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# 應用 XR 技術於變電所教育訓練之研究

A Research on Applying the Extended Reality Technology in Substation Education and Training

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## 摘要

為了改善傳統課程的訓練形式與面對即將來臨的退休潮，擬為新進人員導入新興互動科技，並計劃在變電站中實現 AR / VR / MR 技術。XR 技術能設計出有效的教育應用，有完整的結構與有脈絡的教材，可以增強台電人員的工作經驗，並幫助維護人員熟悉操作變電站設備，例如：電力變壓器，開關裝置等。

AR 擴增實境研究，針對「開關箱」教育訓練的流程，將其改造為可視化互動式教材內容。VR 虛擬實境研究模擬 1:1 二次變電所的場域，透過不同情境讓使用者在安全的環境中，不斷練習、熟悉變電站設備操作。MR 混合實境研究開發 GIS 開關箱電驛輔助操作系統，並以語音控制執行 MR 互動。

透過 AR 雲端平台架設互動式教育訓練課程，搭配 VR 操作教育訓練與 MR 輔助操作系統，以有效的系統設計，整合前後台數據分析，將訓練結果提供給訓練者與長官進行教育訓練成效的評估。

## Abstract

To enhance the learning efficiency of substation training, we introduce the latest technologies such as Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) technologies to remedy the drawbacks of traditional substation training. The Extended Reality (XR) makes maintenance personnel familiar with substation equipment, such as Gas Insulated Switchgear (GIS), Intelligent Electronic Device (IED), Gas Circuit Breaker (GCB) and Circuit Breaker (CB) more easily. As for the AR, operation procedures of 23 kV Gas Insulated Switchgear (GIS) were transformed into an interactive textbook for the purposes of education and training. And the VR, a realistic one to one scale virtual reality secondary substation was constructed. With the aid of diverse scenarios, the users may practice and get themselves familiar with the operation of substation equipment in a safer environment. The MR, we developed an interaction-assistive operation system with voice control for GIS IED protective relay. The results of the said XR education and training courses, AR textbook, VR system and MR interaction-assistive operation system may very well be used to evaluate the training effectiveness.

**關鍵詞 (Key Words)**：擴增實境(Augmented Reality)、虛擬實境(Virtual Reality)、混合實境(Mixed Reality)、變電所(Substation)、氣體絕緣開關(Gas Insulated Switchgear)、智慧型電子裝置(Intelligent Electronic Device)。

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# IEC 61850 變電所互操作性試驗平台建置研究

A Research on Establishing IEC 61850 Based Substation Interoperability Test Platform

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## 摘要

台電公司致力推動並導入 IEC 61850 國際標準，希望藉由整合通訊介面與通訊協定提升調度之靈活性。變電所可比整體電網之神經，負責傳送來自各地之發電資訊，同時扮演溝通協調的角色。變電所內之智慧電子裝置(Intelligent Electronic Device, IED)除負責系統保護外，尚可提供設備狀態監測相關功能。然而過去因各家廠牌 IED 所採用的資料模型不一致造成系統整合困難，IEC 61850 標準的制定即為統一變電所內設備之資料模型，使不同設備間具有互操作性(Interoperability)。為確保變電所內數據採集與監控系統(SCADA)與 IED 後續擴充及維護上可正確互通，本研究建立一套基於 IEC 61850 標準的互操作性測試平台，並針對 SCADA 與 IED 進行各項通訊測試。

## Abstract

Taiwan Power Company is committed to promoting and implementing IEC 61850, an international standard defining communication protocols for intelligent electronic devices for the improvement of dispatching flexibility. As the role of central nervous system (CNS) of power grids, substations are in charge of transmitting, communicating and coordinating the information of power flows. Intelligent electronic devices at substations provide two key functions-system protection and equipment condition monitoring. However, restricted by the inconsistency of data model due to different IED brands, the tasks of system integration had been quite difficult in the past. Therefore IEC 61850 emerges to unify different data models and enable interoperability between devices. This study aims to establish an IEC 61850 based test platform for communication tests to ensure the interoperability and subsequent expansion and maintenance of SCADA and IED communication.

