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# 運用 AMI 資料提供用電作息指標服務

Developing an Electricity Usage Pattern Indicator for Low-voltage Consumers Using AMI Data

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## 摘 要

隨著智慧型電表基礎建設(Advanced Metering Infrastructure, AMI)逐漸普及，掌握用電資訊的方式已不再受限於傳統電表。相較於傳統電表仰賴人工抄表，AMI 具有自動抄表功能，能夠精準紀錄即時用電資訊。此外，AMI 蒐集的用電資訊，亦可運用於提供各項 AMI 加值服務。根據內政部人口統計資料，台灣已邁入高齡化社會，若能有效運用低壓 AMI 資料於日常生活中，將有助於掌握高齡族群的居家生活。本文參考日本居家照護應用案例，務實運用低壓 AMI 資料設計台電專屬的「用電作息指標」。

## Abstract

With the progressive deployment of Advanced Metering Infrastructure (AMI), electricity consumption monitoring is no longer restricted to traditional meters. Unlike traditional meters that rely on manual readings, AMI features automated meter reading capabilities, allowing for the precise recording of real-time electricity consumption data. Furthermore, data collected by AMI can be leveraged to provide various value-added services. According to demographic data from the Ministry of the Interior, Taiwan has officially entered an aging society. Effectively utilizing low-voltage AMI data in daily life can help gain insights into the daily routines and living patterns of the elderly population. Drawing upon home care application cases from Japan, this paper practically designs a dedicated “Electricity Usage Pattern Indicator” tailored for Taipower by utilizing low-voltage AMI data.

**關鍵詞(Key Words)**：居家照護(Home Care System)、智慧型電表基礎建設 (Advanced Metering Infrastructure, AMI)、加值應用(Value-added Applications)、用電資料分析(Electricity Usage Data Analysis)、用電作息指標(Electricity Usage Pattern Indicator)。

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# 應用 AMI 大數據與人工智慧於村里層級用電型態分析及空調負載視覺化應用

Application of AMI Big Data and Artificial Intelligence to Village-Level Electricity Consumption Pattern Analysis and Air-Conditioning Load Visualization

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## 摘 要

隨著低壓 AMI 智慧電表布建增加，電力公司得以取得每 15 分鐘一筆之住宅用電資料，惟其具高頻率、大規模與時間序列特性，須經自動化處理與人工智慧分析，方能轉化為區處可運用之節能決策資訊。本文以「區域用電與預測冷氣資訊分析可視化應用平台」精進試驗為基礎，建立結合 Greenplum 大數據資料庫、Python 自動化 ETL、AMI 用電負載分群、空調用電解析及 Tableau Server 視覺化之應用架構。研究整合全國村里售電、所得、教育程度、婚姻狀態、年齡人口與 AMI 電表資料，將每 15 分鐘用電紀錄轉換為每日時間序列向量，進行分群與語意標籤化，並於村里層級推估總用電、空調用電及用電型態分布。成果可協助台電總處與各區營業處掌握轄內村里用電特徵，辨識具節電潛力區域，作為節能宣導、用電趨勢研判與區域能源管理之參考。

## Abstract

With the progressive deployment of low-voltage Advanced Metering Infrastructure (AMI) smart meters, electric utilities are now able to acquire residential electricity consumption data at 15-minute intervals. However, due to their high-frequency, large-scale, and time-series characteristics, such datasets require automated processing and artificial intelligence analytics to be transformed into actionable energy-saving decision-making information for regional offices. Based on the enhancement project of the Regional Electricity Consumption and Predictive Air-Conditioning Information Visualization Platform, this study establishes an integrated application framework comprising a Greenplum big data database, Python-based automated ETL processes, AMI load pattern clustering, air-conditioning load disaggregation, and Tableau Server visualization. The study integrates nationwide village-level electricity sales, household income, education level, marital status, demographic age distribution, and AMI meter data. Specifically, 15-minute consumption records are converted into daily time-series vectors for clustering and semantic labeling, enabling the estimation of village-level total electricity consumption, air-conditioning load, and consumption pattern distributions. These findings assist Taipower headquarters and regional offices in comprehending village-level electricity characteristics, identifying high energy-saving potential areas, and serving as a reliable reference for energy conservation campaigns, electricity trend forecasting, and regional energy management.

