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# 大型風力機塔架之疲勞損傷分析

Fatigue Damage Analysis of Large Wind Turbine Tower

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## 摘要

由於早期風力機設計時通常採用較高的安全因子，以至於風力機可能會具有超過 20 年的設計壽命，而疲勞損傷分析之結果，為風力機是否能通過延壽評估的重要依據。本文針對 Vestas V80 2MW 風力機以實際的量測負載進行塔架疲勞損傷分析。負載量測依照 IEC 61400-13 進行，於塔架底部黏貼應變規，量測短時間的負載訊號。利用有限元素分析將應變規量測的應變轉換成中下法蘭位置的應力。風力機在 20 年期間所承受的負載頻譜為使用短時間負載量測及運轉資料來重建，再應用 FAMOS 軟體分析疲勞損傷。研究結果顯示，在 IEC 61400-1 之多種疲勞設計負載狀況下，Vestas V80 2MW 風力機塔架之中下法蘭截面不會發生疲勞失效。

## Abstract

Due to the higher safety design margins that had been usually adopted in the design of wind turbines installed in earlier times, the life of those wind turbines may be longer than 20 years. The result of equipment fatigue damage analysis is an important basis for those wind turbine's life extension. To start a fatigue life assessment, the authors chose a Vestas V80 2MW wind turbine tower. According to IEC 61400-13 standard, we stuck some strain gauges at tower bottom, and measured short-time loading. Based on the results of finite element analysis, the loading at the cross-section of middle-lower flange can be obtained from the strain measurement. The wind turbine's endured load spectrum was reconstructed using a short-time load measurement and operational data. Then the fatigue damage was analyzed with FAMOS software. The results showed that fatigue failure will not occur at the middle-lower flange cross-section of Vestas V80 2MW wind turbine tower if it is operated under the design fatigue load cases of IEC 61400-1 standard.

**關鍵詞(Key Words)：**塔架負載量測(Load Measurement of Tower)、流固耦合分析(Fluid-Structural Coupling Analysis)、疲勞分析(Fatigue Analysis)。

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# 風力機塔柱基礎振動變位及勁度之量測與分析

Vibration Deflection and Stiffness Measurement and Analysis of Wind Turbine Foundation

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## 摘要

風力機塔柱基礎在長期承受反覆載重下，由於土壤強度或勁度衰減或基礎系統逐漸劣化，使得基礎變形增加或勁度降低，而可能導致風機發生不定期停機。因此，本文目的即在選擇陸域風力發電機來探討及評估風機塔柱基礎監測儀器安裝、監測及資料分析方法與成果。在監測基礎變量中，主要使用加速度計及傾度計作各方向之變位或傾角量測，而基礎樁帽變位則用動態變位計量測三方向變位，量測取樣頻率為 64 Hz。如此計算基礎樁帽旋轉或傾角角度，但因風機的自然頻率小於 0.5 Hz，因此，進行低頻積分比較困難，本文利用基線修正以及帶通濾波等分析技術，以獲得較為可靠的位移值。本文另安裝應變計，以計算基礎勁度。此風力發電機塔柱基礎監測與分析技術，未來可推廣至業界的陸域或離岸風力發電機塔柱基礎監測維運之參考。

## Abstract

The rotation stiffness of the foundation may reduce after years of services due to soil degradation or deterioration of the foundation system under cyclic loads. Higher rotation or excessive displacement generated by the foundation, resulting from decreasing rotation stiffness, may cause the turbine to initiate braking system or make it shut down, and also increase the maintenance cost of the gear boxes inside the nacelle. The purpose of this study is to evaluate service life extension of wind turbine tower and performance of wind turbine foundation by field instrumentation, monitoring and reporting on selected turbine foundations. The foundation instrumentation and monitoring program are intended to collect the field performance data and convert those measurements to engineering units with basic parameters that can be evaluated by geotechnical and structural engineers for the life and performance of the foundation system. In the instrumentation the tilts, rotation, and lateral displacements of foundation will be dynamic monitoring. The sampling frequency was set to be 64 Hz with nonstop real-time measuring. The basic sensors are accelerometer. The technique of using baseline correction and band filter to integrate acceleration twice to get the low frequency displacement (under 0.5 Hz) was developed. The portable strain gauges were also installed at the bottom of wind tower to measure the moment loading of foundation so that the rotational stiffness can be evaluated. This vibration monitoring and analytic technics can be used as a refereng in monitoring and maintenance approach for the future on-shore or off-shore wind turbine.