**關鍵詞 (Key Words)**：智慧電子裝置(IED)、數據採集與監控系統(SCADA)、IEC 61850、互操作性(Interoperability)。

# 智慧電網 IEC 61850 資通訊架構應用於水力發電系統之研究

A Study on Smart Grid IEC 61850 Information and Communication Structure to be Applied to Hydroelectric Power System

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## 摘要

依據國際電工委員會 IEC TC57 定義有關智慧電網資通訊核心標準中，IEC 61850 應用於電力自動化各領域，透過將現場電力相關資通訊介面標準化，期望打造 OT/IT 資訊互通的情境，以實現未來智慧電網應用所需之資通訊基礎建設。目前國內變電所正逐步規劃改建為新一代 IEC 61850 變電所，而發電領域尚未實現 IEC 61850 之架構，本研究係針對水力發電廠之各系統、各主要功能及參數，進行 IEC 61850 資料建模，同時建立通訊連線測試，下一步我們將持續擴充其功能模擬、控制及應用測試，以提供未來建置 IEC 61850 先導型水力發電廠之參考，並接軌未來智慧電網之應用。

## Abstract

IEC 61850 suits for various fields of power automation-according to the definition of International Electrotechnical Commission (IEC) TC57- the information and communication core standards for Smart Grid. With the aid of the standardization of on-site power-related information and communication interfaces, this study looks forward to developing an accessible OT/IT information context to realize the information and communication infrastructure supporting future smart grid applications. The substations in Taiwan have phased in IEC 61850, when the power plants have not yet begun. This study aims to incorporate IEC 61850 data modeling and communication connection testing into the subsystems, main functions and parameters of hydroelectric power plants. We will continue expanding functional simulation, control and application test to provide a reference for the construction of IEC 61850 pilot hydroelectric power plants to fulfill the future smart grid applications.

**關鍵詞 (Key Words):** IEC 61850、水力發電廠(Hydroelectric Power Plant)、壓油系統(High Pressure Oil System)、資料模型(Data Model)、智慧電子裝置(IED)。

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# 智慧電網關鍵通訊技術探討

## The Key Communication Technologies for Smart Grid

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### 摘要

本文以目前電力資料傳輸時延(Latency)角度，分類系統時延需求：資料回收如(AMI)、電力調度如(SCADA)、電力保護如(RTU)等，討論現階段 3GPP R15 之 5G 無線技術標準下之將來技術如何達成智慧電網整體協調運作情境，並討論通信領域台電未來可規劃導入的技術，及未來智慧電網的無線通信技術挑戰。

### Abstract

When importing up-and-coming ICT technologies, such as 5G formulated by 3GPP into traditional power system, the power system is confronted with critical integration problems regarding power dispatching. From the viewpoint of transmission latency, this paper discusses the future smart grid application demand, such as AMI、SCADA、RTU, etc. The system architecture is classified into three categories to meet the future needs of smart-grid operation.

**關鍵詞 (Key Words)：** 第5代行動通訊技術(5G)、智慧電網(Smart Grid)、延遲時間(Latency)、網路切片(Network Slice)、第三代合作夥伴計劃(3GPP)、IEC 61850。

# 5G 企業專網新契機-從產業與政策解析電信管理法時代 下之電力事業因應策略

The Opportunities of 5G Private Networks and Electric Utilities' Coping Strategies

