INER-F0879 **INER-F0879**

出國報告（出國類別：其他）

赴天津參加『TIANJIN 2014 Symposium on Microgrids』國際會議

服務機關：核能研究所
姓名職稱：姜政綸　副研發師
　　　　　張永瑞　副研究員
派赴國家：大陸地區
出國期間：103 年 11 月 11 日~103 年 11 月 17 日
報告日期：103 年 12 月 17 日

摘　要

本次出國行程由核能研究所(以下簡稱本所)張永瑞副組長及姜政綸博士赴天津參加『TIANJIN 2014 Symposium on Microgrids』國際會議，此會議為國家實驗室專家等級(NREL、DOE、EPRI、NEDO、AIST、CRIEPI、DLRE、EPGC)之重要國際會議，唯有受邀才能出席。本次出席會議參與技術研討外，並特邀張副組長進行台灣微電網技術研發現況之簡報，及張貼本所微電網技術發展之海報，用以說明本所自主式分散型區域電力與微電網技術之研發情形，以及台灣未來規劃方向，會議上且與國際專家學者針對微電網關鍵技術進行心得交換，有助於本所獨立型微電網與自主式分散型電力等計畫之執行。主要心得包括美國微電網發展趨勢與規劃、及大陸、新加坡、美國、拉丁美洲與中非等地區建立獨立型微電網與實際應用之案例探討，可作為我國參考。最後，建議事項主要為：宜加速我國離島微電網的建設，並實際進行相關技術測試與穩定運轉，建立運轉實績，便可扶植國內廠商將產品推廣至國內外市場中；於微電網系統建置前，應先進行分散式能源建置與儲能系統容量的評估與規劃，且同時考量不同區域之氣候特性與用電情形；應有適當之誘因，才能使廠商一同參與微電網建置與開發；本所應持續發展微電網與分散式能源之關鍵技術，未來可應用於台灣本島與離島之電力系統，提高再生能源的占比與發電量，進而達到提昇電力品質、降低離島發電成本、及減少碳排放量等目標。

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一、目　的

本次前往天津參加『TIANJIN 2014 Symposium on Microgrids』國際會議，此會議為國家實驗室專家等級(NREL、DOE、EPRI、NEDO、AIST、CRIEPI、DLRE、EPGC)之年度重要國際會議，唯有受邀才能出席。本所由於發展分散式能源及微電網計畫成果傑出，自 2010 年起每年皆獲邀參與，今年度更受邀進行台灣微電網研究現況的簡報，出席本會議可了解各國智慧電網研發現況、規劃方向及示範工程建置情形，並與國際專家學者針對微電網關鍵技術進行心得交換，有助於本所獨立型微電網與自主式分散型電力等計畫之執行。

二、過　程

表1 行程表

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<tr><td>11/12(三)</td><td></td><td></td><td>大陸</td><td>天津</td><td>1. 會場海報布置
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<tr><td>11/13(四)～
11/16(日)</td><td></td><td></td><td>大陸</td><td>天津</td><td>1. 出席『Tianjin 2014 Symposium on Microgrids』國際會議
2. 簡報台灣研發現況
3. 出席大會安排之參訪
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ENERGY FOUNDATION
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TIANJIN 2014 SYMPOSIUM ON MICROGRIDS

Geneva Grand Hotel, Hexi District, Tianjin
Thursday & Friday, 13 & 14 November 2014

[casual clothing strongly preferred]

Thursday 13 November: Morning Session, Jin Hua (China Gold) Hall, 2F	
08:30 - 09:00	registration, outside Jin Hua Hall, 2nd floor
09:00 - 09:15	Zhipeng LIANG, National Energy Administration Welcome to Tianjin
09:15 - 09:30	Chris MARNAY, Berkeley Lab (Co-Chair: Ben KROPOSKI, NREL) Microgrid Symposium Tradition
Asia 1 - Chairs:	Meiqin MAO, Hefei U. of Tech., & Honghua XU, Chinese Academy of Sci.
09:30 - 09:50	Chengshan WANG, Tianjin U. Economic Analysis and Policy Proposals for Island Microgrids in China
09:50 - 10:00	discussion
10:00 - 10:20	Haijin LI, Zhejiang University Multiple Source Super Uninterruptible Power Supply
10:20 - 10:30	discussion
10:30 - 11:00	coffee served outside, then please take this time to view the posters
11:00 - 11:20	Liuchen CHANG, Guang Dong East Power Economic Analysis and Optimal Design for Industrial Microgrids with PV
11:20 - 11:30	discussion
11:30 - 11:50	Xisheng TANG, Chinese Academy of Sciences DC Microgrid R&D
11:50 - 12:00	discussion

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圖1 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(1/5)

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Thursday 13 November: Afternoon Session	
Asia 2 - Chairs:	Alex CHONG, A*STAR & Se-Kyo CHUNG, Gyeongsang Nat. U.
13:30 - 13:50	Nian LIU, North China Electric Power University Heuristic Strategy for Commercial Blg. Microgrids Containing EVs and PV
13:50 - 14:00	discussion
14:00 - 14:20	Bo Hyung CHO, Seoul National University K-MEG Project DC Distribution Microgrid Control System
14:20 - 14:30	discussion
14:30 - 14:50	Josep GUERRERO, Aalborg U., & Kai SUN, Tsinghua U. Sino-Danish Microgrid Tech. Research & Demonstration
14:50 - 15:00	discussion
back-up	FengYan ZHANG, Xiamen U. Distributed Solar DC Microgrid For Commercial Buildings
15:00 - 15:30	group photo shoot, location will be announced
15:30 - 16:00	coffee served outside, then please take this time to view the posters
Asia 3 - Chairs:	Ryoichi HARA, Hokkaido U. & Toshifume ISE, Osaka U.
16:00 - 16:20	Raymond Yung Ruei CHANG, Institute of Nuclear Energy Research Current Research Status of INER's Microgrid Technology
16:20 - 16:30	discussion
16:30 - 16:50	Hirohisa AKI, AIST DemandS Side Resiliency with DER and Microgrids
16:50 - 17:00	discussion
17:00 - 17:20	Yuko HIRASE, Kawasaki Technology Power Conditioner System with Virtual Synchronous Generator Control
17:20 - 17:30	discussion
17:30 - 17:50	Keiichi HIROSE, NTT Facilities Experience of the Sendai Microgrid and the Next Challenge
17:50 - 18:00	discussion
back-up	Kumudhini RAVINDRA, PRDC Infotech Microgrids for Rural Electrification

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圖2 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(2/5)

ENERGY FOUNDATION
能源基金会

TIANJIN 2014 SYMPOSIUM ON MICROGRIDS

Geneva Grand Hotel, Hexi District, Tianjin
Thursday & Friday, 13 & 14 November 2014

[casual clothing strongly preferred]

Friday 14 November: Morning Session	
Americas - Chairs:	Farid KATIRAEI, Quanta Tech. & Reza IRAVANI, U. of Toronto
09:00 - 09:20	Ross GUTTROMSON, Guillermo JIMENEZ, Hassan FARHANGI, & Dionizio PASCHOARELI Overview of Microgrid R&D in the Americas
09:20 - 09:30	discussion
09:30 - 09:50	Ross GUTTROMSON, Sandia Lab US Microgrids for Enhancing Resilience
09:50 - 10:00	discussion
10:00 - 10:20	Mark McGRANAGHAN, EPRI Requirements for Advanced Microgrid Controllers
10:20 - 10:30	discussion
back-ups	Judith CARDELL, Smith College Cogeneration & Sustainability at Smith College Ben KROPOSKI, NREL Microgrid Standards and Testing
10:30 - 11:00	break
Remote - Chairs:	Guillermo Jimenez, U. of Chile & Xavier VALLVE, TTA
11:00 - 11:20	Bo ZHAO, Zhejiang Electric Power Co. Nanji Island Microgrid Demonstration
11:20 - 11:30	discussion
11:30 - 11:50	Jose Daniel LARA, U. of Waterloo Robust Energy Management System for Isolated Microgrids
11:50 - 12:00	discussion

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圖3 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(3/5)

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Friday 14 November: Afternoon Session	
Remote Cont'd - Chairs: Guillermo JIMENEZ, U. of Chile & Xavier VALLVE, TTA	
13:30 - 13:50	Xavier VALLVE, TTA Demonstration Rural Microgrids with PV in Chad
13:50 - 14:00	discussion
14:00 – 14:20	Markson TANG, DLRE. Pulau Ubin Island Project
14:20 - 14:30	discussion
back-up	Guixiu JIANG, Guangzhou Institute of Energy Conversion Dong'Au Island Microgrid Demonstration
14:30 - 14:45	break
Europe - Chairs:	Mihaela ALBU, Bucharest Poly. & Nikos HATZIARGYRIOU, N.T.U.A.
14:45 - 15:05	Pierluigi MANCARELLA, U. of Manchester Business Cases for Microgrids
15:05 - 15:15	discussion
15:15 - 15:35	Alexandre OUDALOV, ABB Microgrid Storage Integration
15:35 - 15:45	discussion
15:45 - 16:05	Panayiotis MOUTIS, U. of Greenwich Planned Community Residential Microgrids
16:05 - 16:15	discussion
back-up	Jan VON APPEN, Fraunhofer Smart PV Grid Integration
16:15 - 16:30	break
16:30 - 18:00	Panel Session: Standards Development Chairs: Jim REILLY (Americas), Toshihisa FUNABASHI (Asia), & Johan DRIESEN (Europe) Panelists: Ben KROPOSKI, NREL Michel KAMEL, Melrok Farid KATIRAEI, Quanta Technology Gengfeng LI, Xi'an Jiaotong University Guixiu JIANG, Guangzhou Inst. of Enrg. Con. Tsai-Fu WU, N.C.C.U. Se-Kyo CHUNG, Gyeongsang Nat. U. Hirohisa AKI, AIST Mario PAOLONE, EPFL Nikos HATZIARGYRIOU, N.T.U.A Alexandre OUDALOV, ABB
18:00 - 18:30	Chris, Farid, Hiroshi, Nikos, & Johan Retrospective: the First Decade of Microgrid Symposiums

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圖4 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(4/5)

Tianjin Eco-City & TJU Lab
中新生态城 & 天大实验室

free if sponsorship adequate

Schedule Saturday | 15 Nov 2014

09:00-10:00	Bus departs Geneva Grand Hotel for the Eco-City
10:00-11:30	Tianjin Eco-City technical tour
11:30-13:30	Lunch on your own
13:30-14:30	Tianjin University Smart Grid Lab tour
14:30-15:00	Bus returns to Geneva Grand Hotel
	Dinner on your own

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圖5 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(5/5)

三、心　得

(一) 『TIANJIN 2014 Symposium on Microgrids』國際會議開幕部分

本次會議先進行開幕致詞，由於此次地主國為大陸地區，故由亞洲地區先進行簡報，再依序為美洲、其他地區與歐洲。本會議為國家實驗室等級之專家學者參加，圖 6 為『TIANJIN 2014 Symposium on Microgrids』國際會議全體人員合照。

圖6 『TIANJIN 2014 Symposium on Microgrids』國際會議全體人員合照

圖 7 為大陸能源局梁志鵬(Zhi-Peng Liang)副司長致歡迎詞，及圖 8 為本次會議主席美國 Berkeley Lab 的 Crisis Marney 致詞會場照片，本次會議參與人數為 118 人，出席名單如圖 9 所示。

圖7 『TIANJIN 2014 Symposium on Microgrids』國際會議會場照片

圖8 會議主席美國 Berkeley Lab 的 Crisis Marney 致詞

2014 Tianjin Sympoium on Microgrids confirmed attendees

NAME	AFFILIATION
Alex Chong	EPGC, A*STAR
Alexandre Oudalov	ABB Switzerland Ltd.
Amirhossein Sajadi	Case Western U.
Andrea Mammoli	University of New Mexico
Benjamin Kroposki	National Renewable Energy Lab
Bo Hyung Cho	Seoul National University
Bo Zhao	Zhejiang Elec. Power Test & Research Inst.
Byeon Gilsung	KERI
Changhong Deng	Wuhan University
Chengshan Wang	Tianjin University
Chia Meng Hwee	EPGC, A*STAR
Chris Marnay	Berkeley Lab
Chunyi Guo	North China Electric Power University
Darren Hammell	Princeton Power Systems
Deng Changhong	Wuhan University
Dionízio Paschoareli Júnior	Universidade Estadual Paulista
Dong Jun Won	Inha university
Duo Luo	XingYe Solar Energy Technology
Farid Katiraei	Quanta Technology
Fengyan (Wendy) Zhang	Xiamen University
Gengfeng Li	Xi'an Jiaotong University
Gonçalo Mendes	Technical University of Lisbon
Guillermo Jimenez	University of Chile
Guixiu Jiang	Chinese Academy of Sciences
Guoqing He	China Electric Power Research Institute
Haibo Xu	Guang Dong EAST Power
Haijin Li	Zhejiang University
Hassan Farhangi	British Columbia Institute of Technology
He Weiguo	China Electric Power Research Institute
Helen-Xing Huang	ABB China
Hirohisa Aki	AIST
Hiroshi Asano	CRIEPI
Honghua Xu	Institute of EE, Chinese Acad. of Sci.
Hsiao-Yu Hu	National Central University
Huiming Xiao	
Jaeho Choi	Chungbuk National University
Jan von Appen	Fraunhofer
Jheng-Lun Jiang	INER
Jian Zhuang	Tianjin EPRI of SGCC
Jianhua Zhang	North China Electric Power University
Jianmin Zhang	Hangzhou Dianzi University
Jianzhong Wu	University of Cardiff
Jie Shu	GIEC
Jim Reilly	Reilly Associates
Jin Zhong	University of Hong Kong
Jingtao Zhao	NARI
Johan Driesen	K.U. Leuven
Jose Daniel Lara	University of Waterloo
Josep M. Guerrero	Aalborg University
Juan C Vasquez	Aalborg University
Juan Cerva Fris	Acros Training
Judith Cardell	Smith College
Kai Sun	Tsinghua University
Kenichi Sakimoto	Kawasaki Heavy Industries, Ltd.
Kiichiro Tsuji	Osaka University
Kumudhini Ravindra	PRDC Infotech
Lecai Zeng	Shanghai Electric R&D Center
Lei Huang	Chinese Academy of Sciences
Liang Tao	SIEMENS
Lingwei Zheng	Hangzhou Dianzi University
Liuchen Chang	University of New Brunswick

2014 Tianjin Sympoium on Microgrids confirmed attendees

NAME	AFFILIATION
Lorenzo Reyes	EPFL
Man Wang	The Energy Foundation
Marc Rechter	ENERGOPARK
Maria Brucoli	Arup
Mario Paolone	EPFL
Mark McGranaghan	EPRI
Markson Tang	DLRE
Meiqin Mao	Hefei University of Technology
Miao Hong	Sichuan University
Michael Hoff	NEC
Michael Roach	Microgrid Horizons
Michel Kamel	MeiRok
Miky Albu	Politehnica U. Bucharest
Min Sun	Jiangxi Electric Power Research Institute
Ming Ding	Hefei University of Technology
Ming Wu	State Grid
Natalie Samovich	ENERGOPARK
Nicholaus Halecky	MeiRok
Nikos Hatziargyriou	Nat.Tech. U. of Athens
Panagiotis Moutis	Greenwich University
Pekik Dahono	Institute of Technology Bandung
Peng Li	Tianjin University
Pierluigi Mancarella	The University of Manchester
Ratnesh Sharma	NEC Laboratories America
Reza Iravani	University of Toronto
Ross T Guttromson	Sandia National Laboratory
Ryoichi Hara	Hokkaido University
Se-Kyo Chung	Gyeongsang National University
Sheng Li	
Shirong Liu	Hangzhou Dianzi University
Shuichi Tahara	NEC Corporation
Sicheng Wang	National Development & Reform Commission
Stathis Tselepis	CRES
Stella Wang	Berkeley Lab
Suryanarayana Doolla	IIT Bombay
Tian Zhe	Tianjin Univ.
Toshifumi Ise	Osaka University
Toshihisa Funabashi	Nagoya University
Tsai-Fu Wu	National Chung Cheng University
Wei (Eric) Zeng	Jiangxi Electric Power Research Institute
Wei Feng	Berkeley Lab
Weisheng Wang	China Electric Power Research Institute
Xavier Vallvé	Trama TecnoAmbiental (TTA)
Yan Xing	Nanjing U. of Aeronautics and Astronautics
Yi Qin	MicroGrid EMS Lab Shenzhen
Yibo Wang	Inst. of EE, Chinese Acad. of Sci.
YingRu Zhao	Xiamen U.
Yongqiang Zhao	Energy Research Institute
Yue Yuan	Hehai University
Yuko Hirase	Kawasaki Technology Co., Ltd
Yun Liu	Beijing Sifang Automation Co. Ltd.
Yung-Ruei (Raymond) Chang	INER
Zaijun Wu	Southeast University
Zhe Chen	Aalborg University
Zhipeng Liang	NDRC, Energy Bureau

圖9 『TIANJIN 2014 Symposium on Microgrids』全體與會者名單

(二) 『TIANJIN 2014 Symposium on Microgrids』國際會議各國報告內容

1. 亞洲地區：

(1) 大陸－南麂島微電網示範工程

南麂島微電網示範工程是由浙江省電力試驗研究院的趙波(Zhao Bo)進行簡報(圖 10)，南麂島距離大陸溫州有 30 海浬，是一座聯合國生物多樣化管理示範區與海洋自然保護區的離島(圖 11)，島上除了漁業發達外，並致力於旅遊觀光業的發展，於發展微電網建設前，因電力輸送不便，島上是由四台 300 kW 的柴油發電機所供電，但其發電效率低、發電成本高、及具高污染的碳排與粉塵，對於島嶼的自然環境會造成破壞。為了解決供電不足與高污染的問題，大陸地區進行南麂島離島微電網示範工程的建置，將其納入 863 計畫的「含分散式電源的微電網關鍵技術研發」議題中，並投入 1.5 億人民幣進行建置，由浙江電力公司所負責，該離島的建置包括：10 台 100 kW 的永磁直驅式風力發電機、660 kW 的太陽能發電、4 台 500 kW 的鋰電池儲能系統、2 台 500 kW 的超級電容儲能系統、電動車充換電站、智慧電錶，且保留 1,700 kW 的柴油發電系統(圖 12 至圖 13)，為一 MW 等級之多種分散式發電的離島微電網示範場域，於 2012 年 5 月開始進行建設，並於 2014 年 9 月 19 日試運行，經由一周(168 小時)的運轉後，於 9 月 26 日正式投入運轉。其微電網的系統架構如圖 14 所示，主要監控介面如圖 15 所示，控制系統架構如圖 16 所示。南麂島最佳的旅遊季節為春季與夏季，故此時的用電量較大，故需開啟柴油發電機以維持島內旅遊業的使用；而秋季與冬季的負載較少，當分散式發電的量大於負載與儲能的需求時，則會造成再生能源的棄用(圖 17)。而在穩定控制部分著重於電壓穩定控制、頻率穩定控制、系統緊急控制等功能(圖 18)，藉由微電網的建置確實可提高該島居民用電的穩定(圖 19)。當會議結束的 Q&A 時間中，有專家提問建置成本為多少？是否進行經濟效益評估或回收年限估算？但講者回覆規劃要進行離島微電網建置時，並不需要考量花費多少，建置完成並能運轉為其重點。