**關鍵詞(Key Words)：**風力發電機(Wind Turbine)、基礎(Foundation)、振動(Vibration)、加速度計(Accelerometer)、傾度計(Tilt Meter)、監測(Monitoring)。

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# 因應綠能發展輸電線路防鹽害之精進作為

Progressive Action Work to Prevent Salt Damage for the Development of  
Green Energy Transmission Towers

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## 摘要

為配合政府推動再生能源及邁向 2025 年非核家園願景，台電公司規劃於 2018 年 12 月前提供約 100MW 太陽光電容量至彰濱超高壓變電所之既有輸變電系統，並於 2025 年提供 6.5GW 併網容量予彰化離岸風力業者之承諾，而興辦彰化離岸風力加強電力網工程。由於所配合興建相關輸電之地下電纜管路及架空線路工程係位於濱海地區，且緊鄰海岸，為免該等輸電設施日後易受鹽害產生銹蝕，導致使用年限減短，危害供電安全之虞，興建單位台電公司輸變電工程處中區施工處特研擬相關防鹽害技術及解決對策。本文可提供日後沿海地區輸電線路設計之參考。

## Abstract

In accordance with the national vision of promoting renewable energy and moving toward nuclear-free homeland by 2025, Taipower company is planning to complete the installation of approximately 100 MW of solar photovoltaic capacity and connect them to the existing power transmission and transformation system of Changbin extra high voltage substation by December 2018; and make a promise to provide 6.5 GW of grid-connection capacity for the system-integration of Changhua's offshore wind power industry come true by strengthening the power grid of the Changhua offshore wind power project. The transmission underground cable pipeline works and overhead transmission lines to be built in connection with the relevant facilities are all located in the coastal areas. To avoid the rust caused by salt fog, which reduce the service life and compromise the safety of power supply, it needs to make a plan of enhancement actions to prevent salt damage. This paper provides a good reference for the research and development on countermeasures against salt damage in transmission lines in the future.

**關鍵詞 (Key Words)**：加強電力網(Strengthen the Power Grid)、地下電纜管路(Underground Cable Pipeline)、架空輸電線路(Overhead Transmission Line)、防鹽害技術(Against Salt Damage Technology)。

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# 161kV 台澎海纜加入系統模擬及建議

Simulation and Suggestion of 161 kV Tai-Peng Submarine Cable Incorporating with Power System

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## 摘要

本文探討台澎海纜加入系統之加壓試驗，依據不同加入系統時程之系統狀況進行模擬。分析加壓前先行投入變電所匯流排電抗器對各變電所及線路末端電壓之影響，並觀察是否符合公司各級電壓之規定。根據模擬結果建議加壓前之匯流排電壓大小，提供給值班人員操作使用，以確保未來台澎海纜加入系統之安全。

## Abstract

Power voltage tests of Tai-Peng Submarine Cable to be incorporated with the power system were discussed in this thesis. Simulations were conducted for a variety of situations of the cable to be incorporated with Power System under different scenarios of incorporation times. The study analyzes the effect of the cable incorporation on each substation and transmission end voltage when reactors in substations were closed before operating voltage test to make sure that the incorporation can meet the safety rules under different voltage levels regulated by Taipower. It is recommended that the bus voltage simulation results can be offered to the on-duty system operation personnel to ensure the safety of Tai-Peng Submarine incorporation with the power system.