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## 摘要

對電力事業而言，5G 網路能帶來之效益與應用範圍廣泛。以電表為例，5G 網路的巨量設備連線特性可有效滿足大規模設備讀表需求，高可靠度與低延遲通訊則有助於電力事業之配電自動化與負載管理。藉由 5G 網路之邊際運算與數據分析能力，有助於電力事業掌握用戶用電需求，即時回應所需，甚至作為後續建構企業數位轉型策略之參考依據。本研究蒐集國際間數個電力事業運用 5G 網路之案例，再透過分析我國電信管理法與 5G 專網頻譜政策，研議電力事業可採行之因應策略。儘管 5G 網路帶來之特性可滿足不同產業需求，然應就電力事業對 5G 網路之應用規劃，透過盤點使用需求、小規模實驗與多廠區驗證後，評估整體成本效益，供電力事業擬定適合因應策略之參據。

## Abstract

For electric utilities, the 5th generation mobile networks (5G) stand for substantial benefit and extensive applications. In this research, we analyze a number of worldwide electric utility cases which have applied 5G network, use the obtained information to analyze the regulations of private networks and spectrum policy in Taiwan, and put forward our recommendations of the coping strategies for electric utilities. Despite 5G network can meet the needs of different industries, electric utilities before developing coping strategies suitable for them, shall pre-examine their own needs, and assess the overall cost effectiveness to serve as reference with the aid of small-scale experiments and multi-plant verification.

**關鍵詞 (Key Words) :** 5G垂直應用場域(5G Vertical Application)、5G專網(5G Private Network)、智慧電網(Smart Grid)。

# 剖析 5G 專網部署與工控資安之技術

The Analysis of 5G Private Network Deployment and Industrial Control System Security

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## 摘要

5G 提供更快傳輸速率(10Gbps)，低網路時延(1ms)，更大的連接數(1000K)，並與人工智慧、大資料、雲端計算緊密結合，開啟萬物互聯的時代。5G 專用網路部署可以由企業或行動運營商可以建立專用的 5G 網路。另外可以通過共享行動運營商的公眾 5G 網路資源來建構私有 5G 網路。現今因應智慧化生產管理、設備即時監測等需求，大量進行雲端與實體設備間的虛實整合，產線各環節彼此互通聯網，帶來極大的便利性，卻也讓多元化的網路攻擊、惡意軟體滲透等成為日益嚴重的問題。所以工控資安技術需要針對智慧製造系統作異常行為分析並強化智慧製造設施的自我保護能力，保護資料與設施管控安全。透過資安聯防，提供威脅預警、潛伏發掘及應變復原，確保設施正常運作。

## Abstract

5G provides faster transmission rate (10Gbps), lower latency (1ms), and massive connections (1000K). When integrated with artificial intelligence, big data, and cloud computing, 5G opens a new era of internet of everything. The deployment of private 5G network may be established by enterprises/mobile operators and constructed by shared public 5G network resources of mobile operators. To respond to the needs of smart factory and real-time equipment monitoring among others, Cyber-Physical Systems have nowadays been integrated with cloud and physical equipment. Production lines connected to each other not only brings about great convenience but also growing problems of network attacks and malware. The security of industrial control systems relies on the analysis of abnormal behavior of smart manufacturing systems and the strengthening of self-protection capabilities of smart manufacturing facilities. In short, information security joint defense, threat warning, latent discovery and response recovery all together are the key to ensure normal facility operation.

**關鍵詞 (Key Words) :** 5G專網 (5G private network)、AI 網宇實體系統(Cyber-Physical System Artificial Intelligence)、雲端計算(Cloud Computing)、工控資安( Industrial Control System Security)。

# 5G 挑戰與測試

## The Challenges and Testing of 5G

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### 摘要

5G NR (New Radio)標準初始版本於 2017 年 12 月於 3GPP 第 15 版規格發佈，第 16 版本更定義 URLLC 增強版、節省功耗、車聯網與未許可頻譜應用修訂，到目前第 17 版本針對未來可能應用做加強，例如 NR MIMO、更高頻譜或動態頻譜分享加強、NR 鄰近連結應用、NR 在工業物聯網 URLLC 應用與 NR 在非地面通訊網路，5G 已真真實實的開始應用在各個領域。這篇文章我們將針對 5G 的特性，以測試角度來探討面臨的挑戰。

