台電工程月刊 856 期（12 月號）目錄

智慧電網之互通性研究與應用　專輯

由分散式電源整合調控互通性協定談用戶側能源互聯網

A Discussion of Demand-side Energy Internet from the Perspective of Integrated Operation Interoperability Protocols for Distributed Energy Resources (DERs)

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摘　要

本文首先探討國內 2025 年風、光發電高佔比造成電力網之運轉困難。再聚焦於用戶側，由經濟部標準檢驗局所發展的三項互通性協定之使用案例，探討用戶側解決方案。三項互通性協定為：(1)應用 OpenADR 整合調控自動需量反應空調卸載與用戶側 DERs 逆送電至市電網之使用案例；(2)設計 OpenADR / IEC 61850-8-2 之用戶側微網資訊轉換介面標準俾與台電公司的控制中心相介接；(3)探討 Wi-SUN 於 B 路徑（智慧電表至智慧家庭（或智慧建築）能源管理系統）之使用與測試案例，俾符合國內「國家通訊委員會」之屬地要求。最後，分析這些用戶側 DERs 的整合調控體系因應 2025 年高風、光發電滲透率挑戰的不足之處，進一步探討用戶側能源互聯網的設計理念並建議國內的發展重點。

Abstract

This paper evaluates operation difficulties caused by high penetration of wind / solar renewable energy (RE) productions that the power system might encounter in year 2025. The paper then reviews three studies on the demand-side protocol of power utility, conducted by the Bureau of Standards, Metrology and Inspections (BSMI): (1) The use cases of applying OpenADR to integrated operation of the ADR (automated demand response), on air-conditioning (AC) load, and the DERs, both of demand-side microgrids; (2) The OpenADR / IEC 61850-8-2 data conversion standards designed for the reverse power (RP) operation of demand-side microgrids by resource aggregators (RAs) to fulfill Taipower's interoperability requirement; (3) The Wi-SUN use cases of B-route (between smart meters and smart home/building energy management system, HEMS/BEMS) to meet the NCC (National Communications Commission) requirement. In the final part of this paper, we evaluate the deficiency of these demand-side DERs and ADR protocols when dealing with high-penetration of RE in 2025. Based on the evaluation results, we then investigate the design concept of demand-side energy internet (EI) and make suggestions on the future development of demand-side EI in Taiwan.

關鍵詞(Key Words)：分散式電源 (Distributed Energy Resources)、自動需量反應 (Automated Demand Response)、用戶群代表 (Resource Aggregator)、能源互聯網 (Energy Internet)。

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智慧電網架構模型研究與應用

Research and Application of Smart Grid Architecture Model

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摘　要

當今電力系統的主要挑戰之一是可再生能源與分散式能源的整合。由於這些分散式能源(DER)的易變性與分散性，需要複雜的雙向電源管理以達到發電端與負載端之間的平衡。為了滿足這些分散式能源的快速成長，電力系統必須轉變為智慧電網，並且需要發展智慧電網架構模型(SGAM)，因此，需要一種工具與分析方法來做支撐。本篇論文採用參考架構模型來分析 SGAM 的互操作性，提出一個應用案例並分析 SGAM 中的五個互操作性層，未來研究與改善可與其他領域專家協作，透過 SGAM 來進行更多智慧電網情境與應用案例研析。

Abstract

One of the major challenges in today's electric power system is the integration of renewable and distributed energy resources(DER). Due to the volatile behaviors and the decentralized locations of these distributed energy resources, a complicated administration of bidirectional energy flows is necessary to balance generation and consumption. In order to meet the rapid growth of these DER, the power system needs to transform into a Smart Grid and a Smart Grid Architecture Model (SGAM) needs to be developed. Therefore, proper tools and analytical methods are essential to support the development. This paper adopts the reference architecture model to analyze the interoperability of the SGAM. A use case is conducted and five interoperability layers in the SGAM are analyzed. Cooperating with other domain experts, we'll carry out future study and make improvements, and then determine more Smart Grid scenarios and use cases by adopting SGAM.