圖10 趙波(Zhao Bo)進行南麂島微電網示範工程簡報

圖11 南麂島的背景介紹

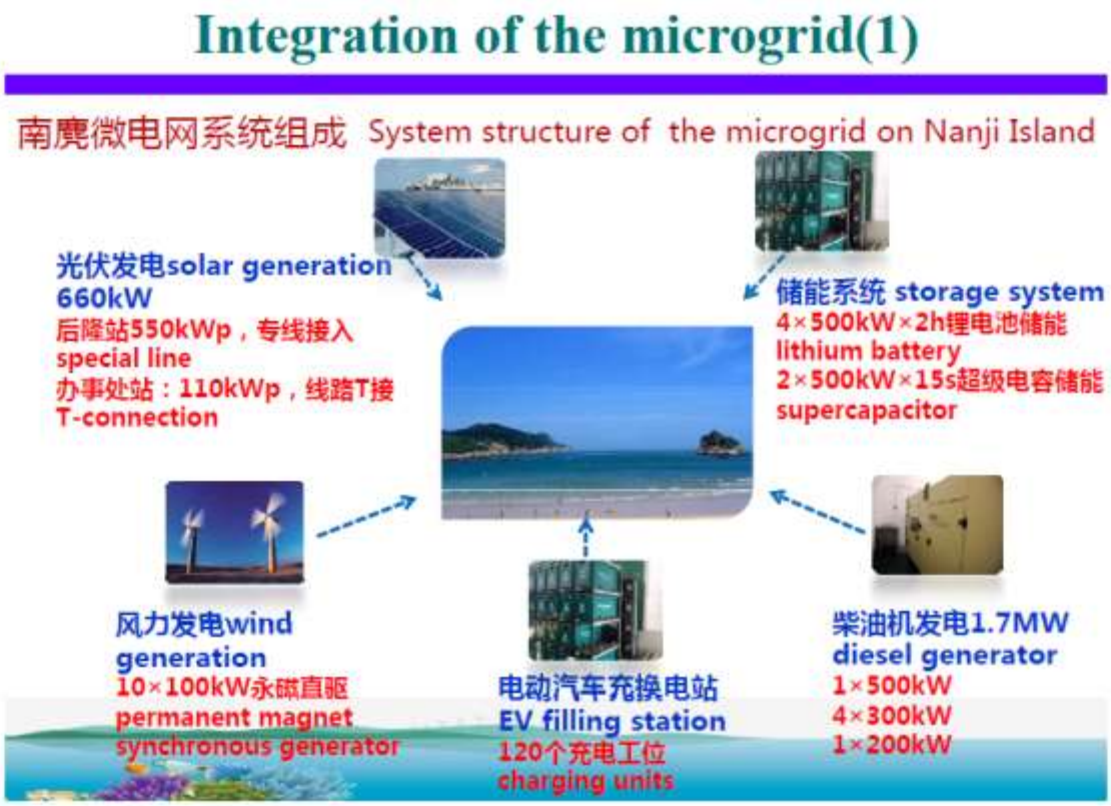


圖12 南麂島微電網系統的組成

圖13 南麂島微電網系統的設備

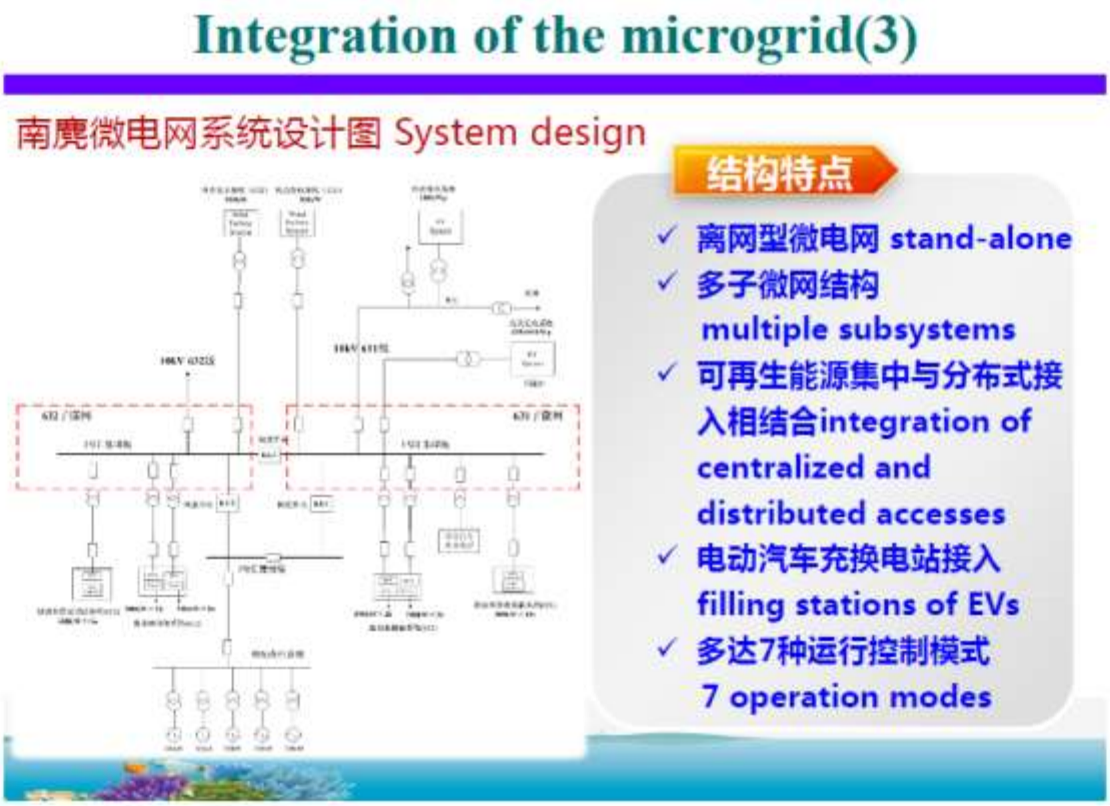


圖14 南麂島微電網系統架構

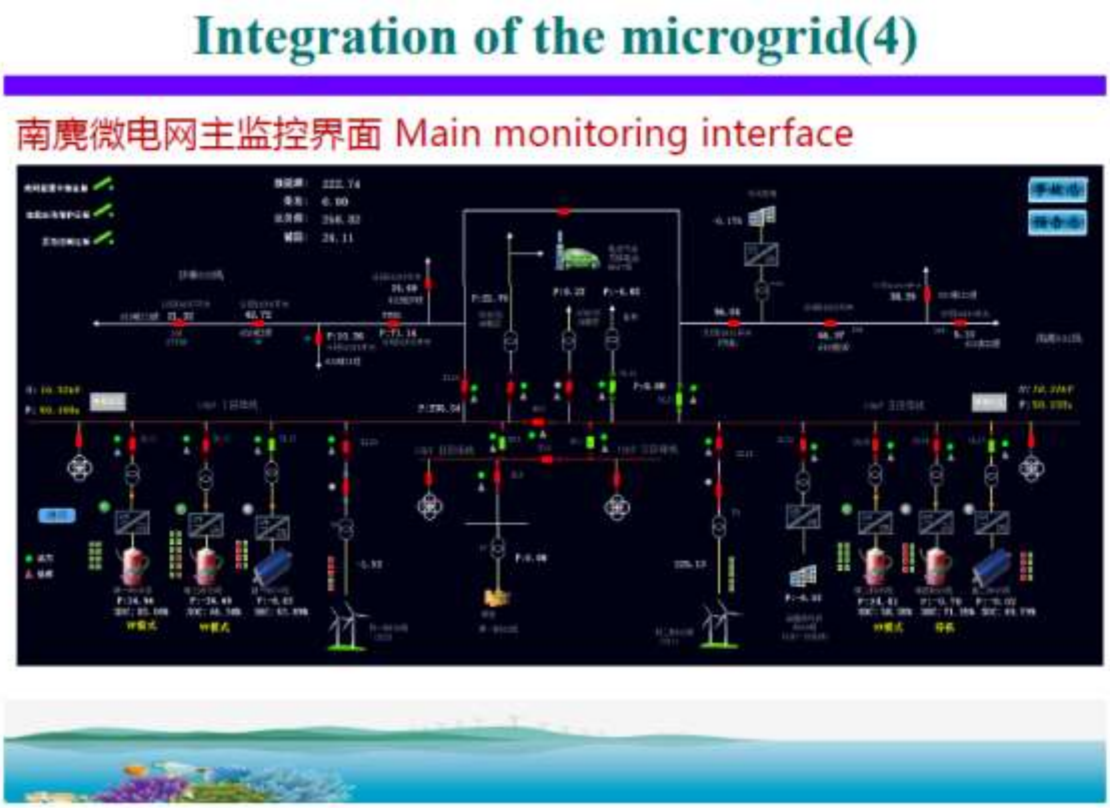


圖15 南麂島微電網監控介面

圖16 南麂島微電網控制系統架構

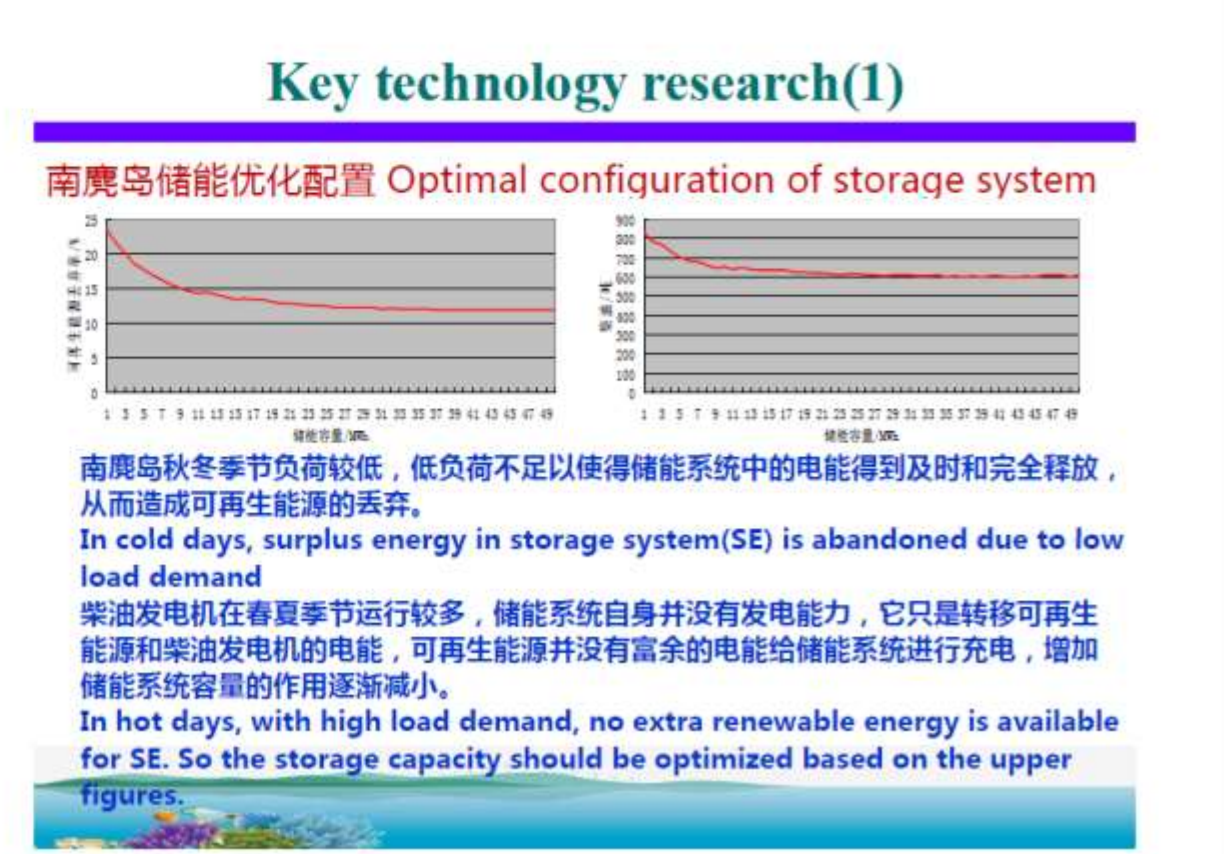


圖17 南麂島儲能系統最佳配置

圖18 南麂島微電網之系統穩定控制功能

圖19 南麂島微電網確實提高島上居民的穩定用電

(2) 大陸－大萬山島微電網經濟效益分析

大萬山島微電網經濟效益分析是由天津大學的王成山(Cheng-Shan Wang)教授進行簡報(圖 20)，大萬山島位於澳門的東南方，距廣東省珠海市香洲區 39 公里處的一座海島(圖 21)，島上人口約 300 人，主要依賴柴油發電機供電，但其具有發電成本高與可靠度低的問題。據了解，大陸南方海上風電聯合開發公司申請珠海萬山海島新能源微電網示範工程，預計在珠海萬山海洋開發試驗區的大萬山島、東澳島與桂山島等離島，建置分散式能源與微電網，包括離岸風力發電機、太陽能發電、柴油發電機與儲能系統等，預估投資 3.86 億人民幣，以解決離島的供電問題。大萬山島是以漁業與觀光業為主，而旅遊旺季集中於 5 月至 10 月，亦為高負載的時期，最大負載量為 810 kW(圖 22)，亦進行該島的風能與太陽能評估，太陽能發電以 5-10 月有較大的發電量，較符合旅遊旺季的需求，而風力發電則與太陽能互補，冬季發電量較大。該島建置 850 kW 的風力發電機、200 kW 的太陽能發電、電池容量為 2,000 kWh、儲能系統為 1,000 kW 及柴油發電機為兩台 500 kW，前述之投資額約為 1,700 萬人民幣(278 萬美元)(圖 23 至圖 24)，並以此配置下進行再生能源與負載預測(圖 25)，及設計適當的控制策略(圖 26)，再以前述基礎下進行操作與經濟的模擬分析與評估，得出其投資報酬率超過 25 年(圖 27 至圖 29)，故提出應於建設初期與電價方式進行補助，以維持微電網的長期運轉(圖 30)。以大萬山島離島微電網為例，應使投資報酬率於 7-8 年間可回收，較能吸引廠商進行投資(圖 31 至圖 32)。

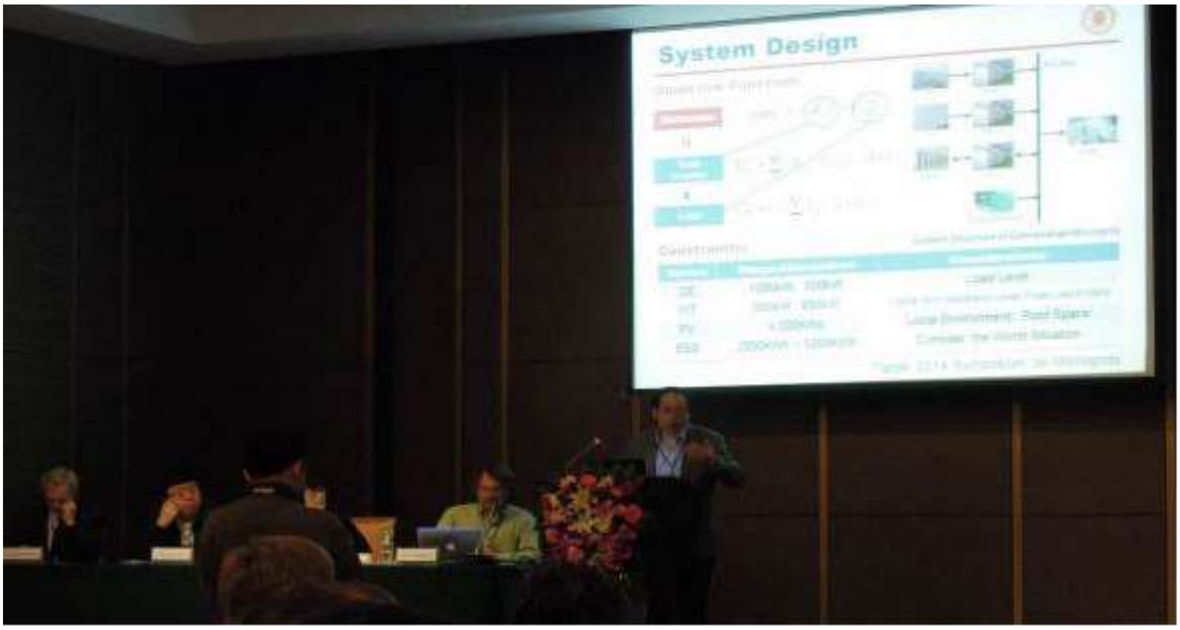


圖20 王成山(Cheng-Shan Wang)教授進行大萬山島微電網經濟效益分析簡報

圖21 大萬山島地理位置

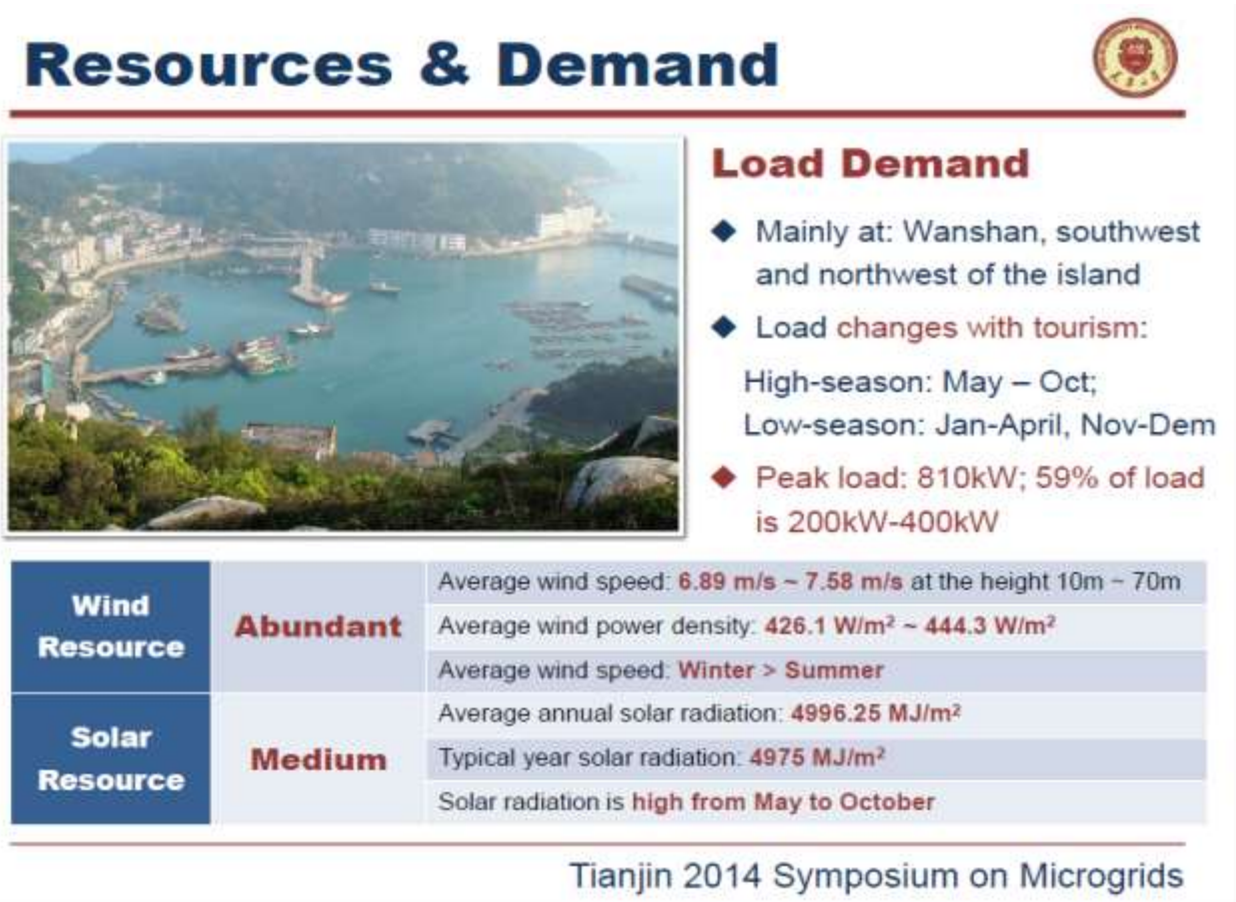


圖22 大萬山島負載需求

System Design

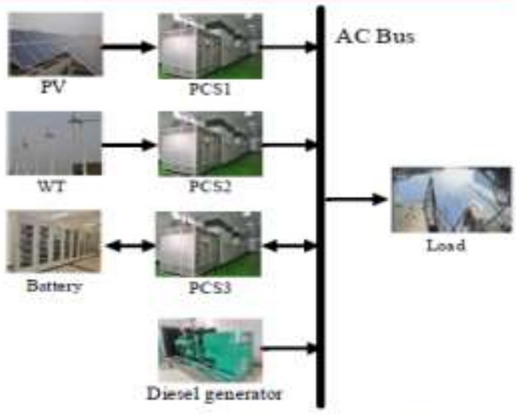
Objective Function:

Net Income = Total Income − Cost

$$\max\ f = B_{net}^{pre} - C_{TEI}^{pre}$$

$$B_{net}^{pre} = \sum_{l=1}^{T} (B_{ele,l} - C_{fuel,l}) / (1+r)^{l}$$

$$C_{TEI}^{pre} = C_1 + \sum_{l=1}^{T} (C_{D,l} / (1+r)^{l})$$



System Structure of Dawanshan Microgrid

Constraints:

Device	Range/Alternatives	Considerations
DE	1×1000kW / 2×500kW	Load Level
WT	1×850kW	Cost & Tech Readiness Level; Peak Load 810kW
PV	≤ 200kWp	Local Environment; Roof Space
ESS	2000kWh ~ 5000kWh	Consider the Worst Situation

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圖23 大萬山島微電網系統設計

Design Results

Sizing Plan

Device	Results
Wind Generators	1×850kW
PV Arrays	200kWp
Lead-Acid Battery	2000kWh
PCS	1000kW
Diesel Generators	2×500kW

Initial Investment

Device	Cost (USD)
Wind Generators	1,400,000
PV Arrays	325,000
Diesel Generators	130,000
Battery & BMS	600,000
PCS	325,000
Total	2,780,000

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圖24 大萬山島微電網之分散式能源及其成本

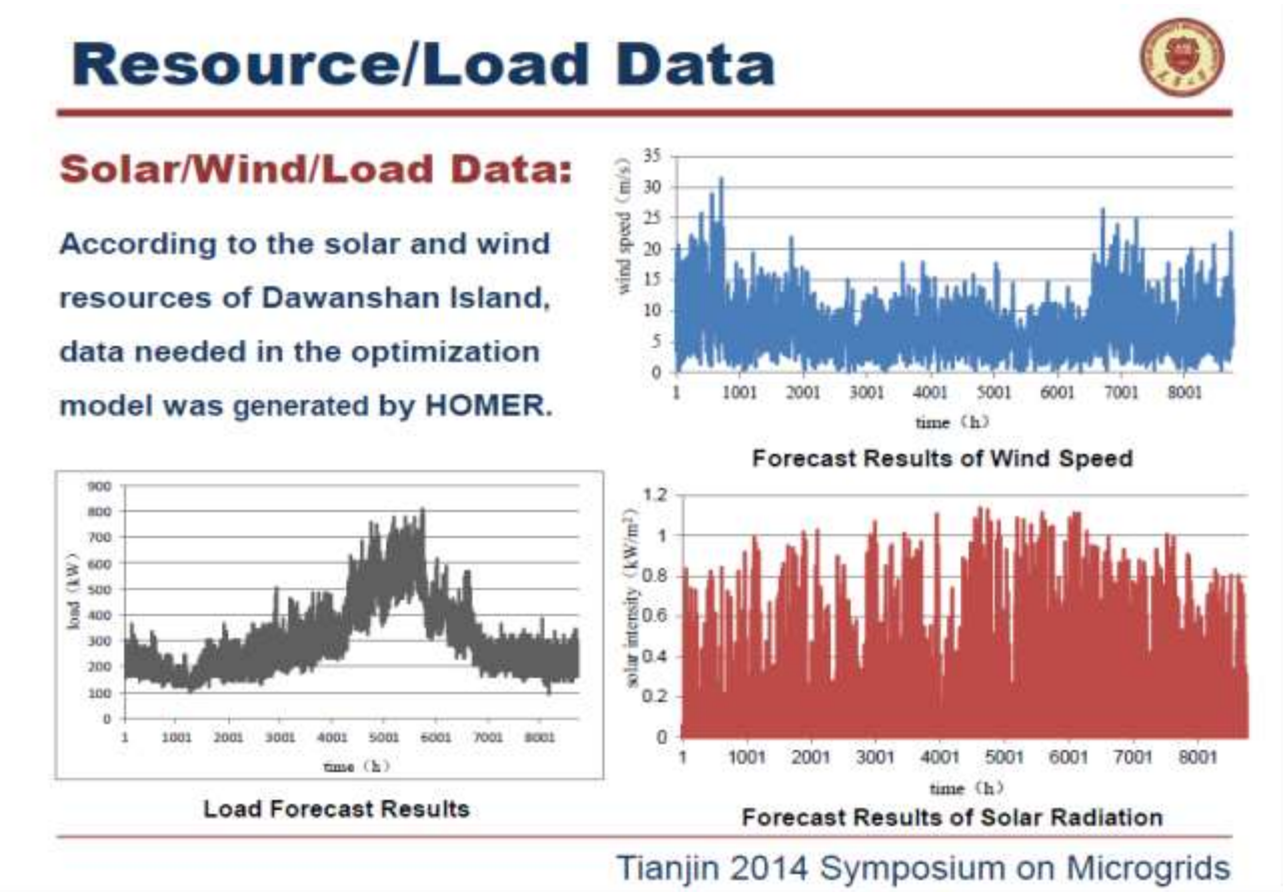


圖25 大萬山島之再生能源與負載預測

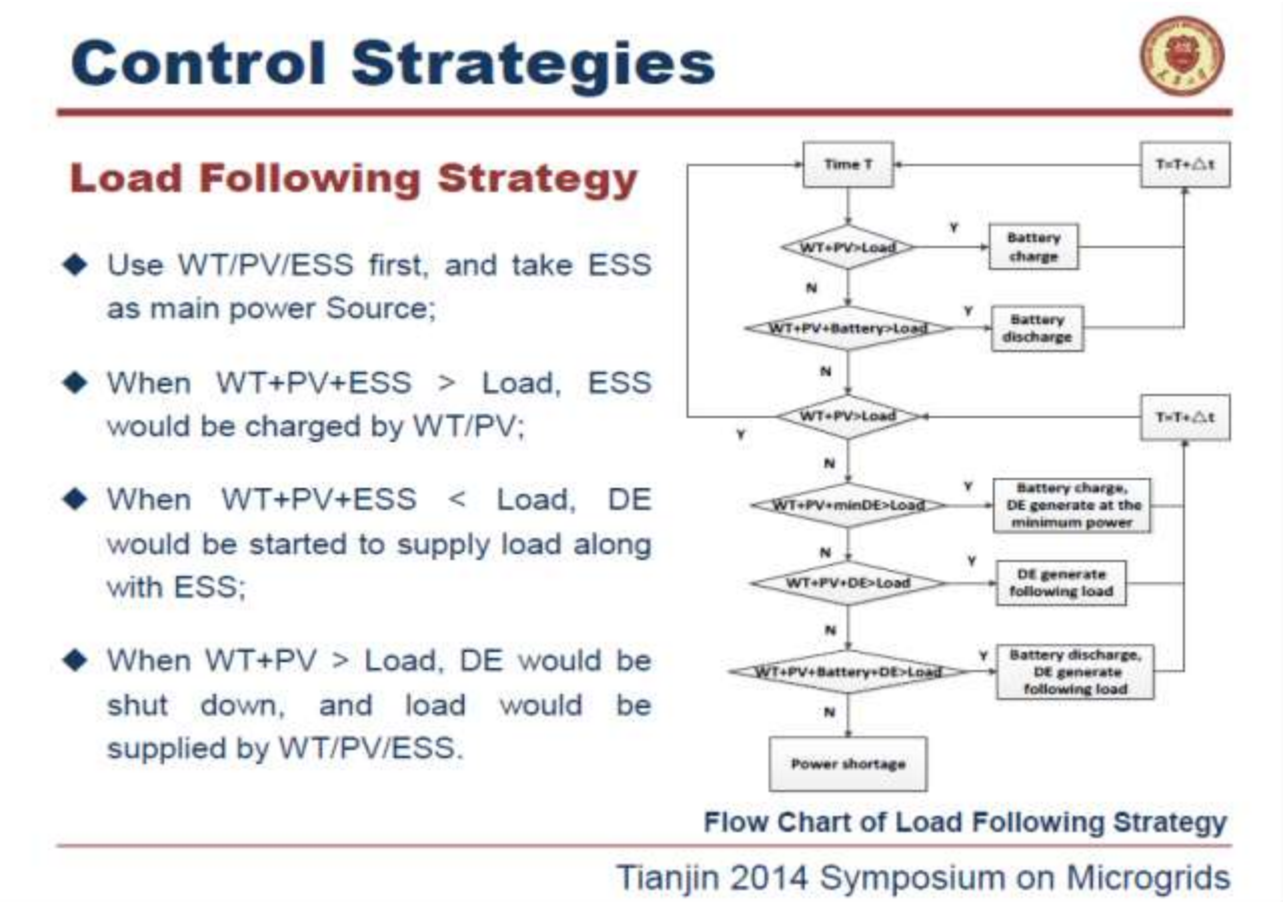
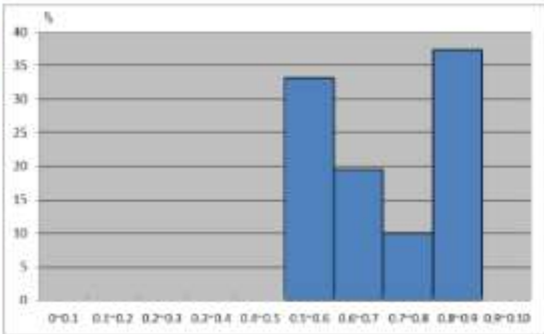


圖26 大萬山島微電網系統之控制策略

Operation Evaluation

Generation of All Power Sources

Device \ Index		Generation (MWh)	Percentage (%)	Utilization Hours (hrs)
Load (810 kW)	WT	1427	53.35	1680
	PV	150	5.60	750
	DE	1098	41.05	\



SOC Statistics of ESS of One Year

Generation of Power Sources in a Year

- SOC of batteries was set within [0.5, 0.9]. Therefore, SOC was kept above 0.8 during 37.35% time of the year to improve the power reliability especially when there is fault for diesel generators.