### Abstract

The initial version of 5G NR (New Radio) standard, a.k.a the 3GPP Release 15, was released in December 2017. In Release 16, more specifications, such as the enhanced version of URLLC, power saving, connected car and unlicensed spectrum applications, had been defined. But only up to the current Release 17, 5G has truly started to be applied in various fields, with the aid of enhancements for future applications, e.g. NR MIMO, higher frequency, dynamic spectrum sharing enhancement, NR sidelink, URLLC for industrial IoT over NR, NR support over non-terrestrial networks. This article aims to introduce the characteristics of 5G and the challenges of its testing.

**關鍵詞 (Key Words)**：NR (New Radio)、超可靠低延遲通訊 URLLC(Ultra-reliable Low-latency Communications)、第三代合作夥伴計劃 3GPP(3rd Generation Partnership Project)。

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# 電力物聯網收發量測技術研討

A Study on the Measuring Technologies of IoT Devices Applied to Power Grid

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## 摘要

由於政府積極推動能源的多樣性發展，並配合智慧電網基礎建設的建置，希望能將能源做最有效的應用，並提升電力調度供需效率。未來想達成效率的提升，區域內相關設備與電網運轉資料即時控管分析就成為很重要的課題，而裝置本身無線化介面就成為電力設施不可或缺一環。在企業專網的頻段(如 4.8-4.9GHz)甚至更高頻段(28GHz)以上開發無線設備以提供資料傳輸，便成為不可或缺的關鍵技術。

本次將模擬本公司設備間的資料即時無線傳輸可行性，提升未來電網及無線化電力設備的資訊收集的硬體測項，以先進 5G/B5G 技術的 1024QAM/4096QAM 高階調變，進行大資料量的傳輸，並量測無線模組各式測項提供未來研究參考。

## Abstract

The government has been actively promoting energy diversification. With the aid of smart grid infrastructure, we look forward that the efficiency of power dispatch will be improved in the foreseeable future. To that end, real-time equipment control and analysis, power grid operation data, and wireless device interface and data transmission become indispensable, such as enterprise networks-frequency bands ranged 4.8-4.9GHz and higher bands 28GHz. This study aims to simulate the feasibility of real-time wireless data transmission system between power grid and wireless electric power equipment to enhance the hardware components' information collection capability; to use 5G/B5G modulation techniques (1024QAM/4096QAM) to achieve the requested high level modulation; and to provide measuring results to serve as reference for future studies.

**關鍵詞 (Key Words)**：能源多樣性(Energy Diversification)、即時無線傳輸(Real-time Wireless Transmission)、能源管理(Energy Management)、收/發模組量測(Tx/Rx Module Measurement Technique)。

# 物聯網 IPv6 位址技術、配置及安全架構芻議

IPv6 Technologies, Address Planning and Security Architecture for IoT Infrastructure

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Huang, Kenny

摘要

網際網路 IPv4 位址資源面臨枯竭，IPv6 是網際網路唯一可持續發放位址資源。本文探討全球導入 IPv6 發展近況、現有資訊基礎設施升級 IPv6 協定主要移轉技術，包含 IPv4/IPv6 雙協定技術、IPv4aaS (IPv4 as a Service)、NAT64/DNS64 等技術。網路技術標準機構 IETF (Internet Engineering Task Force) 推動 IPv6 之技術規範與技術趨勢，大型科技公司推動 IPv6 之產品策略與市場發展方向。

在可預見的未來或許不會發生 IPv6 位址枯竭情形，但我們對於 IPv6 位址政策、巨量擴增的網際網路設備、新型態應用服務、及路由器配置子網路方式仍須保持警惕。本文探討各區域網路註冊管理局 RIRs (Regional Internet Registries) IPv6 及 IPv4 位址政策、位址政策對全球路由與網路安全的影響。