**關鍵詞(Key Words)**：智慧電表(Advanced Metering Infrastructure, AMI)、大數據分析(Big Data Analytics)、人工智慧(Artificial Intelligence, AI)、用電負載分群(Load Pattern Clustering)、空調用電解析(Air-Conditioning Load Disaggregation)、村里用電(Village-Level Electricity Consumption)。

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# 智慧電網結合 AMI 數據進行異常用電之可行性研究

Feasibility Study on Integrating Smart Grid with AMI Data for Detecting Abnormal Electricity Usage

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## 摘 要

配電系統的損失主要分為技術性損失及非技術性損失。其中非技術性損失中，由異常用電所造成的損失佔有很高的比例。現行異常用電之判斷作業，仍主要仰賴具備豐富經驗及專業知識的資深電務人員進行判讀。本研究以智慧型電表資訊建構結合分佈滯後模型(Distributed Lag Model, DLM)、KL 散度(Kullback-Leibler Divergence, KLD)、高斯混合模型(Gaussian Mixture Model, GMM)的複合偵測系統，利用人工智慧(Artificial Intelligence, AI)自我學習之特性自動判斷異常用電疑似程度，做為業務單位異常用電查核與排程之優先順序參考準則，協助集中人力資源於疑似異常用電的用戶群。

## Abstract

Power distribution system losses are primarily categorized into technical and non-technical ones. A significant portion of non-technical losses stems from abnormal electricity usage. Currently, the detection of such anomalies still relies heavily on the expertise and experience of senior power distribution personnel. To address this limitation, this study proposes an integrated detection system utilizing smart meter infrastructure (AMI) data, which combines the Distributed Lag Model (DLM), Kullback-Leibler Divergence (KLD), and Gaussian Mixture Model (GMM). Leveraging the self-learning capabilities of artificial intelligence (AI), the proposed system automatically evaluates the suspicion level of abnormal electricity usage. This serves as a reference criterion for business units to prioritize inspection and scheduling tasks, thereby helping concentrate human resources on consumer groups with a higher likelihood of anomalies.

**關鍵詞(Key Words)**：低壓用電數據(Low-voltage Data)、智慧電表基礎建設(Advanced Metering Infrastructure)、異常用電(Abnormal Electricity Usage)。

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# 住宅用戶用電拆解演算法之研究

A Study on Energy Disaggregation Algorithms for Residential Households

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## 摘　要

本研究以住宅用戶 AMI 資料為研究基礎，透過分析開票計費所使用之低頻用電資料進行非侵入式用電拆解分析，探討不同特徵萃取方法與機器學習模型在估測住宅電器用電占比上的表現，期望在模型效能與實際部署可行性間取得平衡。

研究方法上，以自願受試住宅之實測資料為基礎，針對適用之特徵萃取及用電拆解模型進行實驗，比較數種特徵萃取方法及迴歸分析演算法。實驗結果顯示，在特徵選擇方面，PCA 運算較快且於冬、夏兩季在多種電器皆有相當穩定的表現；LASSO 特徵組合在高耗電之冷氣用電占比估測上具有優勢。在用電拆解演算法比較上，lightGBM 無論冬夏季皆於最多電器項目中取得最低誤差，整體表現最佳。

## Abstract

Based on residential Advanced Metering Infrastructure (AMI) data, this study conducts non-intrusive energy disaggregation analysis using low-frequency electricity consumption data originally collected for billing purposes. By analyzing this aggregated data, the study investigates the performance of various feature extraction methods and machine learning models in estimating the electricity consumption shares of individual household appliances, aiming to strike a balance between model accuracy and practical applicability.

Methodologically, the study utilizes real-world measurement data collected from voluntary residential participants. Experiments were conducted to evaluate suitable feature extraction techniques and disaggregation models by comparing several feature extraction approaches and regression algorithms. The experimental results indicate that, in terms of feature extraction, Principal Component Analysis (PCA) not only achieves the fastest computational speed but also demonstrates stable performance across multiple appliances in both winter and summer. Besides, the LASSO-based feature set exhibits a distinct advantage in estimating the energy consumption share of air conditioning units. Regarding the comparison of disaggregation algorithms, LightGBM achieves the lowest estimation errors for the greatest number of appliances in both seasons, yielding the best overall performance.