關鍵詞(Key Words)：分散式能源(DER)、智慧電網(Smart Grid)、IEC 61850、互操作性(Interoperability)、智慧電網架構模型(SGAM)。

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再生能源之互通性研發與應用
─民營再生能源發電即時資訊平台示範應用案例

R&D and Application of Interoperability for Renewable Energy ─ A Case Study of Real-time Information System for Private Renewable Facilities

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摘　要

為準確掌握民營太陽光電電廠之即時發電量，本文中規劃以引接建置民營太陽光電電廠即時發電量資訊，及自主建置發電資訊收集系統方式，示範及評估適合之方案。最終完成引接 100 座以上民營太陽光電電廠之即時發電量監控資訊，並建置一套再生能源即時發電資訊系統(Green energy Estimate Monitor System, GEMS)。該系統中包括一套基於距離反比加權法 (Inverse Distance Weighting, IDW) upscaling 之發電量推估模型，該模型利用已監控電廠為基礎推估鄰近未監控電廠之發電量。此模型的 RMSE 為 0.042 kW/kWp，而平均月推估真實發電量比則為 89.22%，具有一定的參考價值。然而，為求進一步提升對民營太陽光電電廠之即時發電量的掌握，應將再生能源即時監測納入法規。

Abstract

In order to capture the real-time generation data of private PV plants, this paper builds a demonstrative infrastructure to collect and transmit PV data. The real-time generation data collected from more than 100 PV plants have been integrated into this infrastructure. An estimating model based on IDW upscaling method has also been implemented. The model estimates the power generation of unmonitored plants by using the data from nearby monitored plants. The RMSE of the model is 0.042 kW/kWp, and the ratio of monthly estimated energy generation to the reference data is 89.22%. Furthermore, we give some suggestions for amending the renewable energy regulations.

關鍵詞(Key Words)：再生能源(Renewable Energy)、太陽光電系統(Photovoltaic System)、調度中心(Control Cente)、區域發電量推估(Estimate of Regional Power Generation)、距離反比加權法(Inverse Distance Weighting, IDW)、IEC 61850。

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分散式能源之互通性研究與探討

A Study and Discussion on Interconnection of Distributed Energy Resources

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摘 要

分散式能源(Distributed Energy Resource, DER)，乃利用電網連接多種小型發電和儲能設備的技術與系統。然而，與分散式發電相對的集中式發電，如傳統發電廠的燃煤，天然氣，核電，水力發電等大型發電廠，通常需要將電廠產生電力透過輸電線纜進行長距離傳輸至用戶端。相較之下，分散式發電系統是區域型的、分散的、模組化且更具靈活運用的發電技術。發電設備所在位置相較之下更接近負載端，因此可減少輸電時產生的線損，更加優化能源使用效率。

本文介紹分散式能源整合發展的要素，亦為智慧電網成功的要件之一－資訊的互通性(Interconnection)。透過國際電工委員會(International Electrotechnical Commission, IEC)所制定的IEC 61850 國際標準，將各種常見的分散式能源資料自源頭端進行標準化(Standardization)，以利未來分散式能源管理系統(Distributed Energy Resource Management System, DERMS)進行資料收集與即時調度。

Abstract

Distributed Energy Resource (DER) is a technology and power system using grid to connect a variety of small power generations and energy storage equipment. Unlike distributed power generations, centralized generation, such as coal-fired, gas-fired, nuclear, hydro and other large traditional power plants, usually transmits the power generated over long distance to the load through transmission lines. In contrast, distributed power generation is a regional, decentralized, modular and more flexible power generation technology. Since DER is located close to the load side, thus the transmission line losses could be reduced and energy efficiency could be optimized.

This paper introduces an important element of DER integration development - information interconnection, which is also one of the keys to the success of Smart Grid. Through the international standard IEC 61850 established by the International Electrotechnical Commission (IEC), all kinds of common DER data are standardized at the source so as to facilitate the data collection and real-time dispatch performed by Distributed Energy Resource Management System (DERMS) in the future.

關鍵詞 (Key Words)：分散式能源(DER)、智慧電網(Smart Grid)、微電網(Microgrid)、IEC 61850、互通性(Interconnection)。

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IEC 61850 中故障錄波的應用

Disturbance Recorder Implementation in IEC 61850

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摘　要

目前數位式電驛已普遍使用 IEC 61850 協定來進行故障記錄、保護和控制(以及電驛之間直接交換重要數據)進而提升可靠度和衍生出新的應用。在過去，在變電站自動化中使用 GOOSE 信息僅限於保護跳脫方案、觸發故障錄波器，並為開關聯鎖提供開關位置指示。眾所周知，故障錄波器(DFR)可以提供關鍵的電力系統狀態。信息，包括故障記錄、擺動記錄、事件捕獲和開關設備狀態。在現代已使用 IEC 61850 標準集成的變電站，保護裝置發布保護跳脫事件到變電站中裝設 IED 的區域網路(LAN)；DFR 可以訂閱這些消息或命令來觸發適當的渠道(保存未來擴展評估所需的信息)。換句話說，保護電驛和記錄器應持續通信，使用 GOOSE 信息跟踪電力系統在故障和正常情況下的系統行為。本文闡述了互操作性原則，並討論了 DFR 應用於 IEC 61850 的優點。本文描述了由數位式電驛測試設備模擬出了多功能線路保護繼電器保護功能相關的 GOOSE 實時信息。並使用了兩個不同的電驛供應商來確認 GOOSE 的互操作性可以觸發 DFR，再利用 DFR 記錄來做整個系統的事故後分析。