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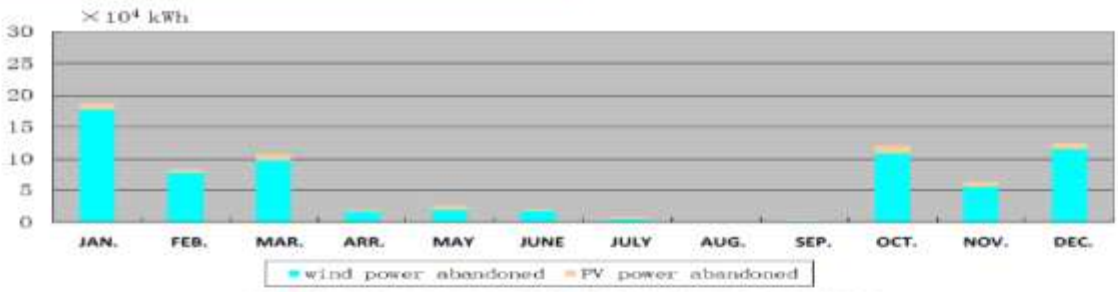
圖27 大萬山島之微電網運轉評估(1/2)

Operation Evaluation

Annual Renewable Energy Abandoned

Device \ Index		Energy Abandoned (MWh)	Percentage (%)
Load (810 kW)	WT	694	32.72
	PV	72	32.43

- In summer, load level is high but wind resource is poor. Therefore diesel generator is used a lot in summer.
- In winter, load level is low but wind resource is abundant. Therefore excess wind energy is abandoned a lot in winter.



Renewable Energy Abandoned During the Year

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圖28 大萬山島之微電網運轉評估(2/2)

Economic Evaluation

Basic Information	Unit	Value
Project Cycle	year	25
Initial Investment	USD	2,780,000
Discount Rate	%	8
User Electricity Price	USD/year	0.33
Capital Ratio	\	0.3/0.7

Operation Results	Unit	Value
Lifetime of ESS	year	6.33
Times of ESS Replacement	time	3
Times of DE1 Replacement	time	4
Times of DE2 Replacement	time	0

Economic Indices	Unit	Value
Annual Operation Cost	USD	560,000
Annual Income Selling Elec.	USD	850,000
Annual Net Income	USD	290,000
Net Present Value of Total Income	USD	-200,000
Internal Rate of Return	%	5.925
Payback Period	year	>25

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圖29 大萬山島之微電網經濟效益評估

Economic Analysis

Economic Analysis:

- Only the replacement of batteries and diesel generators were considered. The replacement of wind turbines and PV arrays were not considered.
- The internal rate of return of this project is low, and the cost cannot be recovered in the project cycle. Therefore, this example cannot commercially operate without subsidies from the government.
- For islanded microgrid, central government should offer the initial investment. Subsidies can be provided through appealing electricity price for long-term operation of microgrid.

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圖30 大萬山島之微電網經濟效益分析

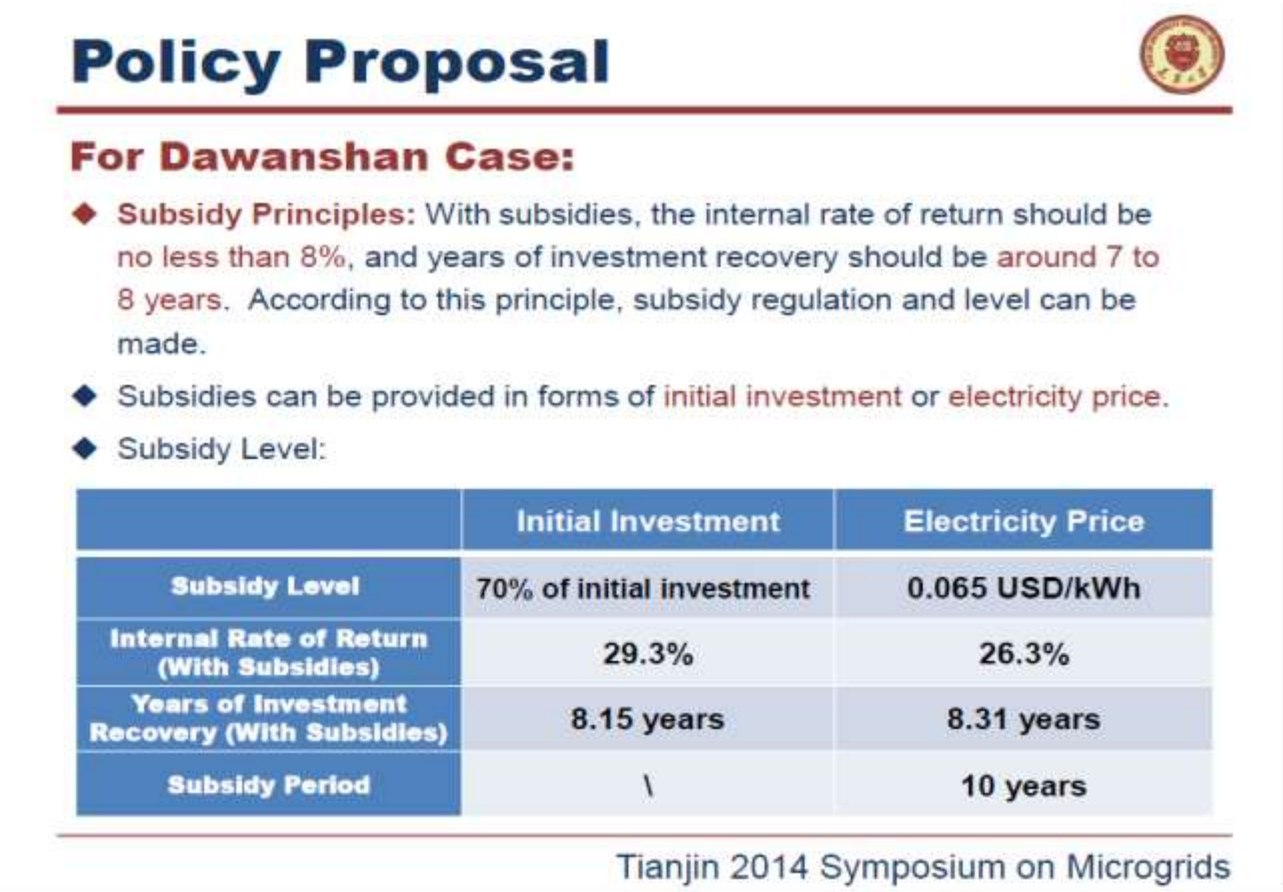

圖31 大萬山島微電網系統之補助建議(1/2)

圖32 大萬山島微電網系統之補助建議(1/2)

(3) 大陸－東澳島微電網示範工程

東澳島微電網示範工程是由廣東能源研究院的黃磊(Lei Huang)進行簡報(圖 33)，東澳島微電網是由興業太陽能技術公司進行建置，根據該島的特性建設了 50 kW 風力發電機、1,004 kWp 太陽能發電、1,500 kWh 鉛酸電池、100 kW 冰水機組及搭配 1,000 kW 柴油發電機組成微電網系統，其相關地理位置如圖 34 所示，單線示意圖則如圖 35 所示。在東澳島微電網所進行的研究議題包括：結合風能、太陽能與柴油發電機的最佳微電網規劃，能源管理，高功率雙向轉換器，儲能監控與管理，電力品質評估，遠端即時監控系統，保護電驛，微電網工程建設等研究方向(圖 36)。而各種分散式能源的建置則分別為：304 kWp BIPV(圖 37)、700 kWp PV(圖 38)、五台 10 kW 風力發電機(圖 39)、及 1,000 kW 的柴油發電機(圖 40)。至於管理系統與平台方面則包含：管理決策、電力潮流計算、發電機控制、儲能系統管理與負載管理等，如圖 41 至圖 42 所示。開發 100 kW 與 500 kW 的雙向轉換器(圖 43)，發展遠端即時監控系統(圖 44 至圖 45)。