**關鍵詞(Key Words)**：非侵入式負載監測(Non-intrusive Load Monitoring)、用電拆解(Energy Disaggregation)、特徵萃取(Feature Extraction)、智慧電表(Advanced Metering Infrastructure)。

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# AMI 於高壓用戶表後儲能建置潛力評估

Evaluating the Potential of Behind-the-Meter Energy Storage Deployment for High-voltage Consumers

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## 摘　要

為因應再生能源併網帶來的電力系統衝擊及政府推動表後儲能之政策，儲能系統已成為用戶節約電費的關鍵之一。然而，各產業用電特性不同，並非所有用戶皆適合建置儲能設備。為瞭解用戶設置儲能設備之潛力，本研究利用 AMI 數據，以經常契約容量達 800 kW 以上之高壓三段式時間電價用戶為對象，進行建置潛力評估。

本研究提出「有效尖離峰移轉指標」與「尖峰用電需求量指標」，前者評估用戶於離峰時段接受尖峰用電移轉的能力，後者則衡量其是否有實質的移轉需求。由分析結果顯示，綜合此兩項指標能有效鑑別各產業的儲能潛力，例如：零售業極具潛力，而鋼鐵業則較不適合。本研究成功透過設定指標閥值篩選出具建置潛力的目標客群，分析結果不僅可協助台電公司掌握產業潛勢，亦可作為政府未來精準投放儲能補助的重要參考依據。

## Abstract

While behind-the-meter (BTM) energy storage helps consumers reduce electricity costs amid power system impacts brought by renewable energy integration, their suitability varies significantly across different industries. To assess the deployment potential of such systems, this study analyzes Advanced Metering Infrastructure (AMI) data focusing on high-voltage, three-period time-of-use (TOU) consumers with a contracted capacity of no less than 800 kW. To achieve this, this study proposes two novel metrics: the Effective Peak-to-Off-Peak Shifting Index, which evaluates a consumer's capacity to shift peak electricity usage to off-peak periods, and the Peak Demand Index, which measures actual shifting requirements. The results demonstrate that combining these two indices effectively differentiates the storage potential among industries; for example, the retail sector exhibits high suitability, whereas the steel industry is less appropriate. By establishing specific index thresholds, this study successfully identifies high-potential target customer segments. These analytical results not only assist Taipower in comprehending industrial potential but also serve as a vital reference for the government in precisely allocating future energy storage subsidies.

**關鍵詞(Key Words)**：表後儲能 (Behind-the-Meter Energy Storage)、AMI 數據分析(AMI Data Analysis)、尖離峰移轉(Peak-to-Off-Peak Shifting)。

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# 整合性預測框架結合負載特徵集群方法研析

An Integrated Forecasting Framework Combined with a Load Feature Clustering Method for Low-voltage Regional Forecasting

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## 摘 要

隨智慧電表(AMI)布建的普及，15 分鐘高時間顆粒度資料，讓負載預測的分析應用範圍逐步展開。本文承襲既有之整合性預測框架，包含 ETL 資料清理程序與 FTSM 預測模型，旨在進行低壓區域範圍的高低峰用電時段預測與分析。藉由已開發之整合性預測框架延伸，考量預測結果有瓶頸的區域，結合集群方法和負載特徵指標的預處理流程篩選，目標在排除影響既有框架穩健性(Robustness)的可能，以期增加整合性預測框架的適用性。為提升既有框架之適用瓶頸，本文選用尖離峰用電比率作為單一特徵指標，透過精簡之集群(K=2)演算，將區域內特徵離群的用戶進行隔離。由集群後再執行預測的結果可看出，集群執行後的選用策略，與不進行篩選步驟的預測比較顯示，特徵離群的用戶確實可干擾建模的穩健性。

## Abstract

With the widespread deployment of Advance Metering Infrastructure (AMI), the availability of 15-minute high-granularity data has significantly broadened the scope of load forecasting applications. Building upon an existing integrated forecasting framework, which incorporates an ETL (Extract, Transform, Load) data cleaning procedure and an FTSM forecasting model, this study aims to predict and analyze peak and off-peak electricity consumption periods across low-voltage regions. To address performance bottlenecks encountered in certain areas, this study introduces a preprocessing filter that combines clustering methods with load characteristic indicators, aiming to eliminate factors that compromise the robustness of the existing framework and thereby enhance its applicability.

Specifically, this paper adopts the peak-to-off-peak electricity consumption ratio as a single feature metric. Through a simplified clustering algorithm (K=2), consumers exhibiting anomalous load characteristics within the region are isolated prior to modeling. The post-clustering forecasting results demonstrate that this screening strategy, when compared to direct forecasting without screening, effectively mitigates the interference of feature-outlier users, thereby substantiating their detrimental impact on modeling robustness.