Abstract

Today digital IEDs using IEC 61850 protocol for fault recording, protection and control (and the exchange of critical data between them) are gaining acceptance and bringing about new applications. In the past, the use of GOOSE messages for substation automation was limited to tripping schemes, triggering disturbance recorders and providing position indication for interlocking. It is known that disturbance fault recorders (DFRs) can provide crucial power system status information, including fault records, swing records, event capture, and switchgear status. In modern power substations that have been integrated using IEC 61850 standard, protective devices publish tripping events to the LAN; DFRs can subscribe to those messages or commands to trigger the appropriate channels (to save the information needed for future extended evaluation). In other words, relays and recorders should continuously communicate, using GOOSE messages to track power system behavior in both fault and normal conditions. This paper explains interoperability principles and discusses the benefits of IEC 61850 applications with DFRs. It describes real time simulations that use relay testing equipment to generate GOOSE messages associated with the protection functions of a multifunctional line protection relay. Protective devices trigger the DFRs, capturing the records for post-event analysis of the overall system. Interoperability is verified by using relays provided by two different suppliers.

關鍵詞(Key Words)：IEC 61850、故障錄波器(Digital Fault Recorder)、類比取樣值(Sampled Values)、互通性(Interoperability)。

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智慧電網下 CIM 之互通性研究與應用

The Study and Application of CIM for Smart Grid

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摘　要

因應智慧電網的發展需求，IEC 建立了電力系統管理與資訊交換之參考架構，並且依據發電、輸電、配電、分散式能源、用戶等不同面向以及程序、場域、變電所、操作、企業、市場等不同層級建立各式標準。在所有標準中，IEC 61850 為新一代電能監控技術標準文件、CIM 則作為各電力系統之資訊模型及互相交換資訊的標準。本文將說明這兩部分標準的資訊模型並且介紹中間的轉換方式。

Abstract

In response to the development needs of the smart grid, IEC has established a reference architecture for power system management and information exchange. Various standards are established based on not only different aspects of power generation, transmission, distribution, decentralized energy, users, but also different levels of procedures, fields, substations, operations, enterprises, market. Among all the standards, IEC 61850 is the standard document for the new generation power monitoring technology, and CIM is used as the information model for each power system and the standard for information exchange. This article will explain the information models and harmonization of these two standards.

關鍵詞(Key Words)：共同資訊模型(Common Information Model)、智慧電網(Smart Grid)。

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智慧電網與市場公平性議題

Market Fairness Issues for Smart Grids

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摘　要

由於電力具有即時平衡的特性，所以電業自由化最重要的項目之一，即是『彰顯每度電的即時價值』。故智慧電網所特有的即時調度、即時計量、即時告知，就成為自由化中最是關鍵的一部分。但其在電業自由化國家也因而衍生出(1)動態定價之用戶選擇、(2)智網投資費用之分攤及(3)網路資訊安全之疑慮等公平性問題。在台灣則因為市場制度設計的特殊性，更增加了特有的(1)用戶資訊壟斷與(2)自動化決策依據兩項可能影響市場力大小之疑慮。

Abstract

The most important task for the liberalization of the electricity industry is to "show the real-time value of electricity." Therefore, operations specific to smart grid such like real-time dispatch, real-time metering, and real-time notification become the key factors to the success of liberalization. Some fairness issues , as a result, have emerged: (1) user selection of dynamic pricing, (2) allocation of smart grid investment costs, and (3) concerns about network information security. In Taiwan, the uniqueness of market design gives rise to additional factors that may affect the market power: (1) user information monopoly and (2) the basis of automated decision-making.

關鍵詞(Key Words)：智慧電網(Smart Grids) 、自由化(Liberalization)、動態電價(Dynamic Electricity Price)。

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智慧電網互通性之資訊安全研究與應用

A Study on Information Security and Applications of Smart Grid Interoperability

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摘 要

智慧電網乃是未來電網之趨勢，但是隨著現有電網加入網路通訊能力之後，伴隨而來對於資訊安全的擔憂則是無法避免的議題。因為智慧電網為關鍵基礎設施當中最重要之一環，緊緊地與國防與民生聯結，因此中興大學資通安全研究與教學中心(Taiwan Information Security Center，簡稱TWISC@NCHU)於2005年4月正式成立，主要整合進行智慧電網資訊安全之研究。本文將著重在TWISC@NCHU對於智慧電網資訊安全四個議題之研究與開發；分別為「安全遠端韌體更新機制設計」、「智慧電表IEC 62056第8版標準的加密機制與驗證模組開發」、「智慧電表之旁通道攻擊抵禦能力分析」、「再生能源資訊安全監控」，並且簡述TWISC@NCHU對這些議題進行開發的結果。

