦因電抗設備偵測到晃動情形，致使線路跳脫而無法供電。系統短時間內喪失數量龐大的電源，除因地震直接造成的極少部分輸電設備損害影響停電外，並未造成嚴重大停電事故，此種電力調度經驗誠屬難得。本文詳實紀錄 403 大地震造成電力系統影響，並提供相關運轉經驗與建議。

Abstract

At 7:58 am on April 3, 2024, a strong earthquake of magnitude 7.2 (referred to as the 403 Earthquake) occurred off the coast of Hualien, causing a total of 3,240 MW generating capability in several power plants to trip one after another. The system frequency thus dropped to 59.46 Hz, causing the first stage of the under-frequency load shedding scheme to be activated and automatic tripping out of the pumped storage generator. In addition, offshore wind turbines far away in the Taiwan Strait were unable to supply power because the inductor equipment detected shaking, causing the line to trip. The system lost a huge amount of power in a short period of time, but except for a very small number of power transmission equipment damaged directly by the earthquake, no serious power outage occurred. This kind of power dispatching experience is truly rare. This article records in detail the impact of the 403 Earthquake on the power system and provides relevant operation experience and suggestions for reference.

關鍵詞(Key Words)：低頻卸載(Under-frequency Load Shedding)、抽蓄機組(Pumped Storage Generator)、中央調度中心(Central Dispatch Control Center, CDCC)、自動頻率控制(Automatic Frequency Control, AFC)。

*台灣電力公司輸供電事業部電力調度處

低壓用戶參與電力資源聚合之可行性研究

Feasibility Study on Low-Voltage Users' Participating in Power Resource Aggregation

鄧勝元**
Teng, Sheng-Yuan

伊永馨*
Yi, Yung-Hsin

簡書敏*
Chien, Shu-Min

詹穎儒***
Chan, Ying-Ju

鄭伊秀***
Cheng, I-Hsiu

摘　要

能源轉型趨勢下，國際上已有許多實施低壓用戶需量反應案例，除了需求面用電效率大幅改善外，相較以往的整體用電量亦呈現正面的回饋，可從中窺見低壓用戶實行需量反應之發展潛力。然目前台灣需量反應實行對象多為高壓用戶，未來聚合台灣低壓用戶需量反應之系統模式尚待探索。

本研究透過聚合低壓商業用戶及住宅用戶，根據「設備控制角色」、「需量反應服務型態」、「需量反應回饋機制」設計需量反應之可行性實證，從中觀察用戶參與需量反應之行為與情境模式，並進一步分析低壓用戶參與電力市場之現況。本計畫亦結合儲能設備之運用，評估儲能設備的搭載對於用戶參與需量反應之實行效益，以及未來儲能設備於低壓用戶運用之發展潛能。最後，考量我國電業環境趨勢與臺灣 2050 淨零排放政策方向，提出我國低壓需量反應及參與電力市場之短、中、長期發展規劃藍圖。

Abstract

Under the trend of energy transition, there have been many cases of implementing demand response (DR) for low-voltage users internationally. In addition to the significant improvement in electricity efficiency on the demand side, the overall electricity consumption has also shown positive feedback, which shows the development potential of implementing DR for low-voltage users. However, the current DR programs in Taiwan are mostly implemented for high-voltage users, and the model of aggregating DR for low-voltage users in Taiwan in the future remains to be explored.

This study aims to aggregate low-voltage commercial and residential users and design a feasibility demonstration of DR based on "equipment control roles," "DR service types," and "DR feedback mechanisms," to observe the behavior and situational patterns of users participating in DR and further analyze the current status of low-voltage users participating in the electricity market. Additionally, this project integrates the application of energy storage systems (ESS) to assess their impact on the effectiveness of user participation in DR, as well as the future development potential of energy storage systems for low-voltage users. Finally, considering Taiwan's electric industry environment and the 2050 net-zero emissions policy, a blueprint for the short-, medium-, and long-term development of Taiwan's low-voltage DR and participation in the electricity market is proposed.

關鍵詞(Key Words)：低壓資源(Low-voltage Resources)、需量反應(Demand Response)、儲能系統(Energy Storage System)、電力市場(Electricity Market)。

---

*聯齊科技股份有限公司
**台灣電力公司綜合研究所
***財團法人台灣經濟研究院

火力發電廠氮氧化物影響因素與因應實務探討

Factors Affecting Nitrogen Oxides of Thermal Power Plants and the Countermeasures

劉建良*
Liou, Jian-Liang

摘　要

隨著國家環保的重視，火力發電廠除了提供穩定的發電量，運轉背後所產生的汙染問題逐漸引起人們的關注，其中氮氧化物與硫氧化物等排放汙染物的影響顯得特別重要。通過個國內外學者們的測試與檢測汙染物等實驗，提供我們基於科學而得的精確化依據。本文探討了燃煤火力發電廠所排放的氮氧化物影響因素。氮氧化物影響因素不僅是控制氮氧化物排放的先決理論，進而提供實際上氮氧化物控制與降低的實際措施，提供火力發電廠排放污染物因應管控之依據。

Abstract

The government pays more and more attention to environmental protection issues. Although thermal power plants can provide stable power generation, the pollution problems caused by such power plants have gradually attracted public attention. Among them, the impact of emission pollutants such as nitrogen oxides (NOx) and sulfur oxides (SOx) is particularly important. Through tests and experiments on pollutants by domestic and foreign scholars, we are provided with precise scientific evidence. This paper discusses the factors affecting NOx emitted by coal-fired power plants. In summary, the factors affecting nitrogen oxides provide a basis for the control of pollutant emissions from thermal power plants.