**關鍵詞(Key Words)**：整合性預測框架(Integrated Forecasting Framework)、先進讀表基礎架構(Advanced Metering Infrastructure, AMI)、集群分析(Clustering)、負載曲線預測(Demand Curve Prediction)、資料探勘(Data Mining)。

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# 高壓用戶參與負載提升型需量反應潛力評估

Evaluating the Potential of High-voltage Consumers to Participate in Load-increasing Demand Response

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## 摘　要

隨著太陽光電近年來快速增加，再生能源高占比之情形衍生之淨負載曲線變化明顯，所謂之「鴨子曲線」型態已然出現。面對鴨子曲線，國內過往需量反應方案多以「抑低尖峰負載」來因應夜尖峰，需求面管理的需量反應中，除「抑低尖峰負載」外，亦有「提高離峰負載」、「轉移系統負載」等兩種模式。台電公司於 2025 年首度進行需求端的負載提升型需量反應試驗，本研究針對負載提升型需量反應，對高壓用戶進行執行潛力的評估。

## Abstract

Driven by the rapid growth of photovoltaic generation in recent years, high renewable energy penetration has significantly altered the net load profile, leading to the emergence of the “duck curve.” To address this phenomenon, demand response programs in Taiwan have traditionally focused on “peak load reduction” to mitigate evening peaks. Beyond peak shaving, demand-side management encompasses two additional operational modes: “off-peak load increasing” and “load shifting.” In 2025, Taipower launched its first pilot program for load-increasing demand response. This study evaluates the implementation potential of such programs among high-voltage consumers.

**關鍵詞(Key Words)**：需量反應(Demand Response)、再生能源高占比(High Renewable Penetration)、用戶潛力(User Potential)。

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# 再生能源導入下系統失載機率評估方法研析

A Study on Loss of Load Probability Evaluation Methods under Renewable Energy Integration

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## 摘　要

再生能源滲透率的提高，依國外的經驗將徹底改變系統負載曲線，即鴨子曲線將慢慢形成。為提早因應鴨子曲線形成後對台灣電力公司(下稱台電公司)的影響，及早了解未來電價的可能調整，有利台電公司研擬因應策略。

為符合電價設計的公平與效率原則，在火力機組發電的主要發電時段與準備時段逐漸轉變為淨負載時，如何合理評估失載機率及不同小時發電容量價值為本文重點。參考國外的發電容量價值評估過程，多採用統計趨勢分析與蒙地卡羅方法模擬。隨著我國智慧電表布建，已累積一定程度的資料可供分析使用，本文提出以機器學習的分析方法，結合國外失載機率的評估流程，建置發電端容量價值分配的評估流程。

## Abstract

The increasing penetration of renewable energy is expected to fundamentally reshape system load profiles, gradually leading to the emergence of the “duck curve,” as evidenced by international experiences. To proactively address the impacts of the duck curve on Taipower and anticipate future electricity tariff adjustments, it is vital to formulate effective response strategies.

To align with the principles of fairness and efficiency in electricity tariff design, as the primary generation and reserve periods of thermal power units progressively transition into net load periods, this study focuses on the rational evaluation of the Loss of Load Probability (LOLP) and the value of generation capacity at different hours. International methodologies for evaluating generation capacity value predominantly rely on statistical trend analysis and Monte Carlo simulations. Leveraging the extensive data accumulated from the deployment of smart meters in Taiwan, this paper proposes integrating machine learning analysis techniques with established international LOLP assessment frameworks to establish an evaluation process for allocating generation-side capacity values.

**關鍵詞(Key Words)**：鴨子曲線(Duck Curve)、失載機率(Loss of Load Probability, LOLP)、機器學習(Machine Learning)、電價設計(Rate Design)。

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# 新興表後儲能應用-先導技術驗證與需量反應方案

Emerging Behind-the-Meter Energy Storage Applications: Pilot Technology Verification and Demand Response Scheme

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## 摘 要

本研究針對台灣再生能源義務用戶以表後儲能參與需量反應方案進行先導實驗，驗證其技術可行性與執行成效。台灣自 2023 年起允許義務用戶以儲能設備履行再生能源義務，並設計需量反應回饋機制，為國內首次將表後儲能納入電業調度之需求面資源。本研究於方案正式實施前招募兩家大型義務用戶，其參與之儲能設備合計義務裝置容量達 1.7MW，進行 2 個月實驗，測試不同預告時間與充放電模式下之履約表現。結果顯示，連續製程產業放電執行率可達 95%，日間生產型企業則因夜間負載較低，執行率為 76%，顯示執行率受用電特性影響；兩用戶對月前、週前及小時前通知之反應並無顯著差異，充電指令執行率亦與放電相當，可為向上需量反應之開發提供依據。經濟性方面，本研究就設置再生能源、購買憑證、設置儲能及繳交代金四種法定履行方式進行成本效益比較，結果顯示對缺乏設置再生能源用地、且用電型態適配批次生產時間電價之用戶，儲能於計入契約容量抑低效益後具經濟優勢，並推得回饋機制之選擇臨界約為義務裝置容量之 1.39 倍。研究另盤點設備認證、AMI 計量與資源競合等制度障礙。作為表後儲能參與電力市場之起點，建議持續強化參與誘因，並研議資源競合規範之彈性化，以發揮表後儲能於能源轉型之關鍵作用。