圖33 黃磊(Lei Huang)進行東澳島微電網示範工程簡報

圖34 東澳島微電網地理位置圖

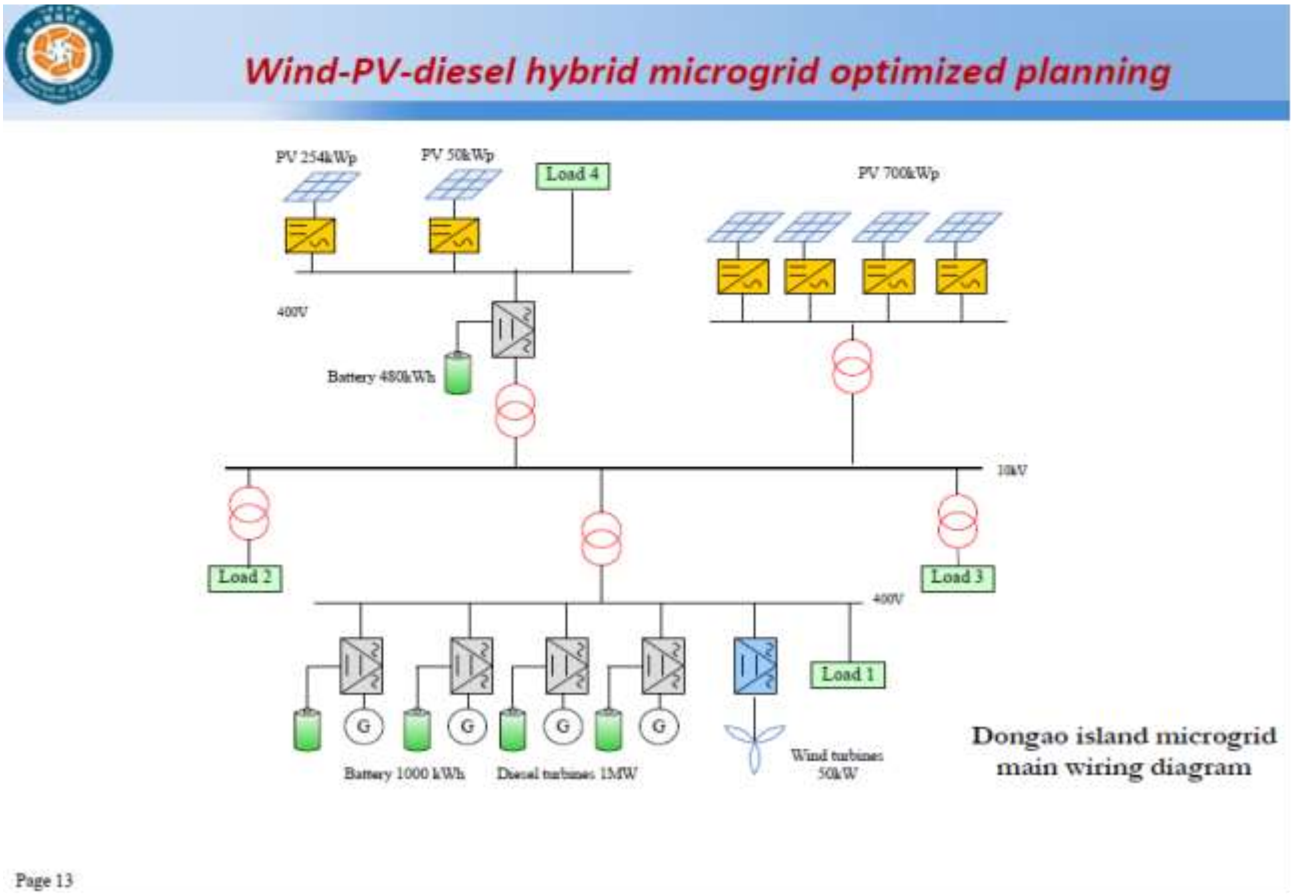

圖35 東澳島微電網系統架構

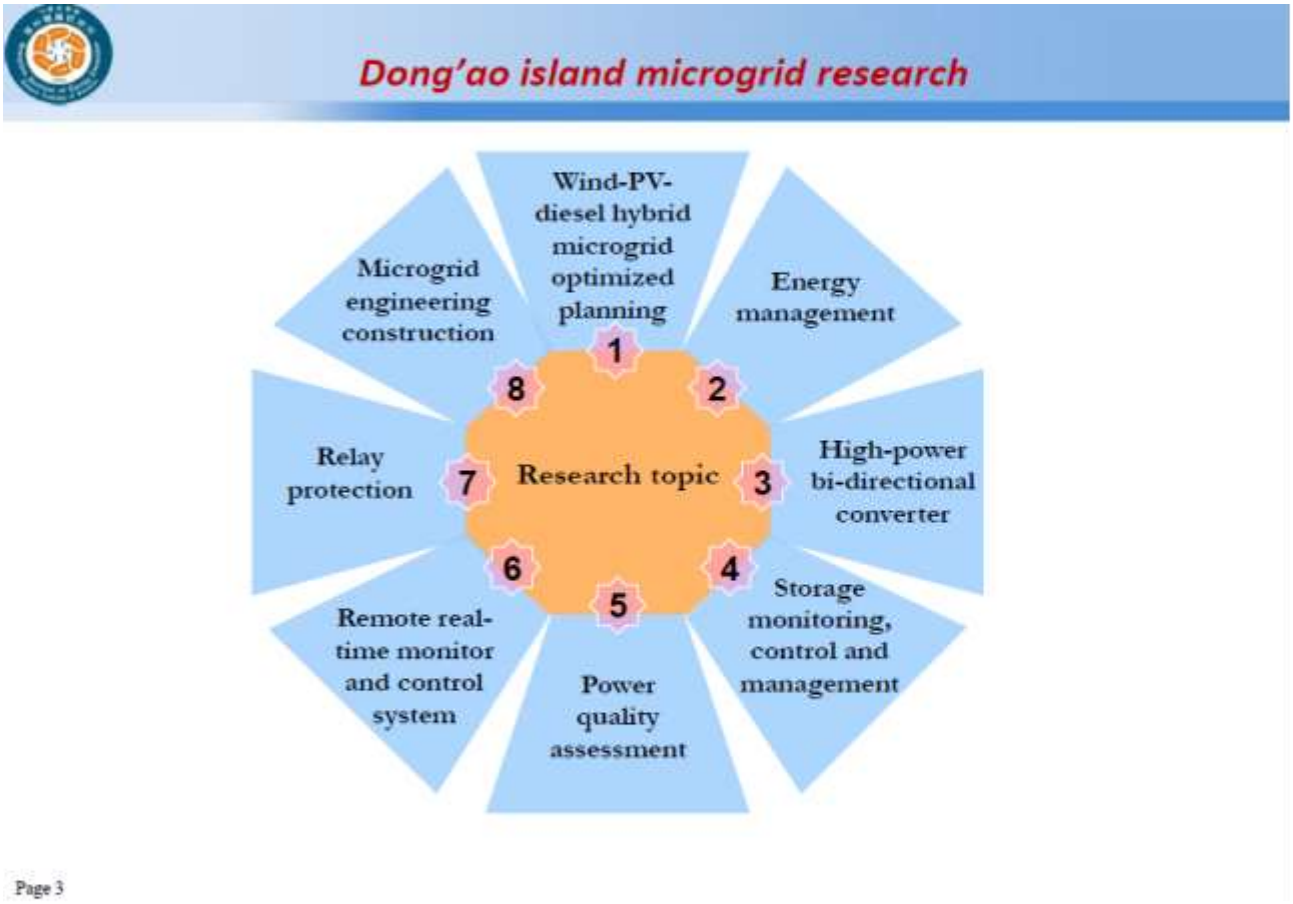

圖36 東澳島微電網研究議題

圖37 東澳島 BIPV

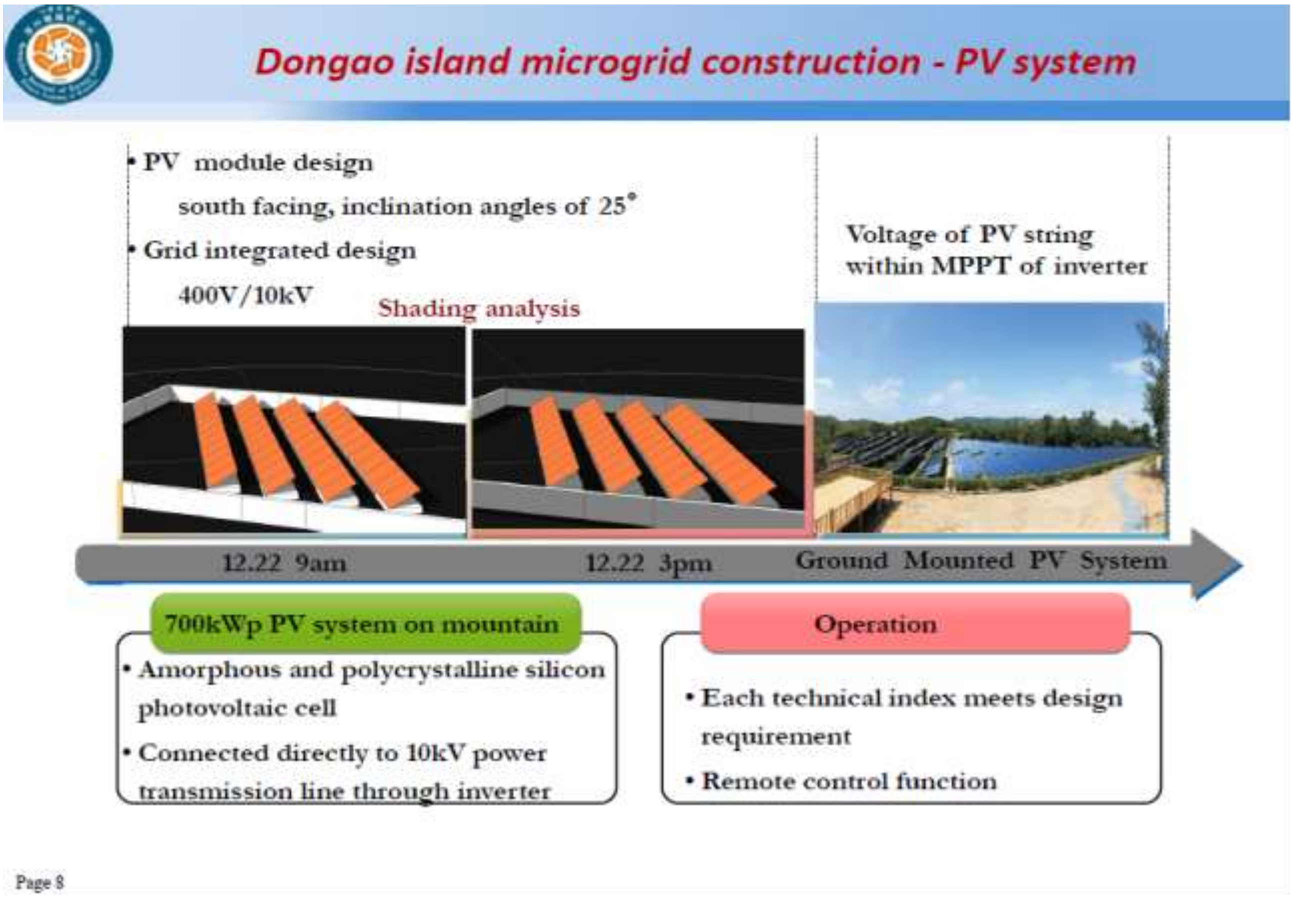

圖38 東澳島 PV

圖39 東澳島風力發電機

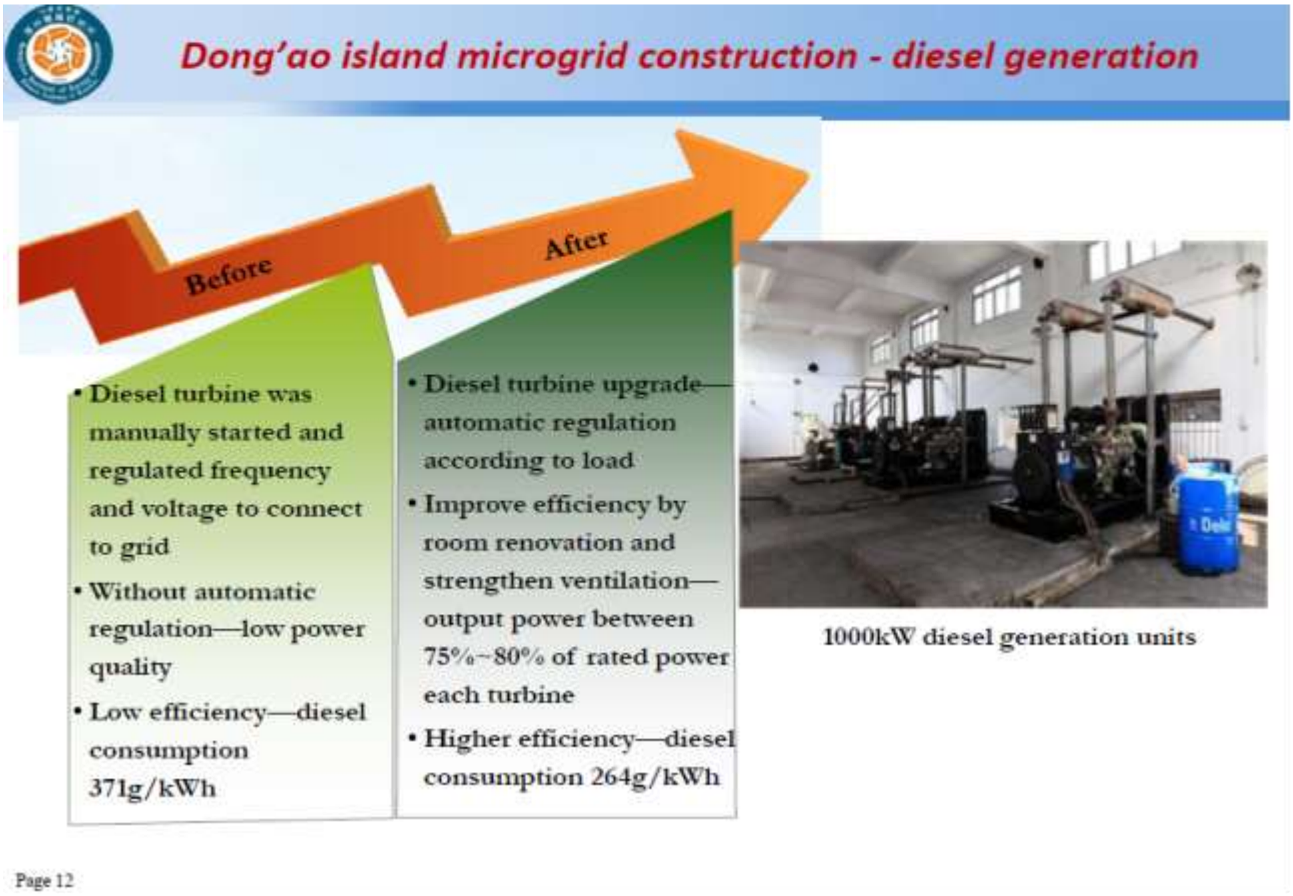

圖40 東澳島柴油發電機

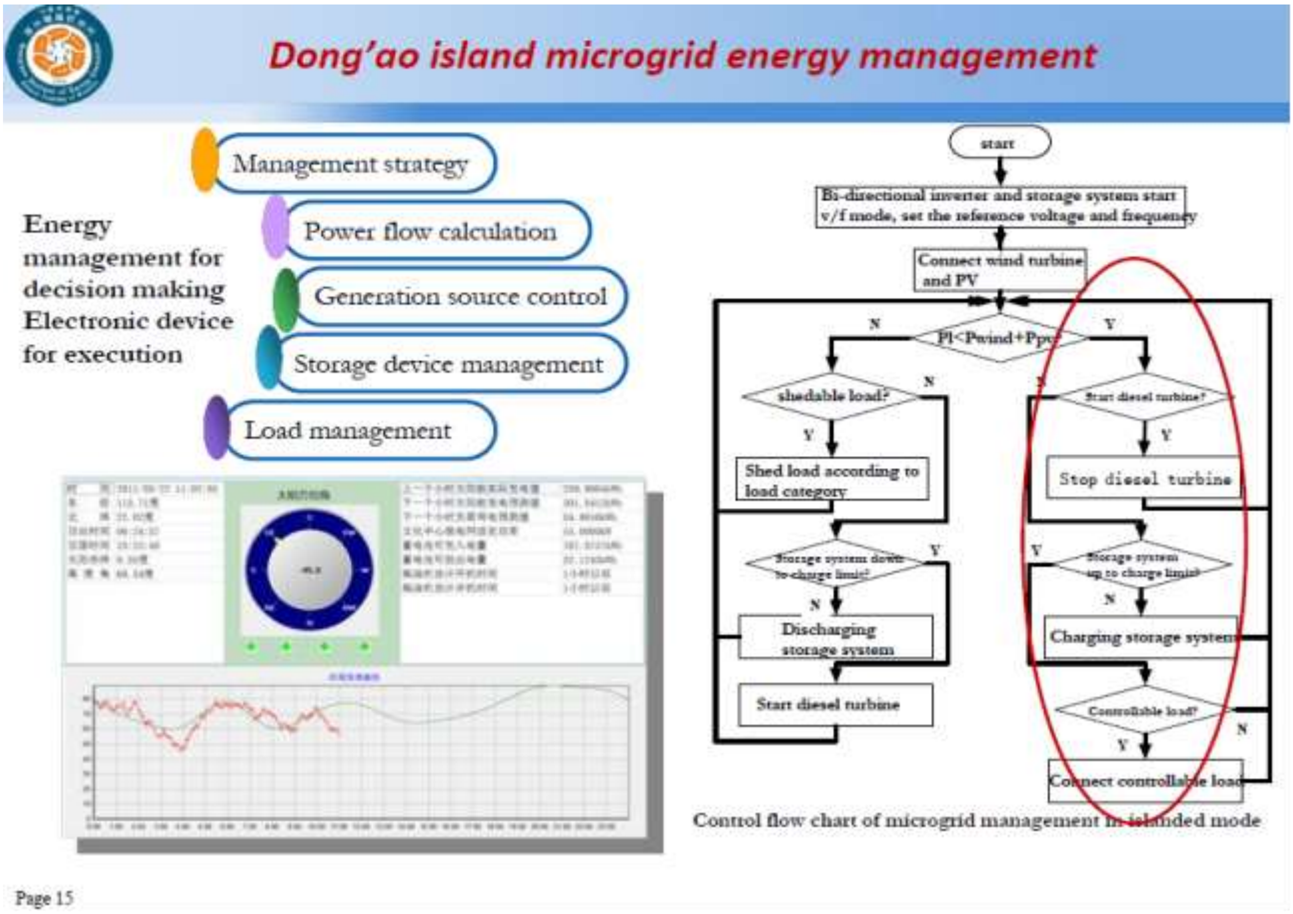

圖41 東澳島微電網能源管理系統(1/2)

Dong'ao island microgrid energy management

- **Load management**
  - ➢ Generation and load balance
  - ➢ Load forecast
- **Generation management**
  - ➢ PV generation forecast
  - ➢ Statistic method (with or without numerous weather predictions)
  - ➢ Local forecast
- **Renewable energy generation monthly penetration in 2012**
  - ➢ Every month was more than 50%
  - ➢ Up to 90%
  - ➢ Average was more than 70%

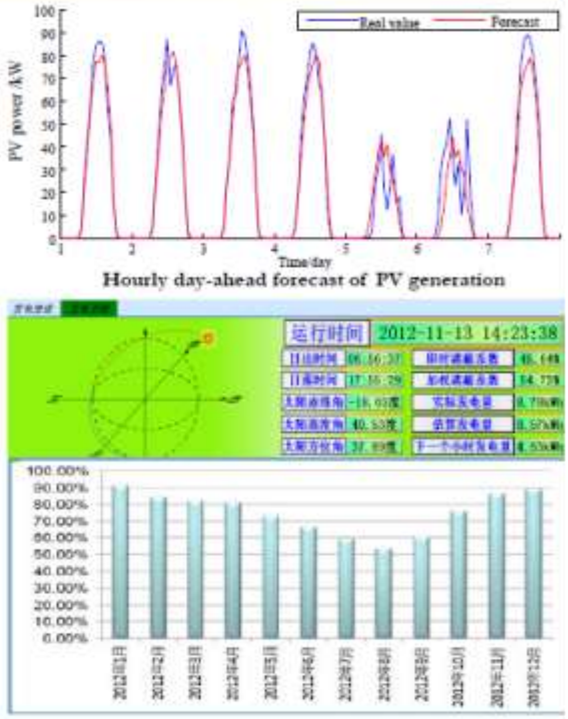

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圖42 東澳島微電網能源管理系統(2/2)

High-power bi-directional converter

- **Topology**
- **Control strategy**
  - ➢ Base on DSP controller TMS320F28335
  - ➢ Phase-locked control
  - ➢ Voltage waveform control
- **Characteristics**
  - ➢ Working at rectification and inverter circuit
  - ➢ Topology
  - ➢ Adapt to balance/unbalance and Linear/nonlinear load
  - ➢ Good waveform of voltage and current
  - ➢ Easy to realize
  - ➢ Efficiency above 95%
  - ➢ Capacity: 100kW, 500kW

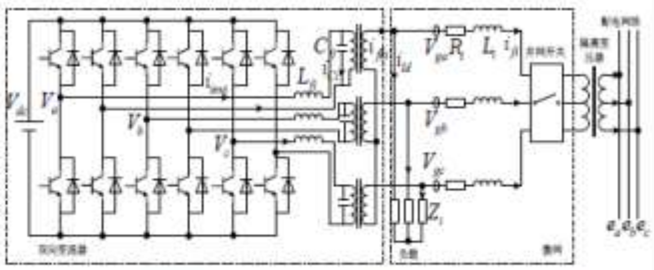

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圖43 東澳島雙向轉換器

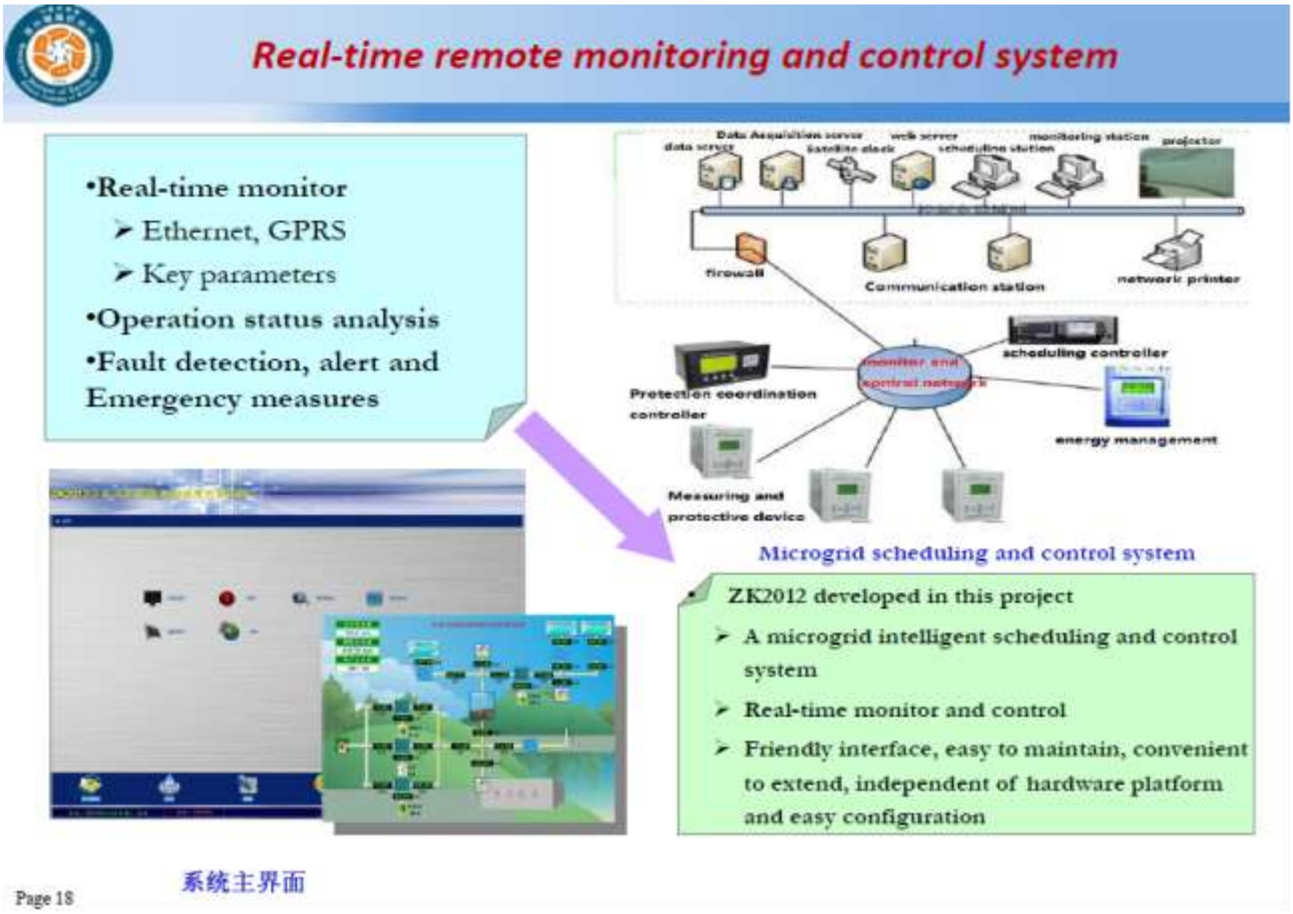

圖44 東澳島微電網遠端即時監控系統(1/2)

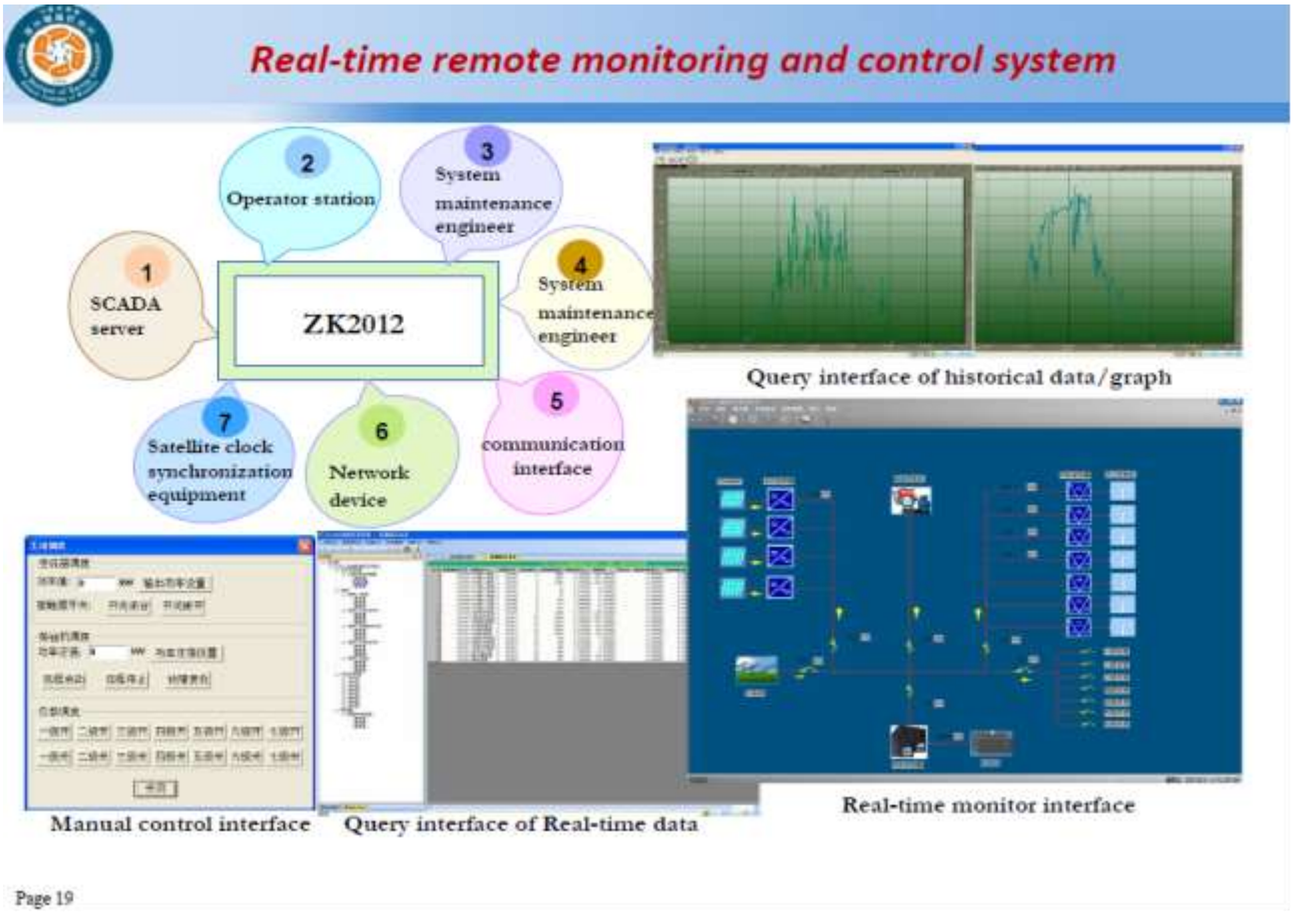

圖45 東澳島微電網遠端即時監控系統(2/2)

(4) 新加坡－烏敏島微電網試驗場

烏敏島微電網試驗場是由 Daily Life Renewable Energy Pte. Ltd(DLRE)的 Markson Tang 進行簡報(圖 46)，烏敏島微電網試驗場為一 240 V 地下電纜系統，約 100 kWp 太陽能發電、1,000 kWh 儲能系統、6 台 40 kVA 的 Hybrid Variable-Speed Generators，於微電網建置前烏敏島電力供應情形如圖 47 所示，烏敏島的第一階段已於 Jetty Area 建置微電網(圖 48)，並完成太陽光電的建設(圖 49 至圖 50)，以供應夜間照明、抽水等用電。於 2013 年 10 月烏敏島有約 30 人參加微電網試驗，且享受到更便宜與可靠的供電。而 2014 年 10 月烏敏島微電網試驗場正進行第二階段的計畫徵求書，著重於能源分析、儲能系統、能源管理系統與狀態監控等內容，此階段之計畫徵求書，台灣中興電工邀請本所一同參與，期能借重微電網相關技術與經驗，打入國際市場中。

圖46 Markson Tang 進行烏敏島微電網試驗場簡報

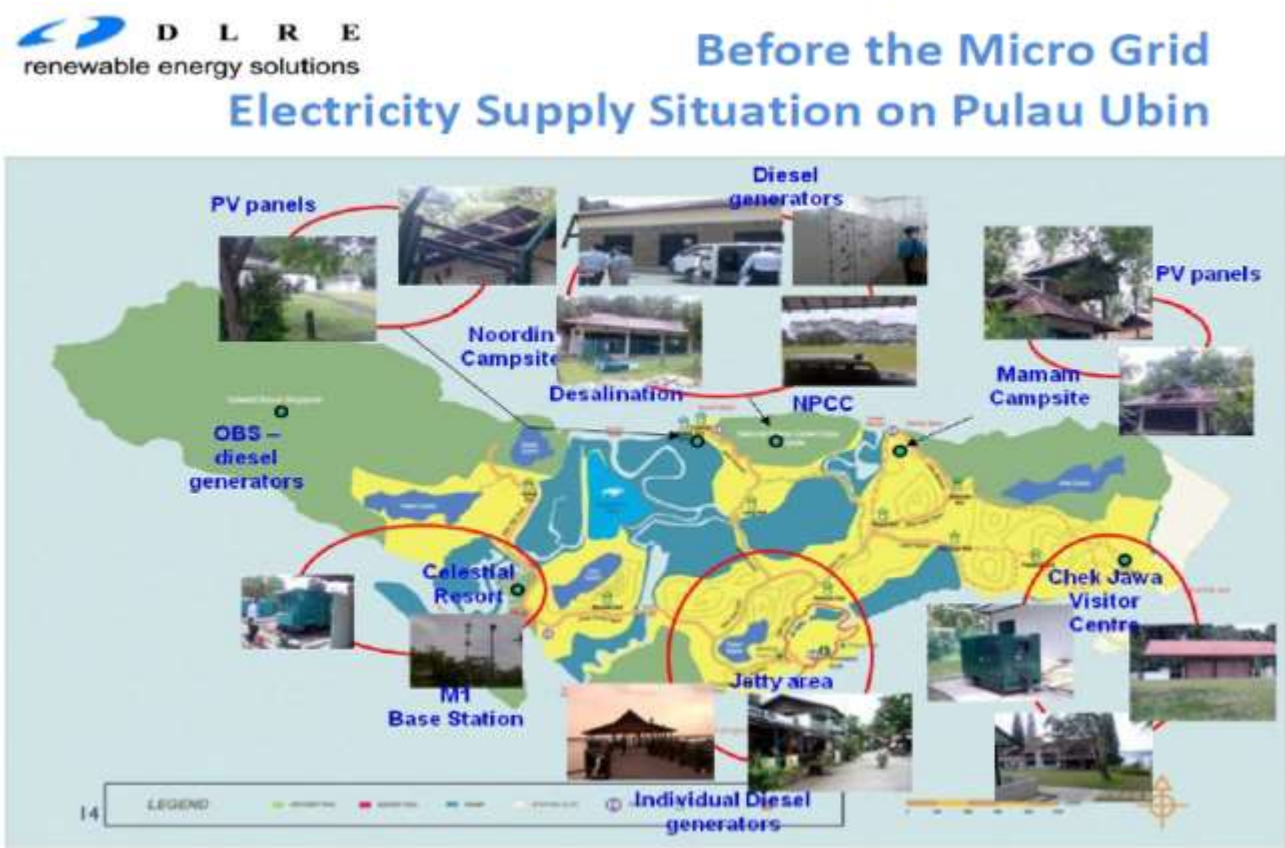

圖47 微電網建置前之烏敏島電力供應情形

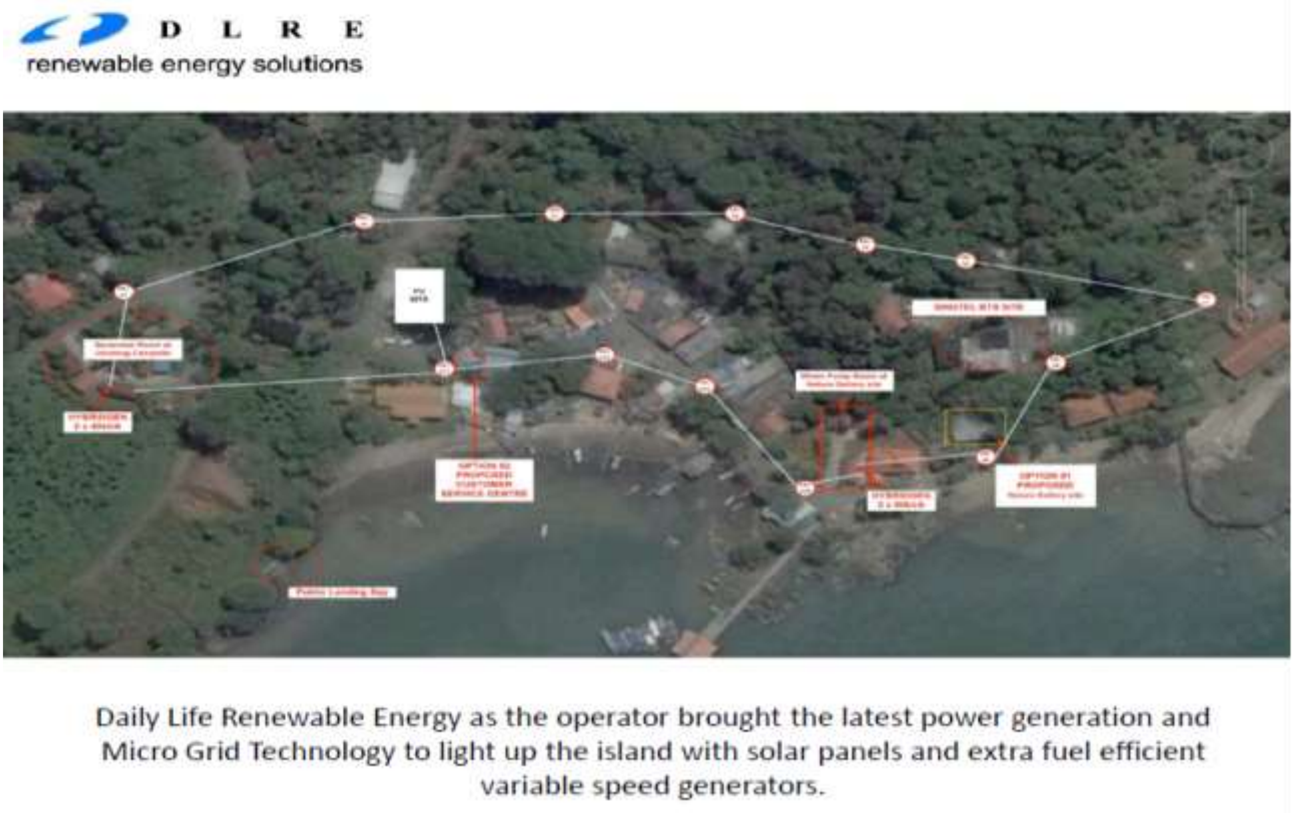

圖48 第一階段已於烏敏島的 Jetty Area 建置微電網

圖49 烏敏島之太陽光電的建設(1/2)