**關鍵詞(Key Words)：**海底電纜(Submarine Cable)、加壓試驗(Voltage Test)、電流不通過零點現象(Zero-missing Phenomenon)、電力系統模擬軟體(PSS/E)、電磁分析暫態軟體(EMTP-ATPdraw)。

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# 透過混和型資料之低壓負載趨勢分析

Through Mixed Data Analyze Low-voltage Load Trend

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## 摘要

近年來本公司已開始著手規劃導入布建低壓 AMI 議題，本文將利用高壓 AMI 電表資訊及調度處電力監測系統(PMS)，對於負載資料進行分析與評估，以利本公司針對低壓用戶曲線分析，未來將可以應用於低壓用戶的需量反應策略制訂，甚至搭配部分的低壓 AMI 資訊亦可確認廣布低壓 AMI 的實質意義。以及在再生能源的衝擊上，下午太陽能消失且負載又急速上升時，該斜率如何運轉調度將是未來的一大挑戰，倘若妥善使用 PMS 資料及高壓 AMI 資料，並於時間軸上進行分割，將可以使調度處更加容易評估系統變化量。

## Abstract

In recent years, the company has also begun to undertake the planning for the issues regarding installation of low-voltage AMI (Advanced Metering Infrastructure). This paper is intended to use the high-voltage AMI meter information and dispatching station power monitoring system (PMS) to analyze and evaluate the low voltage load data. It is expected that by properly analyzing the low-voltage user power-load curve the company will be able to formulate the demand response strategy for low-voltage users in the future. In the future, with the low-voltage AMI information, the company can further confirm the effectiveness of installing low-voltage AMI. And in terms of the impact of renewable energy on the power system operation, when the energy coming from solar power disappears due to the bad weather in the afternoon and at the same time the power load rises rapidly, how to cope with the sharp slope of power demand change will be a big challenge for the system operation. If the PMS data and high voltage AMI data are properly used and segmented on the time axis, it will make it easier for the system dispatcher to assess the amount of system change.

**關鍵詞(Key Words)**：智慧電表(AMI)、電力監測系統(PMS)、低壓 AMI(Low-voltage AMI)。

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# 饋線可併網容量視覺化研究

Research on Visualization of Feeder Hosting Capacity

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## 摘要

為提供外界人員能更直覺的了解各饋線區段可併網容量，本案透過資料萃取(Extract-Transform-Load, ETL)，定期擷取台電公司各營業區處現行配電設備拓樸資訊，再簡化成計算可併網容量所需的資料架構，彙整至中心端作為運算基礎資料。對於在計算饋線區段可併網容量時，所使用的系統衝擊分析運算核心，將探討除了現有配電規劃資訊系統(Distribution Planning Information System, DPIS)的運算單元之外，研究運用其他如美國電力研究所(Electric Power Research Institute, EPRI)的 OpenDSS 及 Streamlined 等運算單元，並進行比較與效益分析，選出可提升各饋線進行多段式系統衝擊分析之運算核心，用以快速計算出各區段最大可併網容量(Hosting Capacity)，進而將計算結果整合地理資訊系統(Geographic Information System, GIS)的技術，於地圖上以顏色呈現饋線各區段可併網容量。

本案所建置之網頁化整合管理介面，可輔助管理者能充分掌握系統各單元運作情況，透過定期公布饋線可併網量資訊，讓民眾或業者可充分瞭解饋線併網量之情況，以期能夠在符合電網安全及品質之下，加速推動再生能源的運用，以提高配電系統分散式能源(Distributed Energy)併網量。