關鍵詞(Key Words)：氮氧化物(Nitrogen Oxides)、火力發電廠(Thermal Power Plant)、燃煤(Coal)。

*台灣電力公司水火力發電事業部台中發電廠

智慧效率發展趨勢與節電效益評估

Development Trend of Intelligent Efficiency and Evaluation of Energy-Saving Benefit

張耀仁* 謝志強* 林志勳*
Chang, Yao-Jen Hsieh, Chih-Chiang Lin, Chih-Hsun

摘 要

「能源效率」被視為全球邁向淨零碳排的「優先燃料」，智慧效率將驅動能源效率改善並開創新願景，同時發展出創新能源效率解決方案與商業模式。本文針對國際智慧效率政策、智慧設備及智慧住宅現況與趨勢進行研究，及對主要智慧設備與不同層級智慧住宅節電成效進行估算，並針對我國智慧效率發展提出策略建議，供政府單位、國營事業或民間企業作為智慧效率政策或行動推動之參考。智慧效率不只是個別設備效率改善，更強調建築用電設備的整合與優化，能源管理系統則是建築用電設備整合的關鍵技術，是建築智慧升級的必要設備，智慧建築是高節能潛力的智慧效率應用場域，尤其擴展至電網互動式建築的應用。對於我國智慧效率發展策略，本文提出以下建議：(1)擴大推動智慧節能標章；(2)擴大能源管理系統建置；(3)補助智慧節能示範計畫；(4)倡議智慧節能融資制度。

Abstract

“Energy efficiency” is regarded as the “priority fuel” for the global net-zero transition. Intelligent efficiency will drive energy efficiency improvements and create new visions, while developing innovative energy efficiency solutions and business models. This paper studies the current status and trends of international intelligent efficiency policies, smart devices and smart homes, evaluates the energy-saving rates of major smart devices and smart homes at different levels, and proposes strategic recommendations for the development of intelligent efficiency in Taiwan, which may serve as a reference for government agencies, state-owned enterprises or private enterprises to promote intelligent efficiency policies or actions. Intelligent efficiency is not just about improving the efficiency of individual equipment, but also emphasizes the integration and optimization of building electrical equipment. Energy management system is the key technology for the integration of building electrical equipment and is also a necessary equipment for building intelligence upgrade. Smart buildings are an area of intelligent efficiency application with high energy-saving potential, especially when extended to grid-interactive buildings. Regarding the development strategy of smart efficiency in Taiwan, this paper proposes the following recommendations: (1) Expand the promotion of smart energy-saving labels; (2) Expand the construction of energy management systems; (3) Subsidize smart energy-saving demonstration projects; (4) Promote a smart energy-saving financing system.

關鍵詞(Key Words)：智慧效率(Intelligent Efficiency)、智慧建築(Smart Building)、智慧節能標章(Smart Energy-saving Labels)、能源管理系統(Energy Management System)。

*工業技術研究院產業科技國際策略發展所

虛擬實境(VR)運用在潛盾洞道上實務經驗

Practical Experience of Using Virtual Reality in Shield Tunneling

蘇博熙*
Su, Po-Hsi

賴永設**
Lai, Yung-She

何茂安**
Ho, Mau-On

許吉良**
Hsu, Chi-Liang

黃又霖**
Huang, Yu-Lin

摘　要

虛擬實境是藉由電腦製作出擬真 3D 空間，使用者透過頭戴式裝置與手把，同時利用空間感測器偵測使用者身上設備，感測現實世界空間座標並將其資訊同步帶入電腦模擬之虛擬空間相互結合，讓使用者產生身處虛擬空間且能與 3D 模型互動之錯覺。

本案例為台灣輸變電工程處北區施工處「161kV 大潭(甲)～梅湖線管路統包工程(二工區)」，其地下電纜管路全線位於新竹縣湖口鄉，於主要道路及住宅密集區，為降低對交通衝擊、民眾干擾及穿越河川與台鐵軌道段，設計採用潛盾工程。本文說明中興工程如何將虛擬實境應用在潛盾工程之安全衛生教育訓練中，提供實務研發經驗供業界參考。

Abstract

Virtual Reality (VR) is a simulated 3D space created by computers. Users use head-mounted devices and handles, and at the same time use spatial sensors to detect the equipment on the user's body, sense the spatial coordinates of the real world and bring this information into the virtual space simulated by the computer to combine them together, giving the user the illusion of being in a virtual space and able to interact with 3D models.

This paper aims to introduce the project of "161kV Datan (A) ~ Meihu Line Pipeline Turnkey Project (Second Work Area)" commissioned by the Northern Construction Office of the Power Transmission and Transformation Engineering Department of Taipower in cooperation with the government's policy goal of developing offshore wind power. The entire underground cable pipeline of the afore-mentioned project is located in Hukou Township, Hsinchu County, on major roads and densely populated residential areas. In order to reduce the impact on traffic, interference with the public and crossing rivers and Taiwan Railway tracks, shield tunneling method is employed. This paper explains how Sinotech Engineering Consultants, Ltd. applies virtual reality to occupational safety and health education and training in shield tunneling, in order to provide practical R&D experience for reference.

關鍵詞(Key Words)：虛擬實境(Virtual Reality)、潛盾工程(Shield Tunneling Method)、職業安全衛生(Occupational Safety and Health)。

*台灣電力公司輸變電工程處北區施工處
**中興工程顧問股份有限公司台電大潭梅湖工程處