圖50 烏敏島之太陽光電的建設(2/2)

(5) 台灣－台灣微電網研發現況

台灣微電網研發現況是由本所張永瑞副組長進行簡報(圖 51 至圖 52)，介紹本所微電網目前的技術發展，以及台灣不同地區的微電網建置規劃，亦藉由海報形式介紹相關技術的研發成果(圖 53)，國外的專家學者都對於研究成果表示認同，且多有興趣至本所參觀與訪問，及進一步的合作開發，並於會場中與多位專家學者交換意見與未來規劃方向。相關之簡報與海報資料置於附錄中供參考。

圖51 張永瑞副組長進行台灣微電網研發現況簡報(1/2)

圖52 張永瑞副組長進行台灣微電網研發現況簡報(2/2)

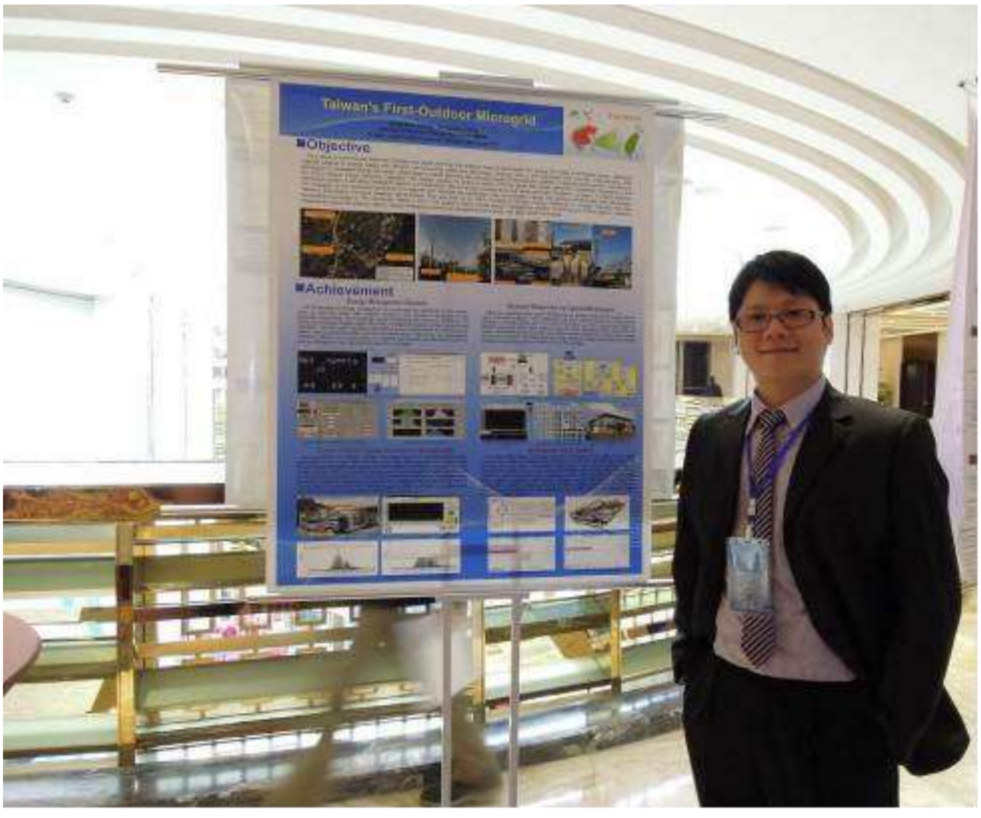

圖53姜政綸博士張貼本所微電網研發現況海報

2. 美洲地區：

(1) 美國微電網計畫與新澤西州 Hoboken 微電網系統

美國微電網計畫與新澤西州 Hoboken 微電網系統是由 Sandia National Laboratory 的 Ross Guttromson 進行簡報(圖 54)，首先進行美國微電網計畫的介紹，圖 55 為由美國能源部的 OE(Office of Electricity Delivery and Energy Reliability)、FEMP(Federal Energy Management Program)與 DOD 進行補助的微電網計畫分布圖，並提出 SPIDERS 計畫(Smart Power Infrastructure Demonstration for Energy, Reliability, and Security)(圖 56)，並規劃建置三個微電網場域，目前 Joint Base Pearl Harbor Hickam 與 Fort Carson 都已經完成，而 Camp Smith 將於 2015 年可進行展示。由於珊迪(Sandy)颶風對於新澤西州造成的影響，進而執行 NJ TransitGrid 與 Hoboken ESDM 計畫，如圖 57 所示，細節將於後描述。並提出微電網的價值屬性為能源效率、系統效率、可靠度、恢復力與安全等部分，如圖 58 所示。此外，並提出恢復力(Resilience)與可靠度(Reliability)的比較，如圖 59 所示，可靠度是固定的評估方式並與恢復速度有關，主要是評估對於系統的影響；而恢復力則需考慮到威脅、系統漏洞等風險，其主要評估是對於人類的影響。

珊迪(Sandy)颶風於 2012 年 10 月 22 日從開始到結束約莫 10 天，經過了古巴、海地、美國與加拿大等地，並對於各地造成嚴重影響，尤其是美國東岸各州造成百人以上的喪生，並使得地鐵交通設施、淹水、停電、資訊中斷等關鍵基礎設施被破壞，如圖 60 至圖 62 所示。因此導入微電網的方式對於 Hoboken 與 NJ TransitGrid 進行重建，且特別強調恢復力。於 Hoboken 微電網建置時，特別強調停電時要能恢復供電、維持 7 天的供電、市電異常需能轉成孤島運轉、太陽能發電與燃料電池能持續運作等重要項目(圖 63)，且微電網需滿足於淹水與停電情形下運轉，最後於 Hoboken 微電網採用雙微電網拓撲架構，圖 64 為架構圖，圖 65 為連接的方式。NJ TransitGrid 微電網系統之示意圖如圖 66 所示，除原有運輸系統的電力架構外，並新增微電網系統的電力網路與運輸系統連接，而微電網電力系統中也存在大量太陽能發電、電動車、燃料電池等再生能源與分散式能源，便可避免市電異常無法使用。NJ TransitGrid 微電網系統建置的前後差異如圖 67 與圖 68 所示，可看出新增微電網輸送電力，提高運輸系統的供電恢復力與可靠度。

圖54 Ross Guttromson 進行美國微電網計畫與新澤西州 Hoboken 微電網系統簡報

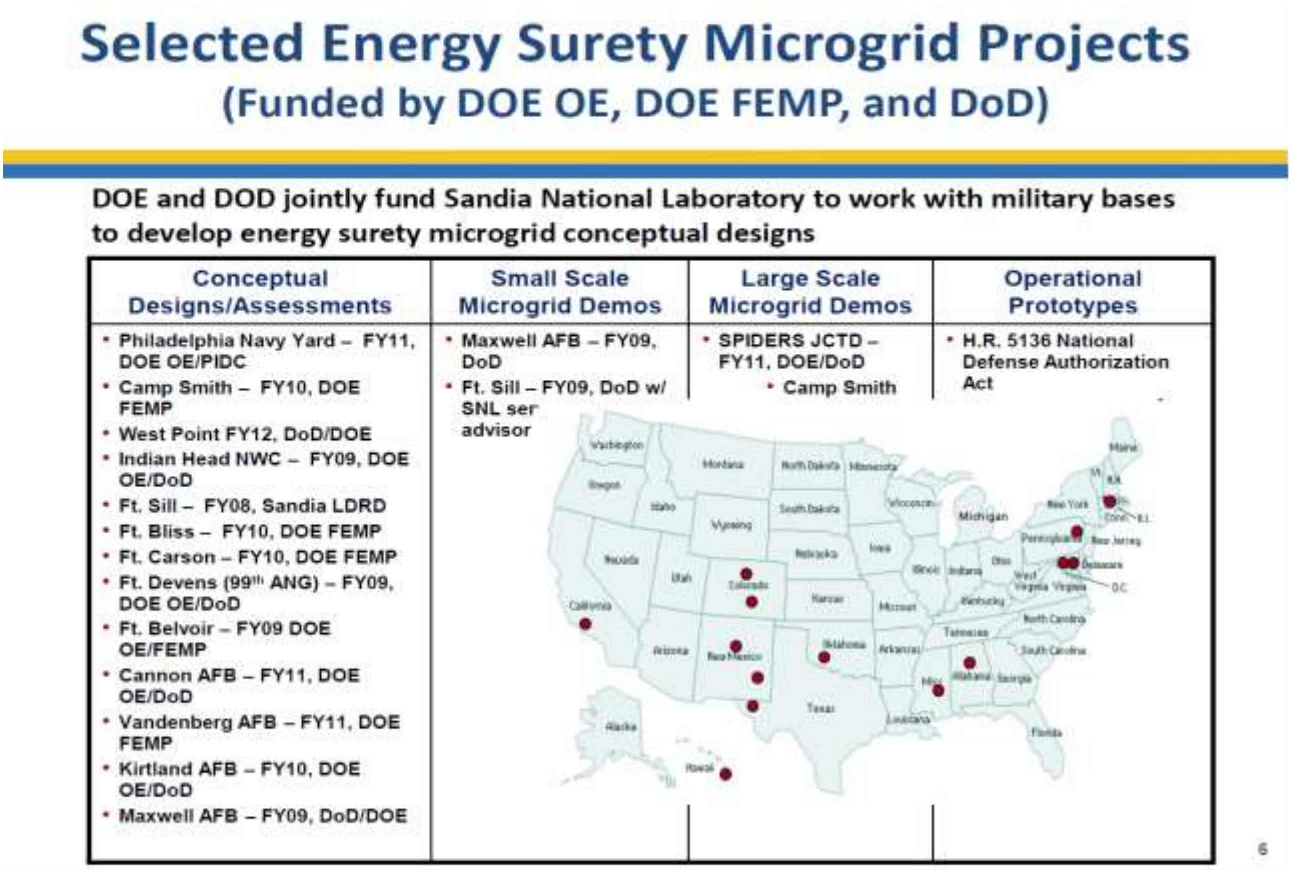

圖55 美國微電網計畫分布圖(受 DOE 或 DOD 補助)

Smart Power Infrastructure Demonstration for Energy, Reliability, and Security (SPIDERS)

- SPIDERS is building three microgrids, each with increasing capability, which will function as permanent energy systems for their sites
  - Site 1 (Joint Base Pearl Harbor Hickam) is complete
  - Site 2 (Fort Carson) is complete
  - Site 3 (Camp Smith): completed preliminary design, demo in FY15
- The project will promote adoption of microgrid technology for DoD through:
  - Design and requirements methodology
  - Cyber security architecture

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圖56 美國 SPIDERS 微電網計畫

State Partnerships Supporting the CAP Strategy

(Rebuilding and Learning From Hurricane Sandy Memo)

NJ TransitGrid Project

- Microgrid to enhance grid-rail resiliency to serve over 900,000 riders/day
- Key evacuation service for Manhattan & N. New Jersey
- MOU between DOE and State of NJ
- **Completed the feasibility study of a microgrid to fortify the public transportation network**

Hoboken ESDM Project

- Provide electrical power to support critical functions up to 7 days for 52,000 residents in 1.2 sq. mi.
- Key evacuation route for Manhattan
- DOE-Hoboken-BPU-Sandia-PSEG Partnership
- **Completed a microgrid conceptual design for Hoboken, NJ, to enhance system resilience post-Sandy**

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圖57 NJ TransitGrid 與 Hoboken ESDM 計畫

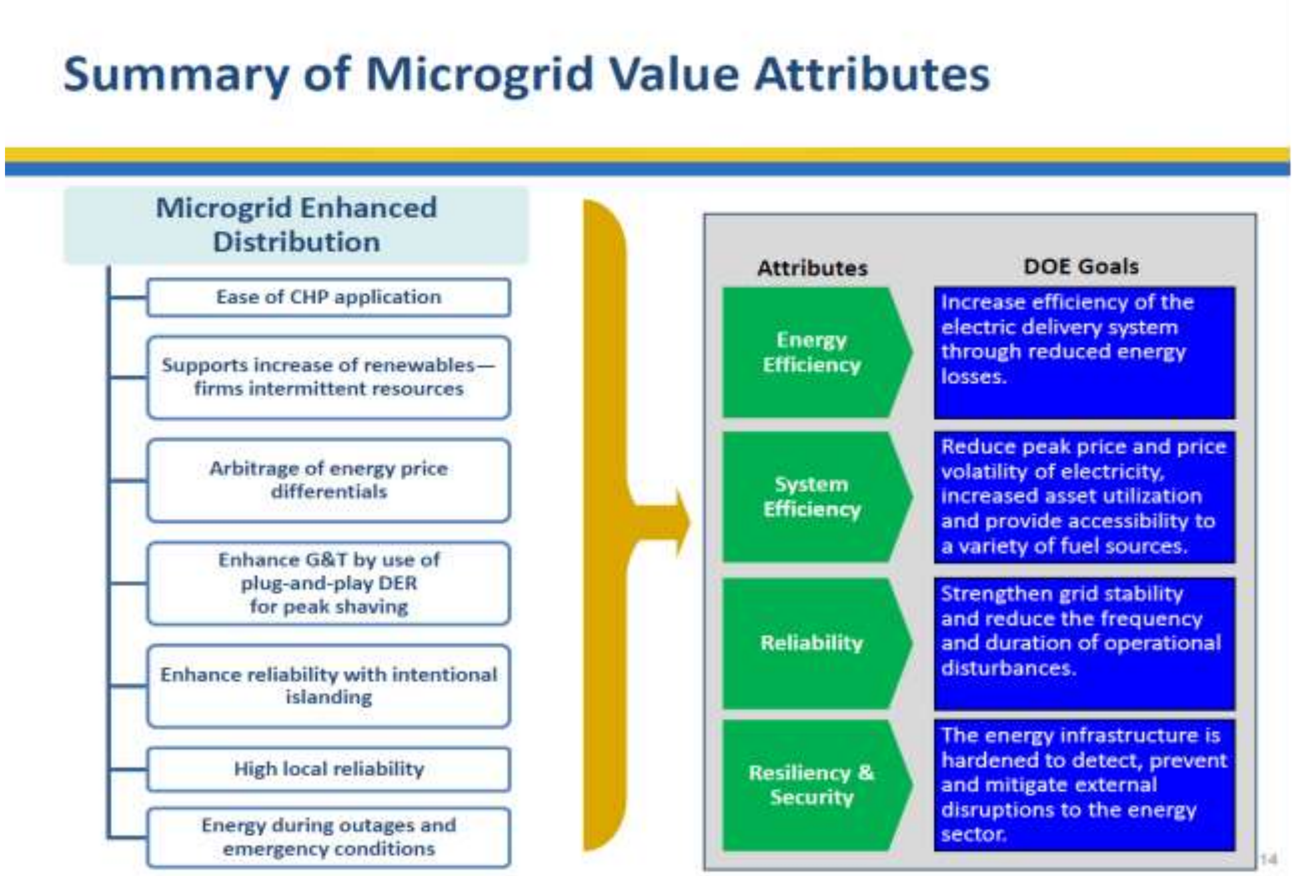

圖58 微電網的價值屬性

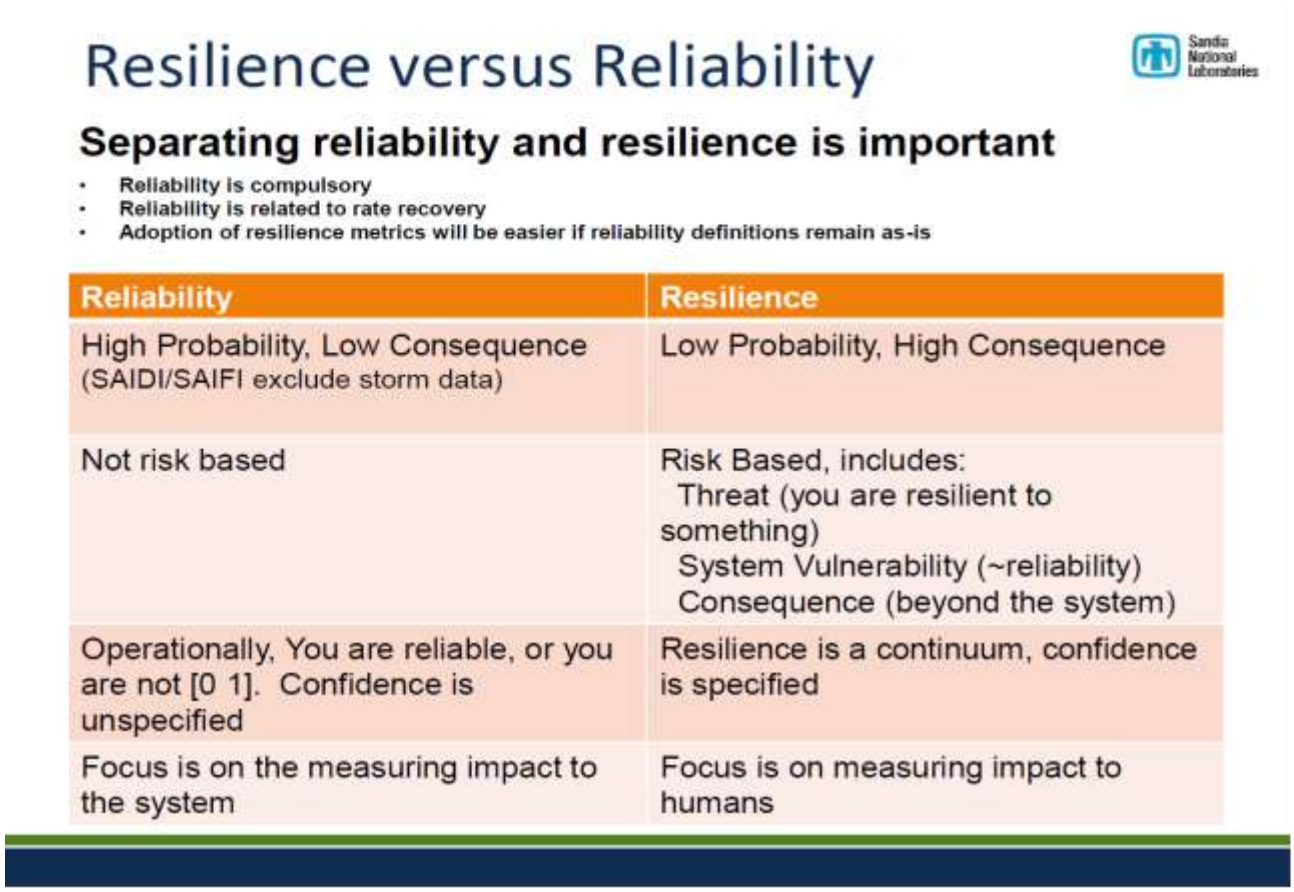

圖59 恢復力(Resilience)與可靠度(Reliability)的比較

圖60 2012 年 10 月珊迪(Sandy)颶風之路徑圖

圖61 珊迪(Sandy)颶風造成之影響

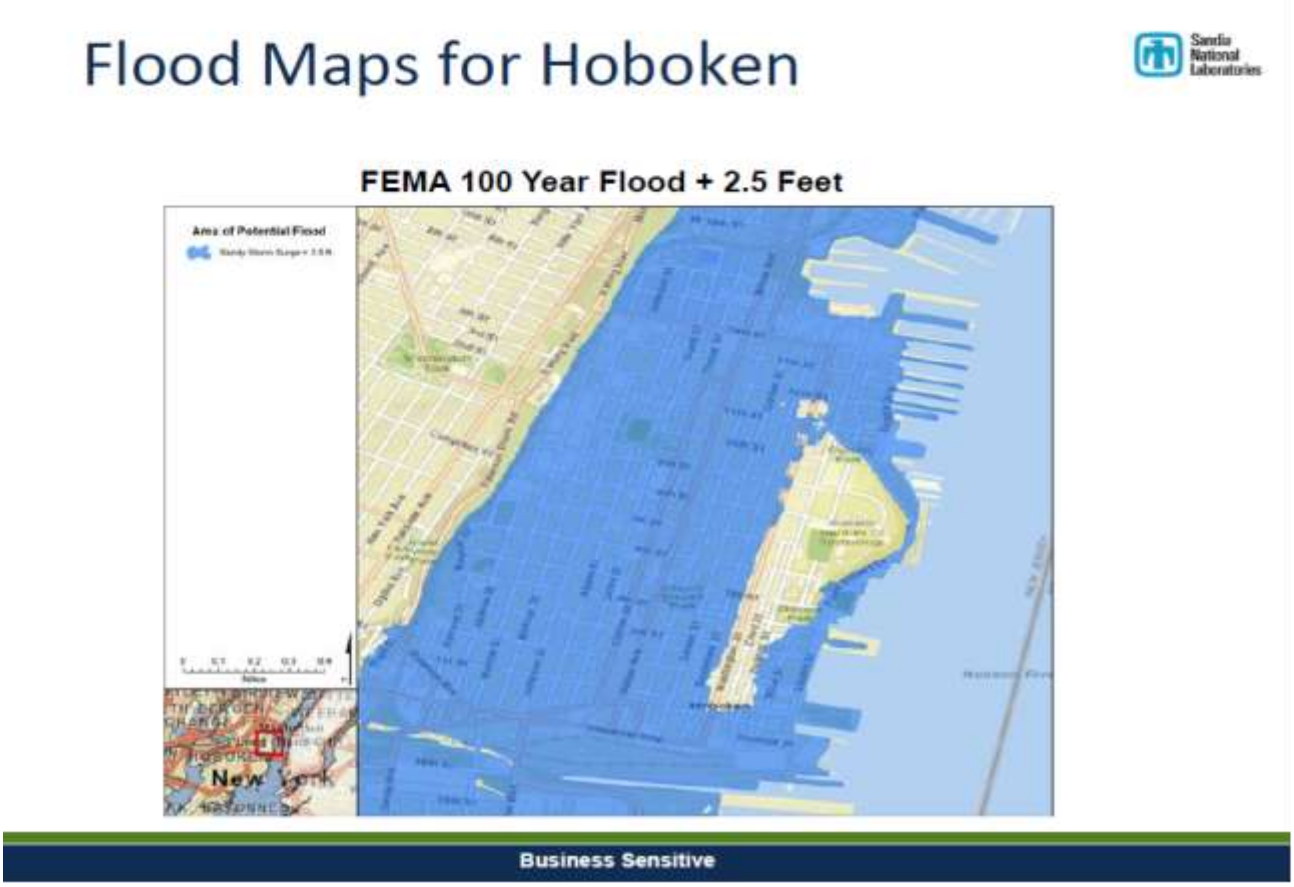

圖62 珊迪(Sandy)颶風造成 Hoboken 淹水的範圍

Hoboken Performance Objectives

Sandia National Laboratories

- Supply electric power to facilities during a blackout and/or a flooding condition at 19.5 feet above MSL.
- Microgrid must be able to supply power continuously for 7 days.
- Microgrid will be isolated from the utility when operating
- PV and CHP will operate continuously
- Ability to withstand loss of largest generator without loss of load in individual building or microgrids forming clusters of buildings