物聯網帶動網際網路高度擴充與成長，物聯網 IPv6 部署方式、產生的安全議題與原有網際網路發展模式完全不同。物聯網設備部署可參考網際網路網域名稱系統 DNS (Domain Name Systems)，發展具彈性的部署模式、整合多元應用服務、建立更安全的物聯網架構。

## Abstract

Internet IPv4 address resources are almost exhausted, and IPv6 is the only sustainable address resources on the Internet. This article discusses the current status of the global IPv6 deployment and IPv6 transitional technologies. Main IPv6 transitional technologies comprise IPv4/IPv6 dual-stack protocol, IPv4 as a Service (IPv4aaS), NAT64/DNS64 among others. This article discusses Internet Engineering Task Force (IETF)'s IPv6 technical specifications and protocol evolution, and large technology companies' IPv6 strategies and market development direction.

The exhaustion of IPv6 address may not occur in the foreseeable future, but still we need to stay vigilant against IPv6 address policies, massively proliferated Internet of Things (IoT) devices, new types of application services, router subnetting configuration, etc. This article discusses the impact of Regional Internet Registries (RIRs) address policies and policy implications on global routing stability and network security.

IoT drives the rapid expansion and rapid growth of the Internet. The approach of IPv6 deployment and security consideration of IoT are completely different from the legacy Internet model. IoT deployment can refer to Internet Domain Name Systems (DNS) to develop resilient deployment models, integrate multiple application services, and establish a securer IoT architecture.

**關鍵詞 (Key Words):** IPv6 技術 (IPv6 Technologies)、IPv6 政策 (IPv6 Policy)、IPv6 位址規劃 (IPv6 Address Planning)、物聯網 (Internet of Thing)、網路安全架構 (Cybersecurity Architecture)。

# 智能頻率選擇技術於智慧電網之應用

Intelligent Frequency Selection Technology Applied to Smart Grid

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## 摘要

伴隨著智慧電網中智慧電表基礎建設發展的需求，頻率選擇面技術因具備隔絕射頻訊號干擾等之強大功能，因此被視為有效解決目前智慧電表佈建後所遭遇到的通訊瓶頸等問題的關鍵性技術之一。因此本論文針對可應用於智慧電表通訊模組之頻率選擇技術進行研究，其中在中心工作頻率位於 5G 企業專網頻譜(4.8~4.9 GHz)的設計中，本論文提出 2 種不同的樣品設計，其中心工作頻率為 4.85 GHz 而 3 dB 頻寬則分別為 8%與 5%。從模擬結果分析得知本論文所提之設計均具備極化不敏感及角度穩定(0 度至 45 度)之特性，而插入性損失亦皆小於 1.1 dB，其中頻率偏移量最多亦不超過 0.82% (45 度入射)。與文獻發展之技術比較而言，本論文所提之設計不論是在頻寬表現、插入性損失或是極化及角度穩定性乃至於整體之樣品厚度等各方面均有相當優異之性能表現。預期藉由此關鍵技術之實現將能達到智慧電表通訊傳輸效能改善之目的。

## Abstract

This paper aims to introduce the key technologies of ultrathin band-pass frequency selective surface (FSS), with polarization insensitivity and angular stability at the operation bandwidth of private 5G networks (4.8~4.9 GHz). In this research, a FSS design on the base of aperture-coupled resonator approach had been proposed. A fast roll-off and narrow passband (high selectivity) had also been achieved by coupling two square loop aperture metallic layers and one square aperture metallic layer. From a great number of simulations, the center frequency of the proposed FSS had been measured as 4.85 GHz and the 3 dB bandwidth 4.73~4.99 GHz, around 5.36 % of the center frequency. Moreover, a maximum frequency deviation of 0.82 % with incident angles from 0° to 45° had been measured. The results of the proposed work in many aspects outperform the previous researches.

**關鍵詞 (Key Words)：** 頻率選擇技術(Frequency Selective Technologies)、帶通濾波器(Bandpass Filter)、智慧電網(Smart Grid)。