## Abstract

This study conducts a pilot experiment on behind-the-meter (BTM) energy storage for renewable energy-obligated users in Taiwan, validating its technical feasibility and operational effectiveness. Taiwan has permitted obligated users to fulfill their renewable energy obligations using energy storage equipment since 2023, introducing a demand response incentive mechanism that marks Taiwan's first integration of BTM storage into electric utility dispatch as a demand-side resource. Prior to the formal implementation of the scheme, two large obligated users with a combined obligated capacity of 1.7 MW participated in a two-month pilot to test compliance performance under various notice lead times and charge-discharge modes. The results show that the continuous-process industry achieved a discharge execution rate of 95%, whereas the daytime-production enterprise achieved 76% due to lower nighttime loads, indicating that execution rates are influenced by electricity consumption characteristics. Both users exhibited no significant differences in response to month-ahead, week-ahead, and hour-ahead notifications, and charging execution rates were comparable to discharging rates, providing a foundation for developing upward demand response. Regarding economic viability, this study compared the cost-effectiveness of four statutory compliance options: installing renewable energy, purchasing certificates, deploying energy storage, and paying a substitution fee. The results demonstrate that for users lacking land for renewable energy installation whose load profiles align with batch-production time-of-use tariffs, energy storage holds an economic advantage once contract capacity reduction benefits are factored in, with the threshold ratio for selecting the incentive mechanism estimated at approximately 1.39 times the obligated capacity. The study also identifies institutional barriers, including equipment certification, AMI metering, and resource competition. As a starting point for BTM storage participation in the power market, it is recommended to continuously strengthen participation incentives and deliberate on the flexibility of resource competition regulations to maximize the critical role of BTM storage in the energy transition.

**關鍵詞(Key Words)**：表後儲能(Behind-the-Meter Energy Storage)、需量反應(Demand Response)、再生能源義務(Renewable Energy Obligations)、彈性(Flexibility)。

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# 台灣電動小客車 V2X 商業模式與成本效益分析

V2X Business Models and Cost-Effectiveness Analysis of Electric Passenger Vehicles in Taiwan

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## 摘　要

本文以成本有效性分析評估台灣電動小客車在 V2X 商業模式下之經濟可行性。商業模式主要以建築物為主體之家戶 V2H/V2G 模式進行探討，比較其相對於 V1G 智慧充電「基準情境」之新增成本與效益。成本面納入電動小客車購置成本與壽命縮短造成之年均折舊差額，以及家用與商用充電樁由 V1G 升級為 V2X 的相關費用；效益面則考量在電動車充換電設施電價方案下之尖離峰移轉效益及參與輔助服務獲得容量費之分潤收益。實證分析包含上述情境與基準情境之年均化成本與效益之相互比較，並進行敏感度分析。最後提出政策建議與未來研究之方向。

## Abstract

This article evaluates the economic feasibility of vehicle-to-everything (V2X) business models for electric passenger vehicles in Taiwan using a cost-effectiveness analysis framework. The study primarily investigates building-centric household V2H/V2G models, comparing their incremental costs and benefits relative to a V1G smart charging “baseline scenario.” On the cost side, the framework incorporates the purchase costs of electric passenger vehicles, the annualized depreciation difference caused by shortened vehicle lifespans, and the expenses required to upgrade household and commercial chargers from V1G to V2X. On the benefit side, it considers peak-to-off-peak load shifting benefits under electricity tariff schemes for EV charging facilities, as well as capacity revenues earned through participation in ancillary services. The empirical analysis compares the annualized costs and benefits between the aforementioned V2X scenarios and the baseline scenario, followed by a sensitivity analysis. Finally, policy recommendations and future research directions are proposed.

**關鍵詞(Key Words)**：電動小客車(Electric Passenger Vehicles)、電動車雙向充放電技術(Vehicle-to-Everything, V2X)、成本效益分析(Cost-Effectiveness Analysis)。

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