## Abstract

In order to allow external users to have a more intuitive understanding of the possible hosting capacity of feed line, this project will regularly extract the topology information of existing distribution equipment from each business branch of Taipower by using the Extract-Transform-Load (ETL) technology. This project then simplifies it and make it become the information structure required to calculate the possible hosting capacity and subsequently summarize and send it to the information center as the basic information for computation. For the computing cores used to analyze the impact while calculating the possible hosting capacity of the feed line sections, in addition to exploring the existing Distribution Planning Information System (DPIS) computing units, this project will study the use of other computing units such as the OpenDSS of Electric Power Research Institute (EPRI) and Streamlined, and then make comparison and benefit analysis to enhance the performance of multi-stage system impact analysis run by each feed line and quickly calculate the maximum hosting capacity of each section, thereby integrating the computing results to the Geographic Information System (GIS) technology and displaying the possible hosting capacity of each feed line section on the map with colors. Furthermore, to solve the performance problems that may be caused by external users downloading a large number of map

data, this project will construct a feed line visualization hosting capacity system through the use of Map Tile display technology that allows the external users to inquire data with telephone number or address, so as to achieve the purpose of establishing feeder visualization of possible hosting capacity.

The web-based integrated management interface built by this project can help managers fully grasp the operation of each unit of the system. By regularly publishing information on the feeder hosting capacities, the public or the industry can fully understand the usage of the feeder hosting capacities, in the hope of accelerating the use of renewable energy in line with the safety and quality of the grid and improving the hosting capacity of the distributed energy resource in the distribution system.

**關鍵詞(Key Words)**：資料萃取(Extract-Transform-Load, ETL)、配電規劃資訊系統(Distribution Planning Information System, DPIS)、可併網容量(Hosting Capacity)、地理資訊系統(Geographic Information System, GIS)、分散式能源(Distributed Energy)。

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# 多功能需量反應資訊系統建置之研究

Research on the Demand Response Information System Development

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## 摘要

台電公司為解決尖峰用電的問題，已提出多種需求端負載管理的策略，包含需量反應措施方案。目前台電主要有需量競價平台和需量反應措施統計系統支援執行需量反應措施方案。然而，該兩系統並未進行系統整合，無法提供業務處進行所有需量反應措施選用查詢與效益分析比較等功能，及調度處進行各種需量反應措施需量監控與事件發布。為了達到此目的，本研究進行多功能需量反應資訊平台建置，在不影響兩個系統的日常功能運作下，透過系統整合方式，提供業務處、調度處單一介面進行現行各種需量反應措施需量調度查詢管理與智能調度功能。本研究已完成多功能需量反應資訊系統建置，可在不影響既有系統的日常功能運作下，以系統整合方式，提供業務處、調度處單一介面進行現行各種需量反應措施管理與智能調度功能，並且依據業務處、調度處各種需量反應報表需求，透過圖形化、視覺化的方式進行資料呈現，利於進行資料判讀。

## Abstract

Taipower has developed a variety of demand-side load management strategies to solve the spike load problem including demand response programs. At present, there are two platforms in operation: "the demand bidding program platform" and "the measures platform of demand response program" to perform the demand response programs. The former provides an electronic process for the demand bidding programs and some other functions for participants, and the staff in the department of System Operation or Business. However, at present the two systems are not integrated. The staff in the department of the Dispatch or Business could not look for or look up the information or get entire benefit among all demand response programs through single interface. This project is intended to achieve the goal of integrating these two platforms, and to present graphical reports to users through the implementation of demand response information platform. This study planned to integrate and exchange the data which come from the demand bidding program platform or the measures platform of demand response program through the Data Base. The demand response information system would provide a unique interface to manage the demand response programs and dispatch the demand response source. It also would provide several kinds of Data Visualizations of the demand response programs - based on the requirements from the staff of System Operation department and Business Department.

**關鍵詞(Key Words)**：需量反應(Demand Response)、需量競價(Demand Bidding)、資料分析(Data Analysis)、負載管理(Load Management)。

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# 電費帳單引導用戶自主電能管理之調查分析與策略規畫

The Investigations and Strategies of Autonomous Power Management Guided by Electricity Bill