圖63 Hoboken 微電網之績效目標

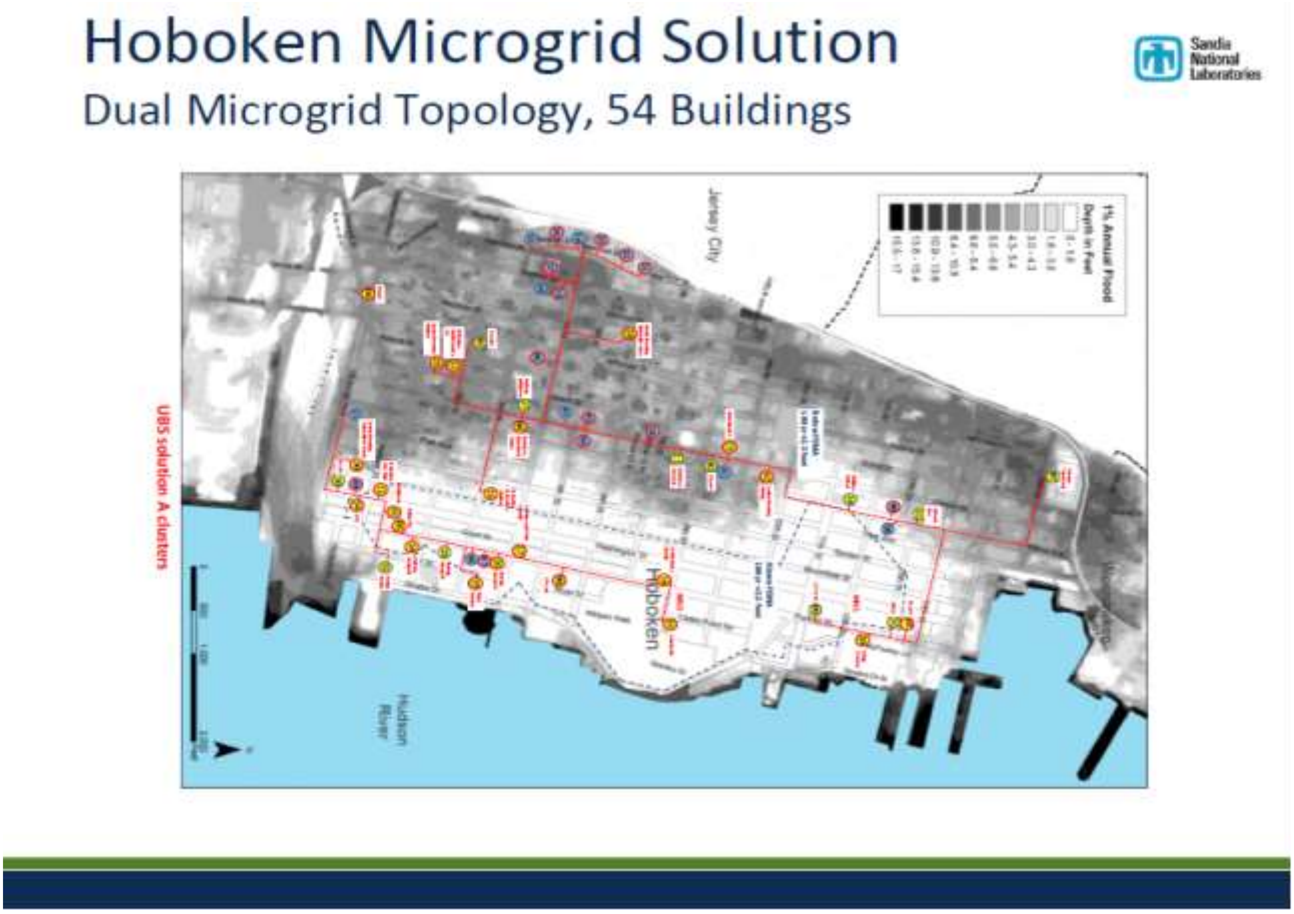

圖64 Hoboken 雙微電網拓撲架構

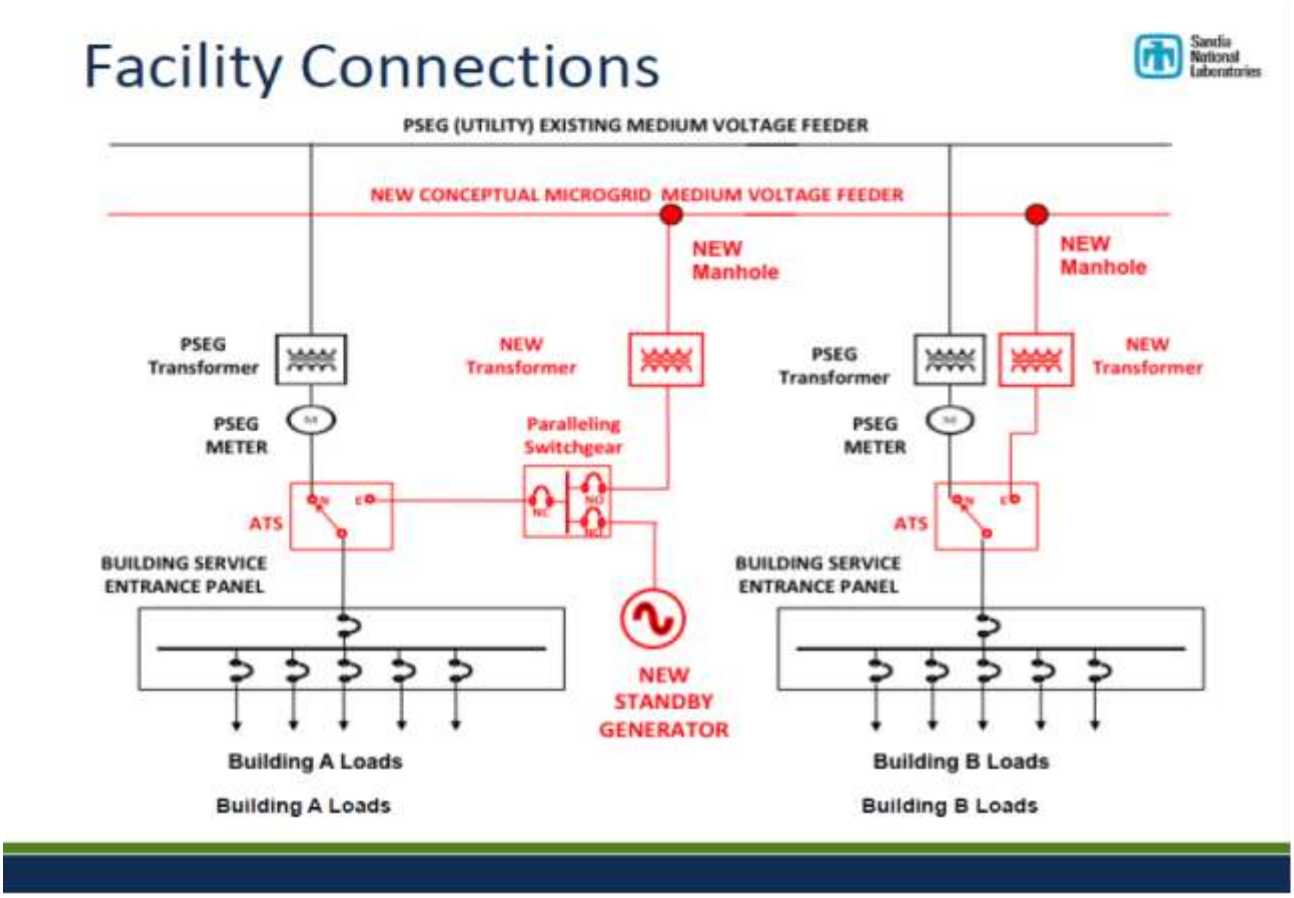

圖65 Hoboken 微電網連接方式

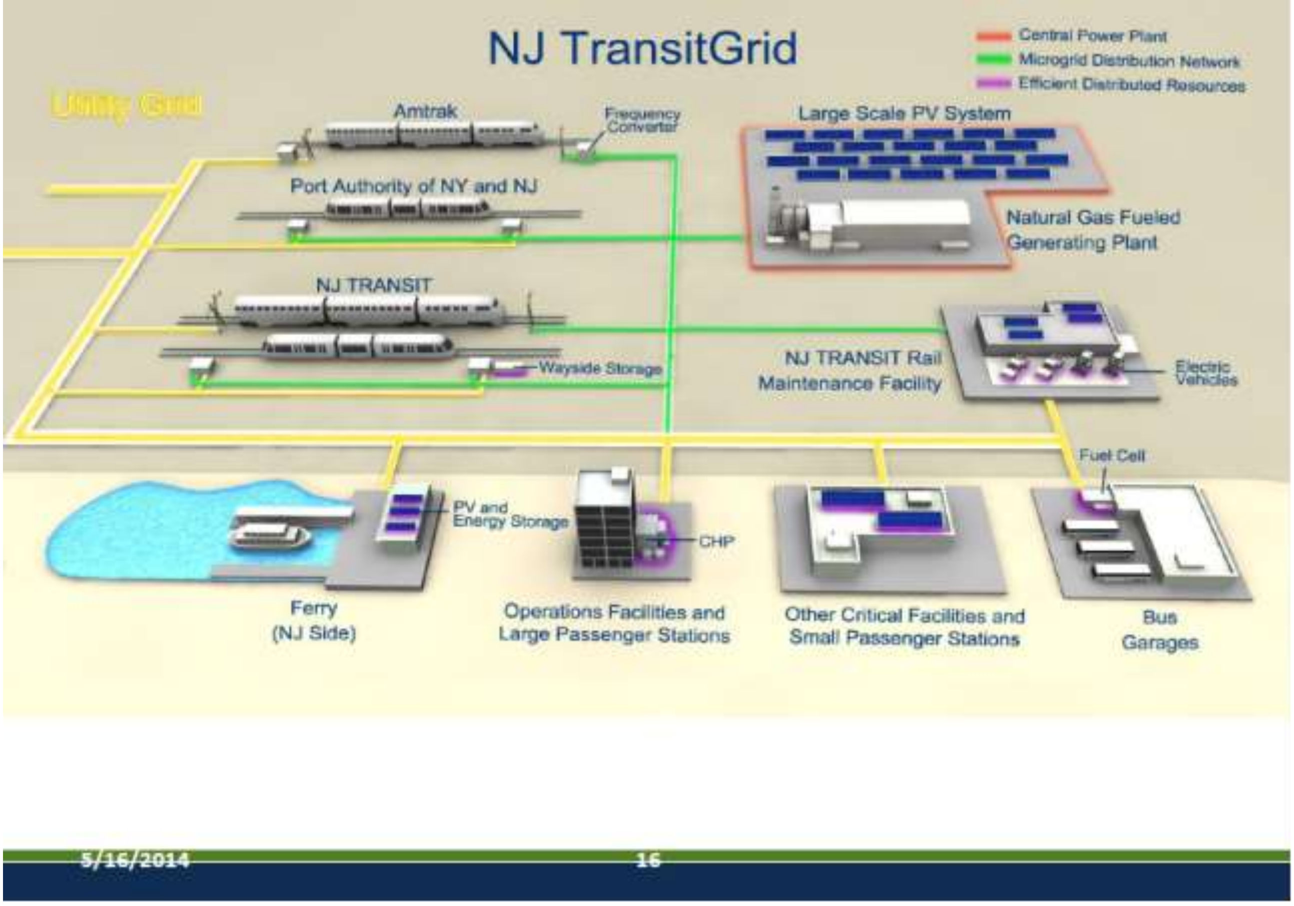

圖66 NJ TransitGrid 微電網系統示意圖

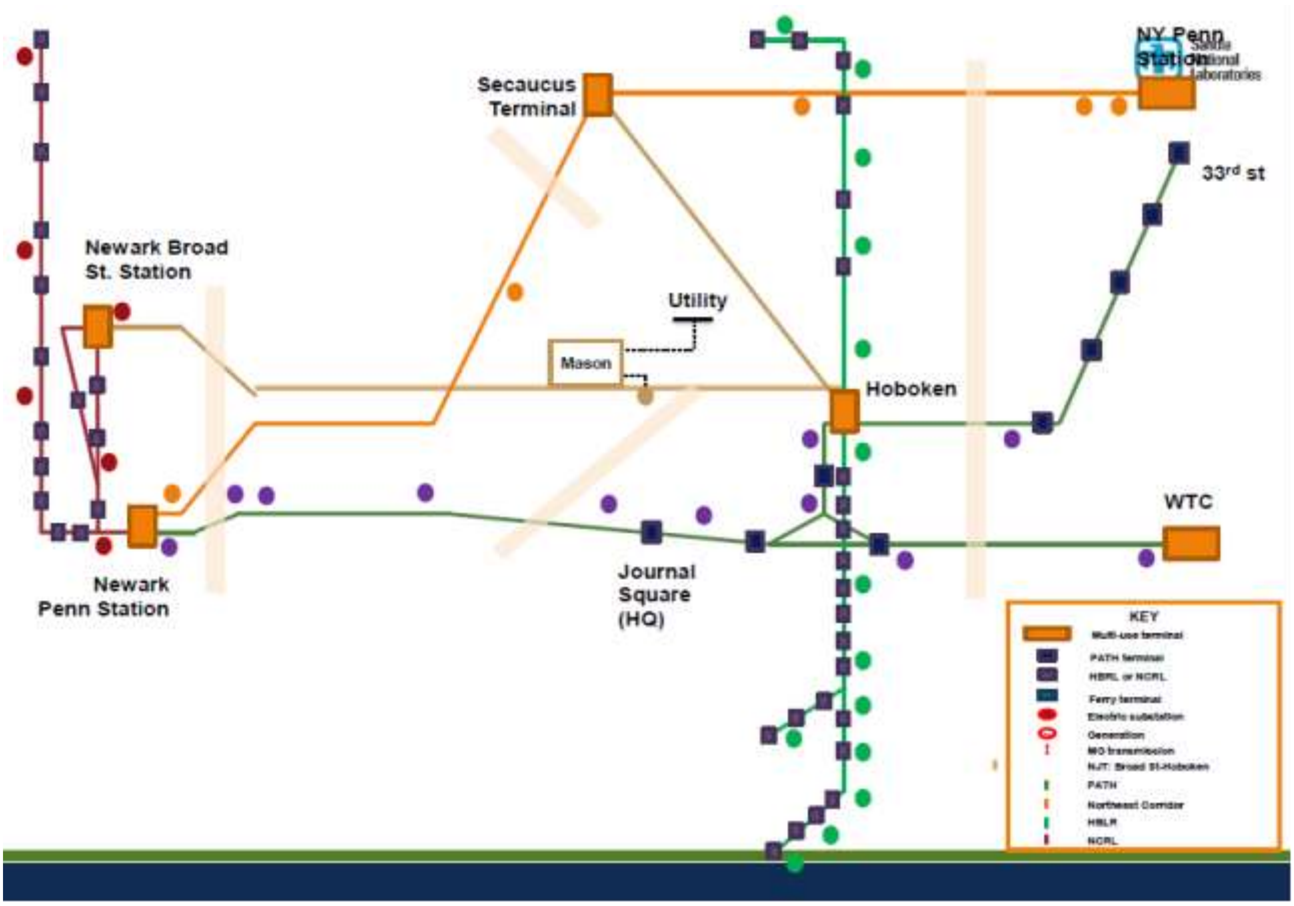

圖67 NJ TransitGrid 微電網系統(建構前)

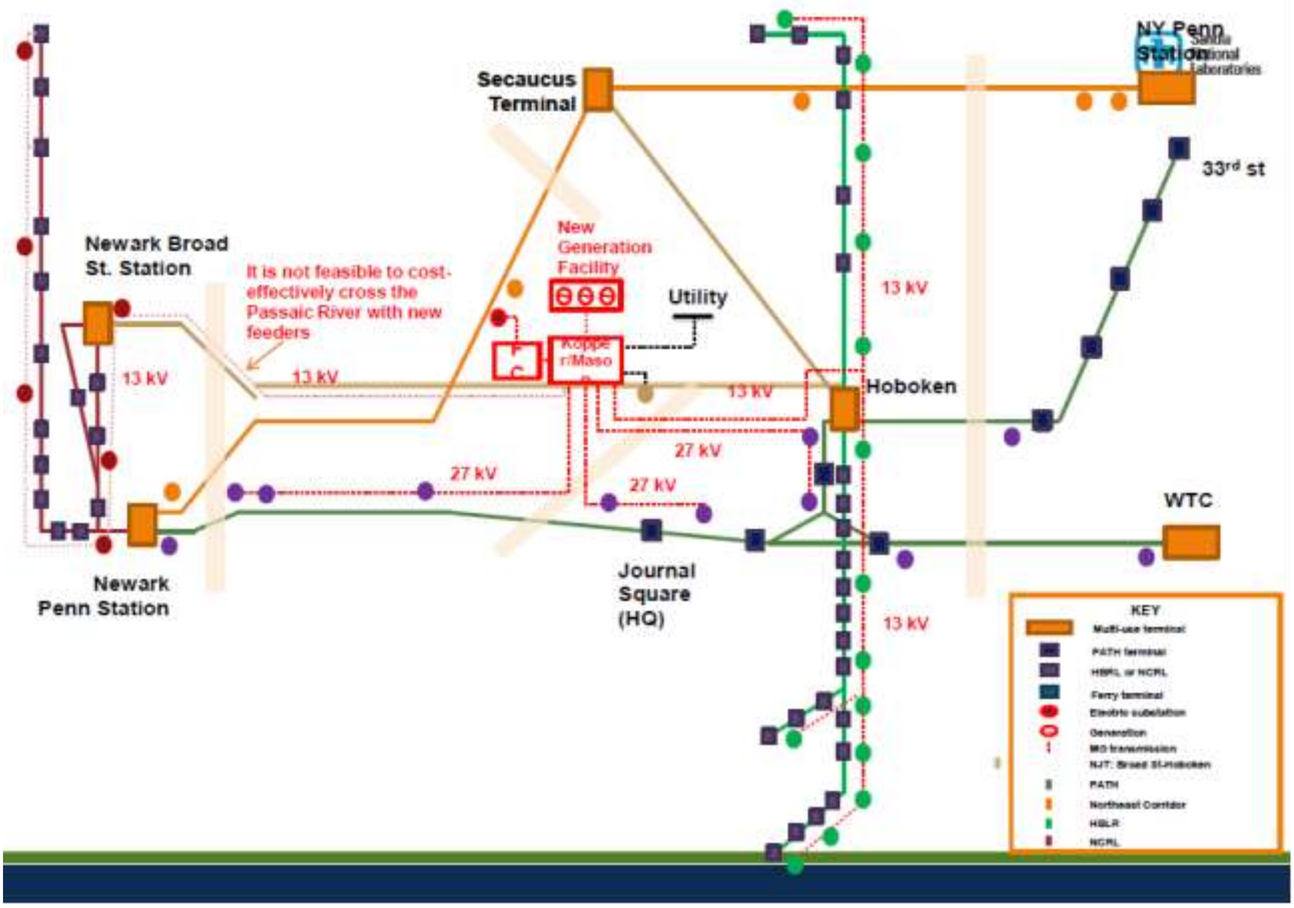

圖68 NJ TransitGrid 微電網系統(建構後)

(2) 拉丁美洲之微電網研發現況

拉丁美洲之微電網研發現況是由智利大學的 Guillermo Jiménez Estévez 教授進行簡報(圖 69)，介紹拉丁美洲的用電覆蓋率，如圖 70 所示，以現況而言仍有許多地區無電可用，為了能夠使人民有電可用，已在 12 處地區進行微電網的開發(圖 71)，較去年多增加了 3 處，且提出智利有多達 79 處適合發展獨立型微電網(圖 72)。而在智利的 Huatacondo 正進行微電網的測試，目前已開發監控介面、能源管理系統、微變壓器、及電動車等系統與設備，如圖 73 至圖 76 所示，且進行微電網的模式切換與運轉測試，如圖 77 至圖 79 所示。整體而言，拉丁美洲的微電網技術落後於我國，微電網與再生能源相關技術仍處於剛發展的階段。