Abstract

Smart grids, the power grids equipped with networking capability, are gaining popularity. Since smart grid plays a key role in critical infrastructure, the information security becomes the most important issue. Taiwan Information Security Center at National Chung Hsing University (TWISC@NCHU) established in 2005 has being focusing on the research and development of information security mechanisms in smart grids. In this article, we describe four specific topics addressed by TWISC@NCHU, which are (1) secure remote firmware update, (2) IEC 62056v8-compliant crypto module design, (3) defense capability of smart meter against side channel attacks, and (4) information security montoring for renewable energy .

關鍵詞(Key Words)：韌體更新(Firmware Update)、物聯網(Internet of Things)、加密(Cryptography)、完整性(Integrity)、IEC 62056、ECDSA with P-256、ECDH with P-256、智慧電表(Smart Meter)、旁通道攻擊(Side-channel-attack)、隱藏(Hiding)、掩碼(Masking)、滲透測試(Penetration Test)、弱點掃描(Vulnerability Scanning)、再生能源系統(Renewable Energy System)。

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歐洲智慧電網互通性之發展與應用

A Study of Development and Application of Smart Grid Interoperability in Europe

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摘　要

本文介紹歐洲之能源服務開放系統(Open System for Energy Services, OS4ES)計畫，其如何針對智慧電網的需求，提出一個能源服務互通性之方案，讓分散式能源和電網營運者間相互作用時，擁有一個共通資訊模型，可使分散式能源併網時，能有統一溝通的介面。其從最原始的需求制定了 13 項使用案例；也使用了符合分散式能源及智慧電網參與者使用情境之架構；接著根據架構及使用案例的需求，使用了能兼容於 IEC 61850 之 XMPP 中介軟體；最後透過了實驗室及場域進行了系統整合測試。藉由探討歐洲於能源服務應用之解決方案，提供國內未來相關發展之參考。

Abstract

The purpose of this article is to introduce the project of Open System for Energy Services (OS4ES) in the Europe. According to the requirement of the Smart Grid, a solution of interoperability of energy services was proposed. There would be a common information model to let the DER systems and the Smart Grid Actors share the same interface while communicating with each other. The project defined 13 use cases. It used the architecture which is suitable for the DER systems and the Smart Grid Actors. According to the use cases and architecture, the XMPP middleware, which is compatible with IEC 61850, was used. Finally, lab test and field test were conducted for system integration testing. The solution of energy service applications in Europe would be a good reference for developing the energy services in Taiwan.

關鍵詞(Key Words)：智慧電網(Smart Grid)、能源服務開放系統(Open System for Energy Services, OS4ES)、分散式能源(Distributed Energy Resources, DER)、IEC 61850。

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智慧電網互通性標準之測試與驗證

Testing and Certification for Smart Grid Interoperability

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摘　要

智慧電網透過通訊傳遞相關電力資訊並加上智慧化的控管來使電力調度、電力資訊揭露、電力系統保護、…等實務與應用都能更加地自動化與智慧化。智慧電網內亦有各式各樣的通訊技術，電網內各式裝置藉由選定的通訊技術傳遞資訊，即使資訊傳送的兩端選用相同的通訊，但可能因為裝置設備的製造商不同，設計作法不同導致通訊兩端設備的資料無法相互溝通，即所謂的互通性問題。

在本文，將針對智慧電網內幾種國內常用或趨勢的通訊技術如 G3-PLC、OpenADR 與 IEC 61850，就通訊互通性的角度介紹與探討相關測試與驗證。

Abstract

The smart grid transmits power information through communication facilities, and achieve automation and intelligence of power dispatching, power information disclosure, power system protection through intelligent control. A variety of communication technologies are applied to the smart grid. The various devices in the power grid transmit information by way of selected communication technologies. Even though the same communication standard is used at both ends of the information transmission, they may not be able to communicate due to different manufacturers' different design . Problems like this are called 'interoperability' problems.

In this paper, focusing on several common or trendy communication technologies such as G3-PLC, OpenADR and IEC 61850 employed in the smart grid, we will introduce and discuss related tests and certifications from the perspective of interoperability.

關鍵詞(Key Words)：智慧電網(Smart Grid)、互通性(Interoperability)、G3-PLC(G3-PLC)、OpenADR(OpenADR)、IEC 61850(IEC 61850)。

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