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## 摘要

本計畫為利用新版帳單提升節電效益，以期解決台灣用電問題之窘境。亦透過資料探勘技術分析用電行為模式，並產生相應節電策略，作為新版帳單中節電措施提醒內容之依據。此外，在本研究規畫之節電效益評估指標的有形效益方面，非時間及時間電價用戶中的節電實踐家，在用電負載效益及用戶經濟效益皆高於其他類用戶。在無形效益方面，非時間電價用戶中的節電實踐家，在帳單閱讀行為影響度、節電意識影響度及台電企業形象影響度皆較高於其他類用戶，而時間電價用戶之節電實踐家在帳單閱讀行為影響度及台電企業形象影響度之表現略佳。整體而言，曾採取節電措施者較無採取者之整體效益約高3~8%。本研究也發現，有部分被動節電者願意採取節電措施，進而提高節電效益，表示新版帳單確實能幫助用戶進行自主電能管理。

## Abstract

This research aims to develop a new version of electricity bill to help energy-saving and solve problems related to the power use in Taiwan. The research also analyzes the behavioral patterns of electricity use through data mining techniques, and develop appropriate relevant electricity saving strategies by making use of “reminder of electricity saving measures” marked on a new version electricity bill for customers. In addition, in terms of tangible benefits based on the indicators of evaluation by Taipower, those electricity-saving practitioners of both Non-TOU and TOU (Time of Use) users had shown better performance in electricity load benefit and economic benefit than the other types of users. In the aspect of intangible benefits, the electricity-saving practitioners of Non-TOU users also had shown better performance in “bill-reading behavioral influence”, rise in electricity-saving awareness and better altitudes toward TPC image ; the electricity-saving practitioners of TOU users had shown lightly better performance in bill-reading behavioral influence and TPC image . In general, those users who had adopted electricity-saving strategies had 3~8% higher score on overall benefit than those who had not. The research also found that, some passive electricity-saving users, who expressed their willingness to adopt the electricity-saving strategies, have shown better benefit in electricity-saving. This implies that the new version of electricity bill can indeed induce the users to improve their power management.

**關鍵詞(Key Words)**：電費帳單(Electricity Bill)、自主電能管理(Autonomous Power Management)、節電策略(Electricity-saving Strategy)、資料探勘(Data Mining)、節電效益評估(Evaluation of Electricity-saving Benefits)。

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# 公務機關建築能源可視化與空調負載抑低管理實驗 系統評估與示範

Evaluation and Demonstration for Experimental System of Energy Visualization and Air  
Conditioning Demand Shedding in Government Buildings

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## 摘要

本系統以經濟部國際貿易局及標準檢驗局為例，進行實驗系統建置及效益驗證，作為後續經濟部所屬單位導入範本，再逐步擴散至全體公務機關，放大尖峰抑低規模，並建立因應突發事件輔助服務。

完成的項目包含標檢局與國貿局兩研究場域的能源管理系統軟體開發、用電量測試與空調系統負載控制設備的實體布建、自動需量反應系統的安裝與設定以及能源可視化系統的實作。

本報告將分各章節逐項詳述各研究項目的施行細節，包含計畫進度、研究方式以及成果，並介紹後續的工作項目。

## Abstract

The project is designed to take the Bureau of Foreign Trade (BOFT) and the Bureau of Standards, Metrology and Inspection (BSMI) as example case study for establishment of an experimental system and for verification of its installation benefits, which can serve as the good pattern for similar application by other units affiliated to the Ministry of Economic Affairs in the hope of reducing peak power load and providing ancillary services to respond to possible emergency situations of power shortages in the future.

The research items completed include: the development of the energy management system software of the two research fields of the BOFT and BSMI, the electricity power usage measurement and the physical deployment of the air conditioning system load control equipment, and the installation of the automatic demand response system setting and energy information visualization system.

This report elaborates on the details of this research project in the following chapters - including the progress of the project, the research methods and research results, and then introduction of the subsequent working items.

**關鍵詞(Key Words)**：自動需量反應(Automated Demand Response, ADR)、建築能源管理系統(Building Energy Management System, BEAMS)、能源資訊可視化(Energy Consumption Visualization)、空調需量反應(Air Conditioner Automated Demand Response)、冰水主機卸載(Chiller Load Shedding)。

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