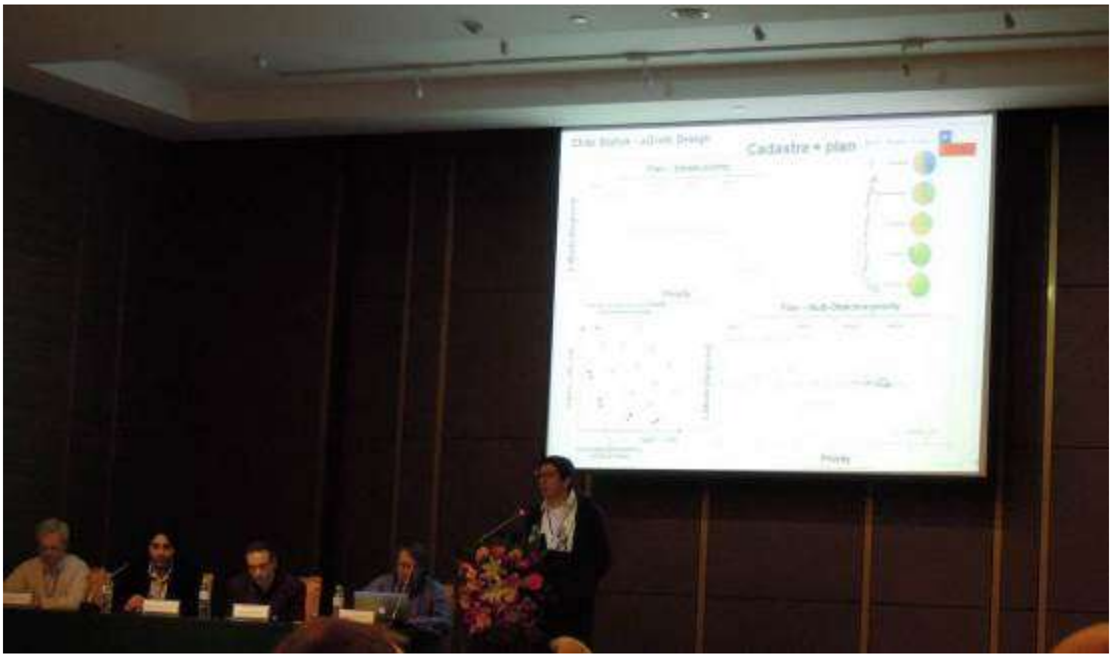

圖69 Guillermo Jiménez Estévez 進行拉丁美洲之微電網研發現況簡報

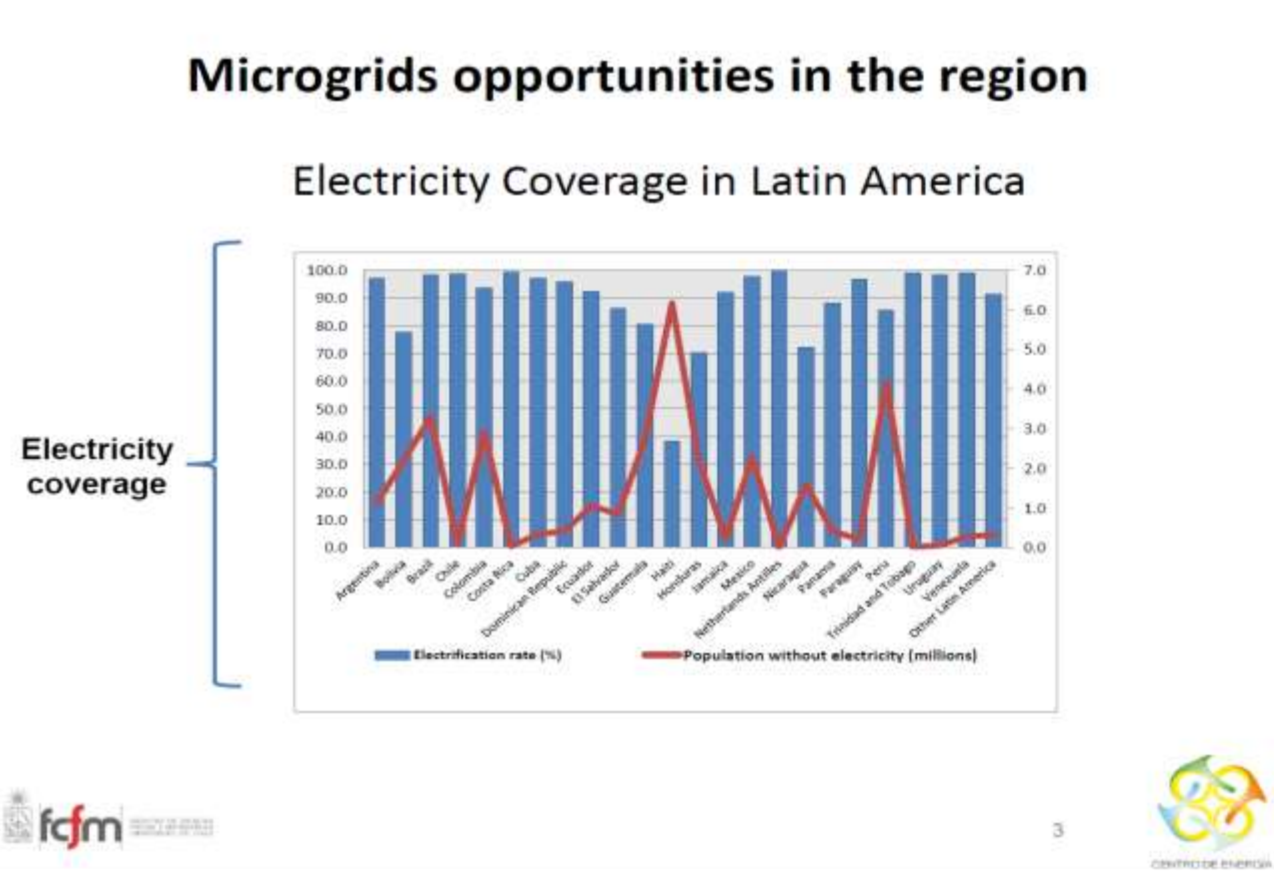

圖70 拉丁美洲的用電覆蓋率

圖71 拉丁美洲進行微電網開發的地區

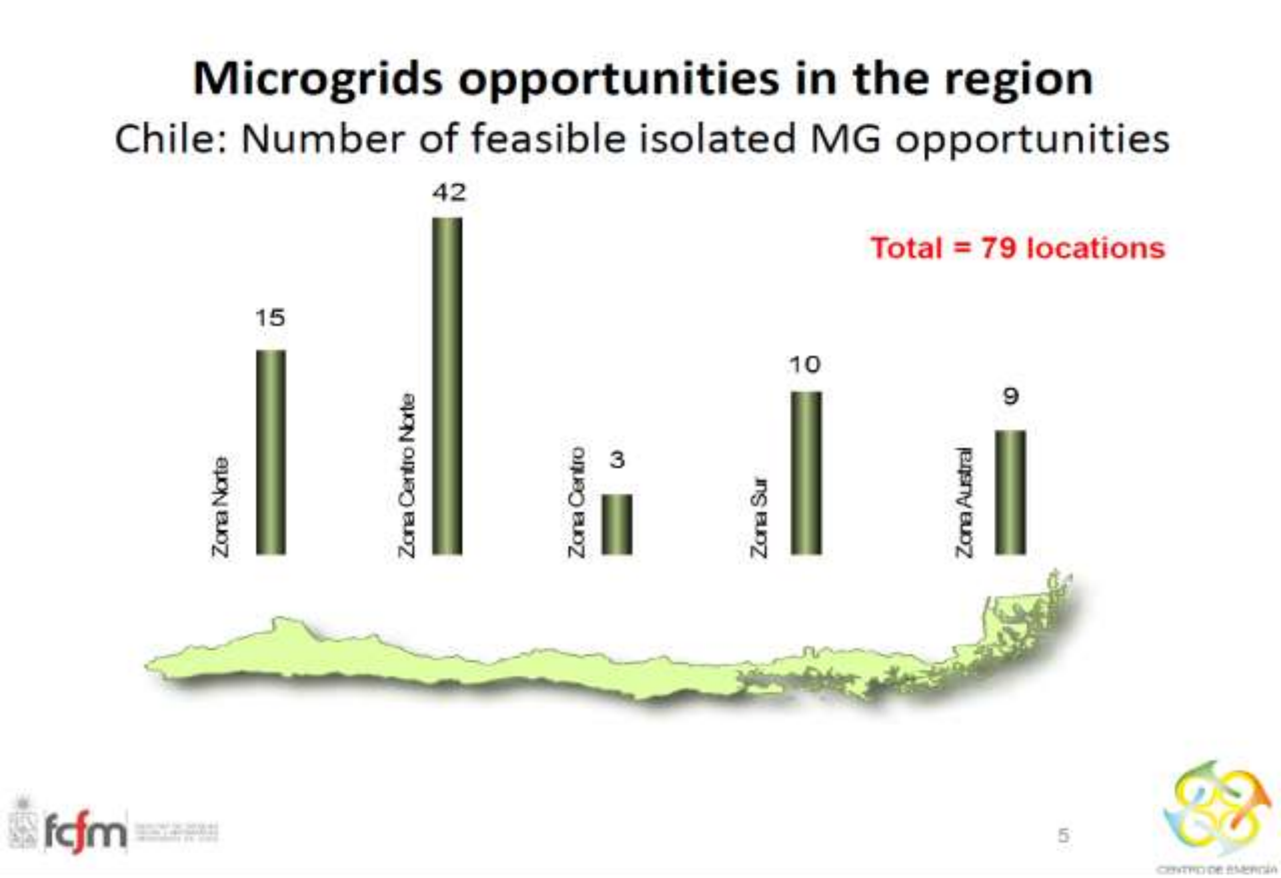

圖72 智利適合發展獨立型微電網的數量

Control software — Huatacondo

.NET application-> "Operación Huatacondo"

µGrid monitoring and control

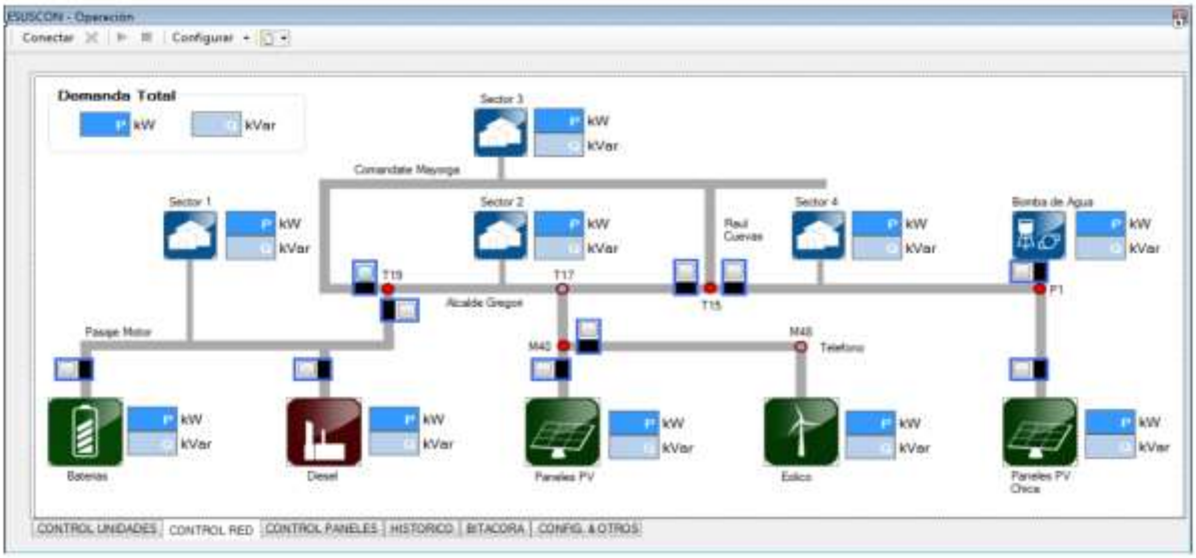

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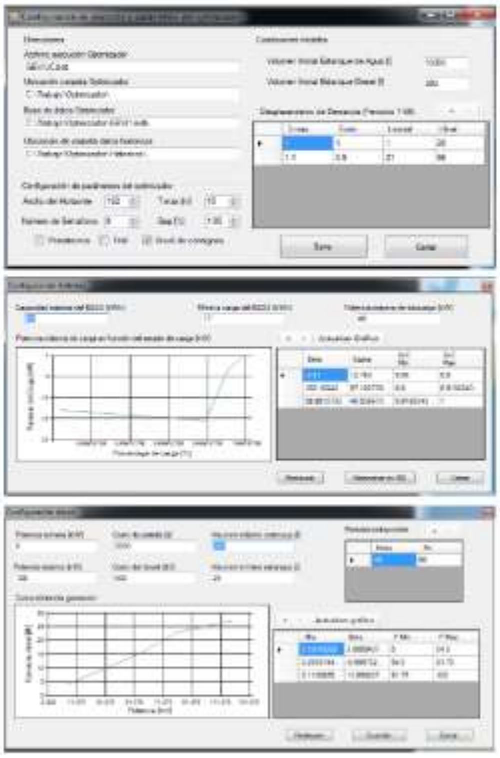
圖73 Huatacondo 的微電網監控介面

Control software — Huatacondo

EMS Software



General configuration:
- DBs
- Optimization parameters
- DSM parameters

BESS configuration:
- Load curve
- Pmax, Cap (Ah), Efficiency

GenSet configuration:
- Consumption curve
- Pmax, Pmin
- Star-up costs, Diesel
- Operational constraints
- Diesel fuel storage

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圖74 Huatacondo 的微電網能源管理系統

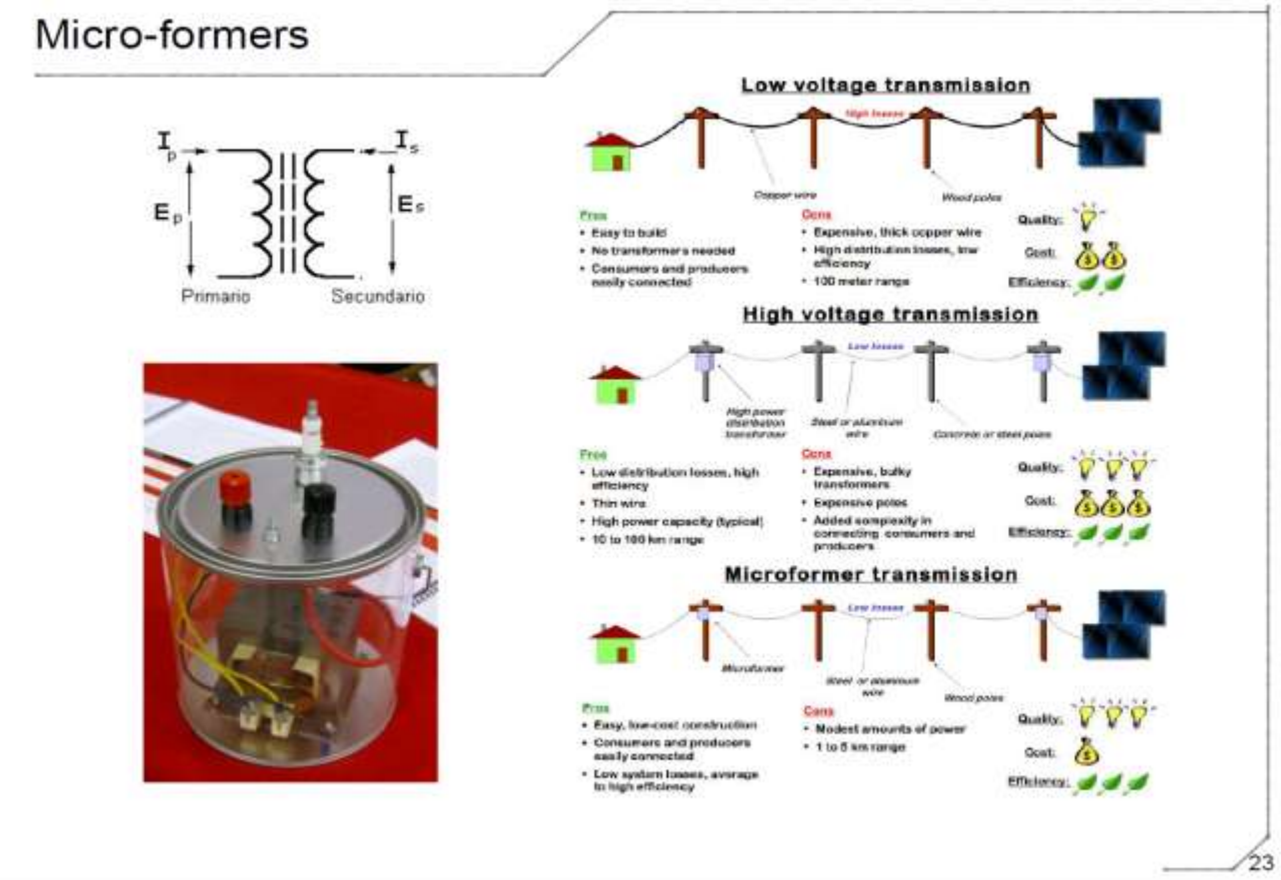


圖75 自行開發之微變壓器

圖76 自行開發之電動車

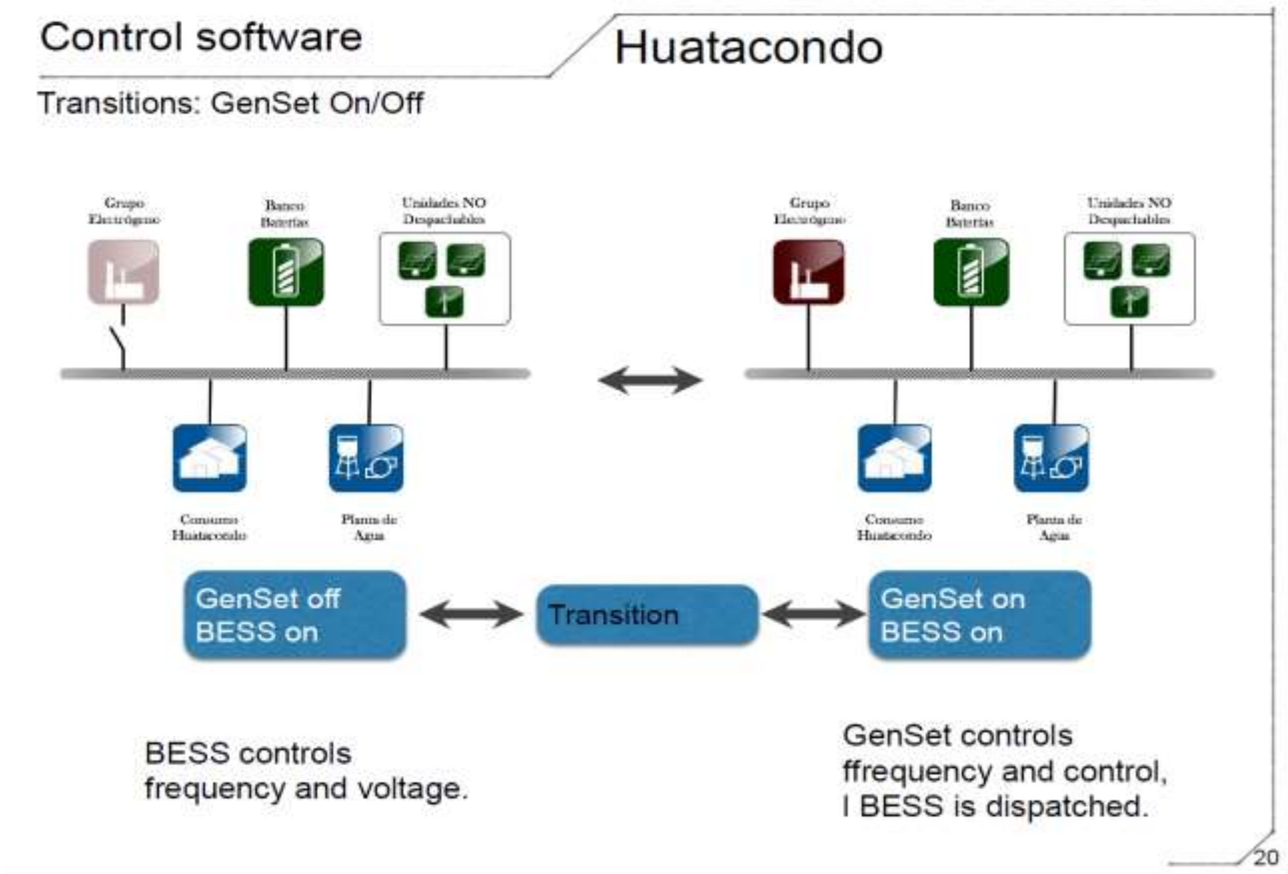


圖77 微電網轉態切換示意圖

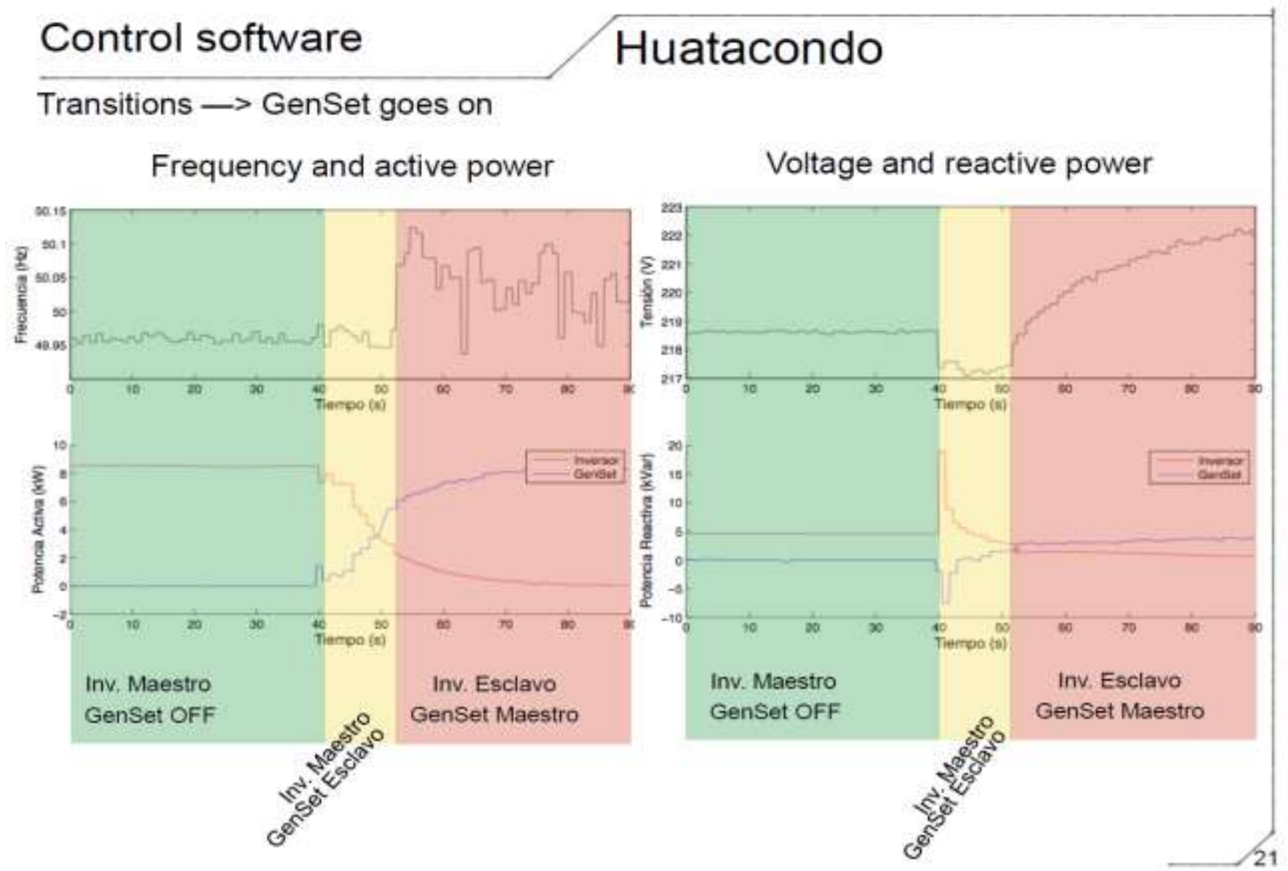


圖78 微電網轉態切換測試

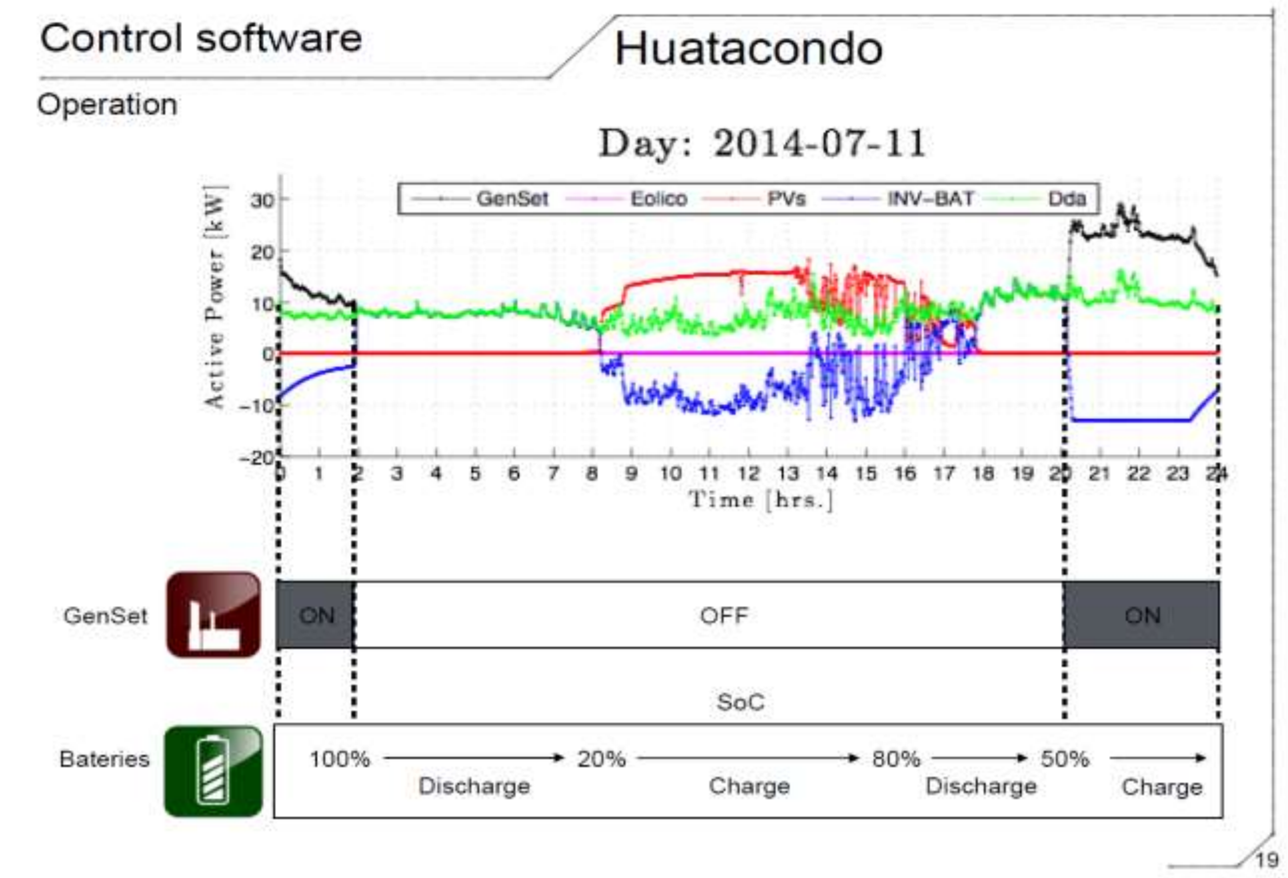


圖79 Huatacondo 的微電網運轉測試

3. 其他地區：

(1) 中部非洲－Chad 太陽光電微電網示範場域

中非 Chad 太陽光電微電網示範場域是由 Trama TecnoAmbiental(TTA)的 Xavier Vallvé 進行簡報(圖 80)，TTA 預計於 2012 年至 2015 年間於 5 個村落建立微電網，目前已於 2014 年 6 月完成 Chad 的 Mombou 村落之微電網建設，該村落是屬於偏遠落後的地區(圖 81)，預估負載量如圖 82，該微電網系統容量不大，其設計圖如圖 83 至圖 85 所示。當建置完成太陽光電、電池、柴油發電機等設備(圖 86 至圖 87)，其完成後之負載、再生能源與電池 SOC 曲線如圖 88 所示，當白天有太陽能發電且電池 SOC 接近 100 %時，則須放棄再生能源的使用，以避免電池過度充電的問題，且藉由此微電網系統的建立，已使當地即便晚上也有路燈可使用(圖 89)，TTA 確實推廣微電網到偏遠有需求的地區。

圖80 Xavier Vallvé 進行 Chad 太陽光電微電網示範場域簡報

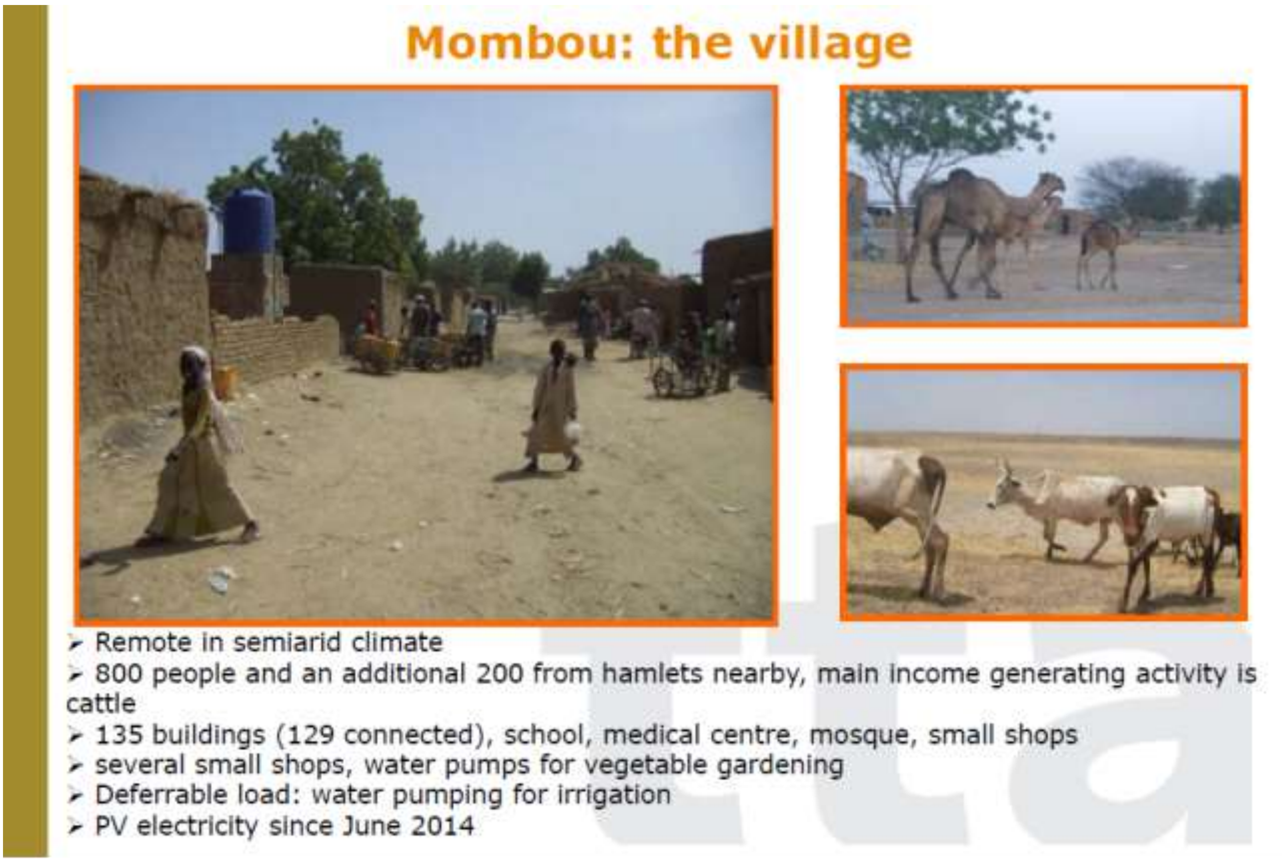


圖81 Chad 的 Mombou 村落簡介

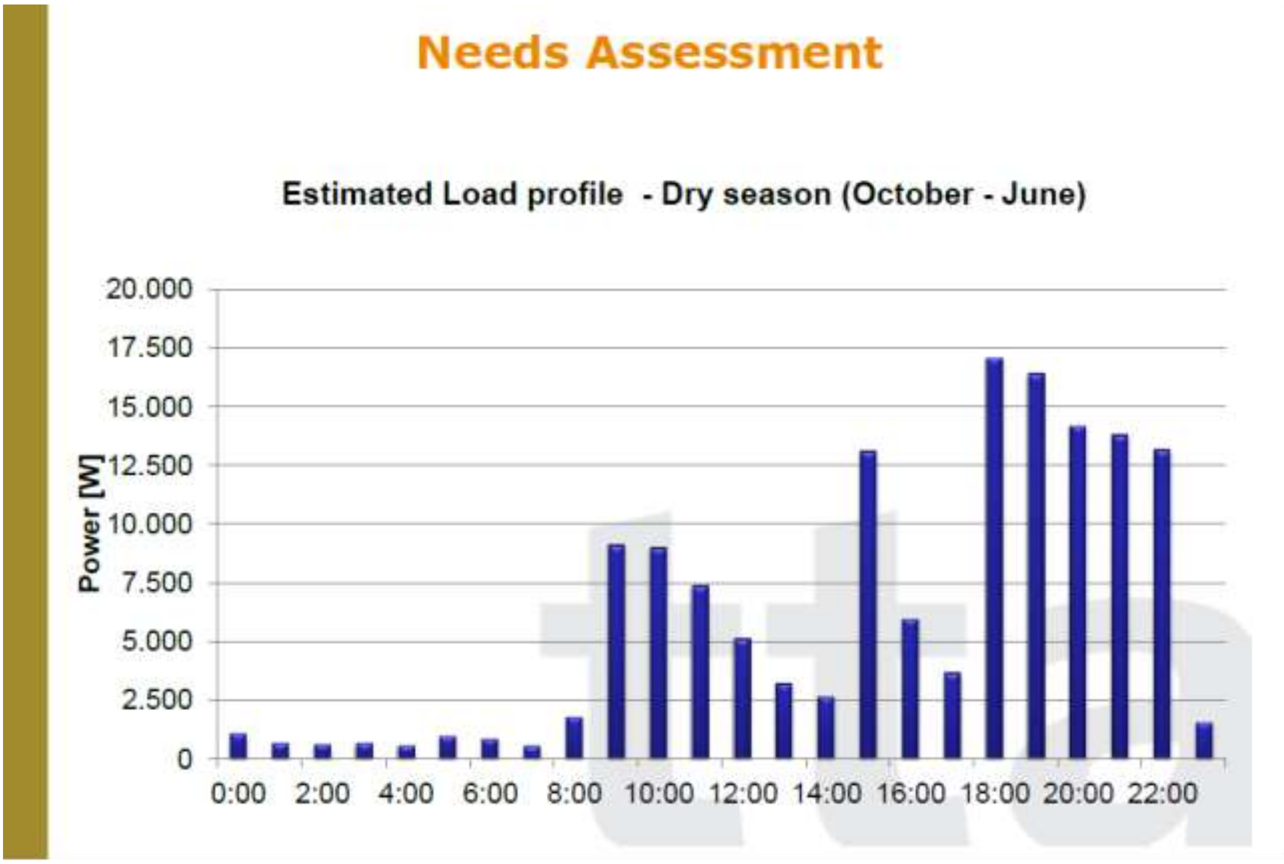


圖82 Chad 的 Mombou 村落之預估負載量

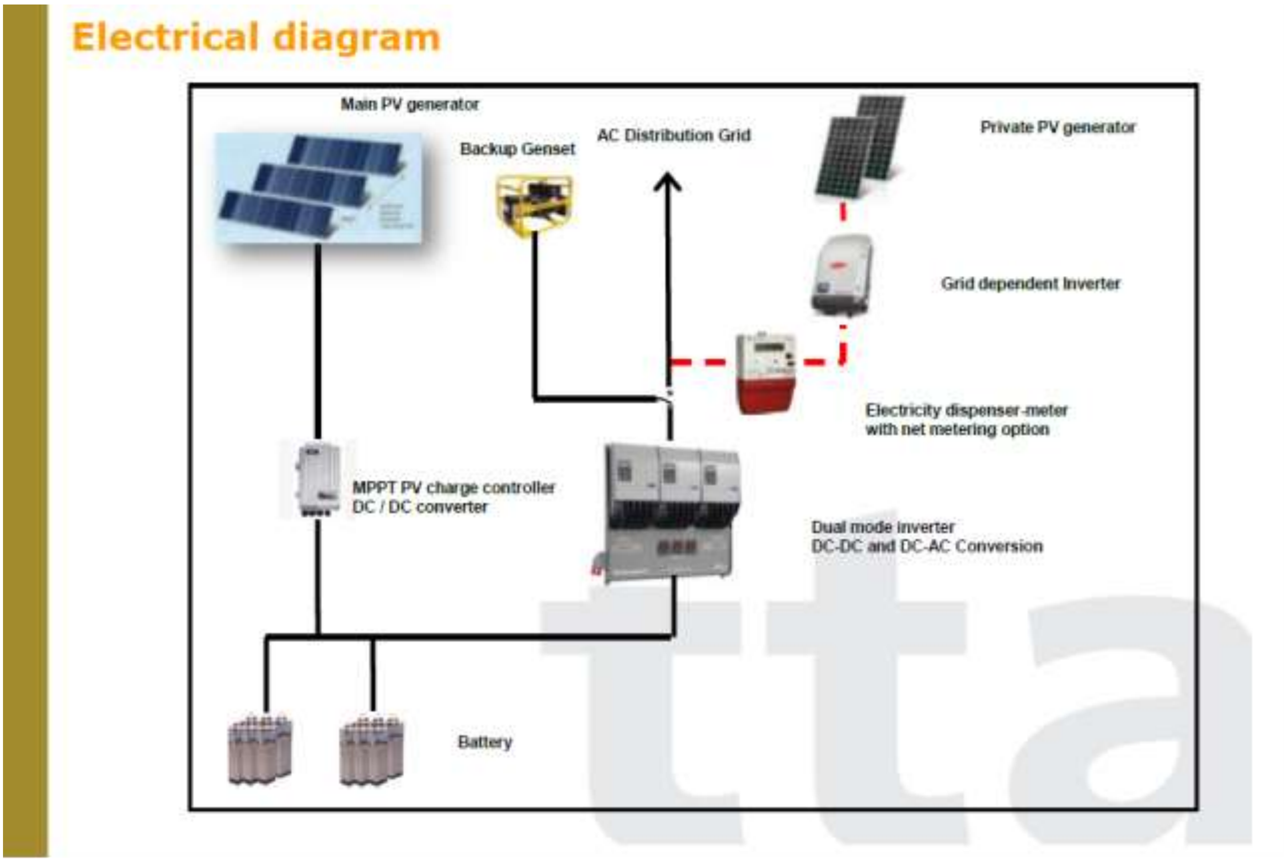


圖83 Mombou 村落的微電網單線圖

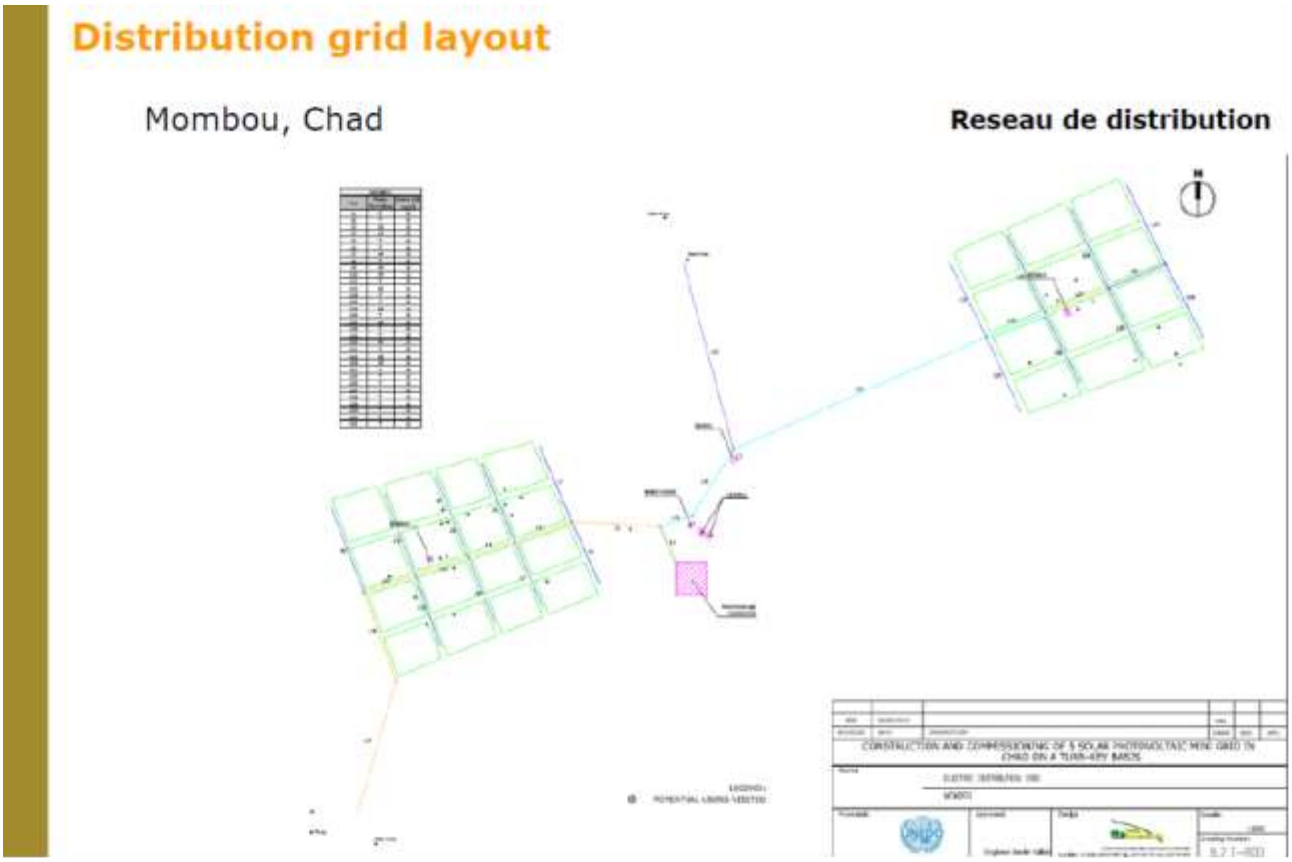


圖84 Mombou 村落之分散式能源配置

Technical Specifications Mombou

MOMBOU MSG	
MAIN CHARACTERISTICS	
Owner	UNIDO / MEP
Contractor and Operator	TTA and Local Association
Electrical service	24 h/day, 230 V/400V three-phase
Number of user connections	129 (135 potential)
Public street lighting	yes
Type of tariff	Energy Daily Allowance (EDA)
Demand growth factor	30%
Rated Average Solar Daily Yield	140,4 kWh/day – 5,91 HPS
PV GENERATOR	
Total PV capacity (STC)	39.600 kWp
Type of PV module / capacity STC	polycrystalline / 240 W_p
Brand and Model	REC240PE
Number of PV module	165
Inclination / orientation	10º / +25º S
EMERGENCY GENSET	
Brand and Model	FG Wilson P50-1
Nominal power	50 kVA
BATTERY	
Technology	Lead acid deep cycle OPzS
Brand and Model	Hoppecke 24 OPzS 3000 rated at 4 464 Ah (C100)
Rated Voltage	48 V
Total / Practical capacity (-70%) (C_{100})	434 kWh / 304 kWh
DUAL-MODE INVERTER	
Brand and Model	Studer-Innotec XTH 6000-48
Number of inverter	6
Total rated power (5" – 30')	90 000 VA – 36 000 VA

DATA LOGGER and CONTROL	
Price signal broadcast	Frequency
Type of data	Energy, voltage, temperature, radiation , etc.
Remote access	GPRS
ELECTRICITY DISPENSER – ENERGY METER	
Power supply	230 V_{CA} 50 Hz
Model	CIRCUTOR Electricity Dispenser BII
Algorithm	Energy Daily Allowance (EDA) configurable
PUBLIC STREET LIGHTING	
Type of lamp	36 W LEDs and 23 W CFL
Number of lamp	17 (11 poles and 6 wall)
DISTRIBUTION LINE	
Type of cable	Aluminium XPLE
Length of line	10200 m
Type of distribution	Underground

圖85 Mombou 村落之微電網技術規格

圖86 柴油發電機與電池實景照

圖87 太陽能板實景照

圖88 負載、再生能源與電池 SOC 曲線

圖89 運用微電網系統供應路燈照明

(三) 中新天津生態城參訪

『TIANJIN 2014 Symposium on Microgrids』國際會議結束後，大會安排參觀中新天津生態城(圖 90)，該生態城是由大陸與新加坡合作建設完成，且示範工程內容(圖 91)包括：分散式能源、微電網與儲能系統、智慧變電站、配電自動化、設備狀態監測系統、電力品質監測系統、用電資訊匯集系統、智慧社區與館舍、電動車充電設備、通訊網路、可視化平台、及智能營業廳。生態城內的分散式能源包含太陽光電與風力發電機，如圖 92 與圖 93 所示，其整體生態城的微電網控制系統如圖 94 所示。本次主要是到智能營業廳進行參訪，其內包含智慧電網相關技術說明及組件展示(圖 95)、整體生態城模型(圖 96)、互動式螢幕之動態解說(圖 97)等內容，且大量運用多媒體互動使參觀人員了解節能減碳的效果與助益(圖 98)，及透過娛樂方式使民眾體驗電動車的效果(圖 99)。該營業廳的展覽方式，或能提供我國進行相關技術展示之參考。

圖90 中新天津生態城

圖91 中新天津生態城示範工程內容

圖92 中新天津生態城的太陽光電

圖93 中新天津生態城的風力發電機

圖94 中新天津生態城之微電網控制系統

圖95 智能供電營業廳內智慧電網組件展示

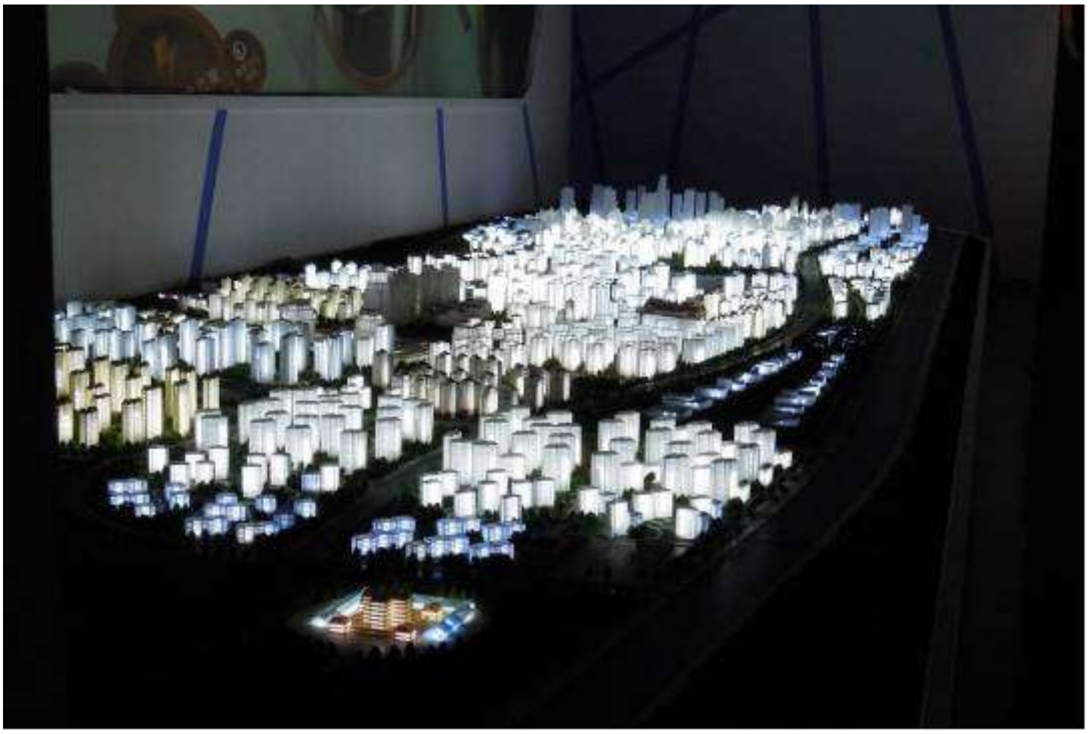


圖96 智能供電營業廳內模型展示

圖97 智能供電營業廳之動態解說

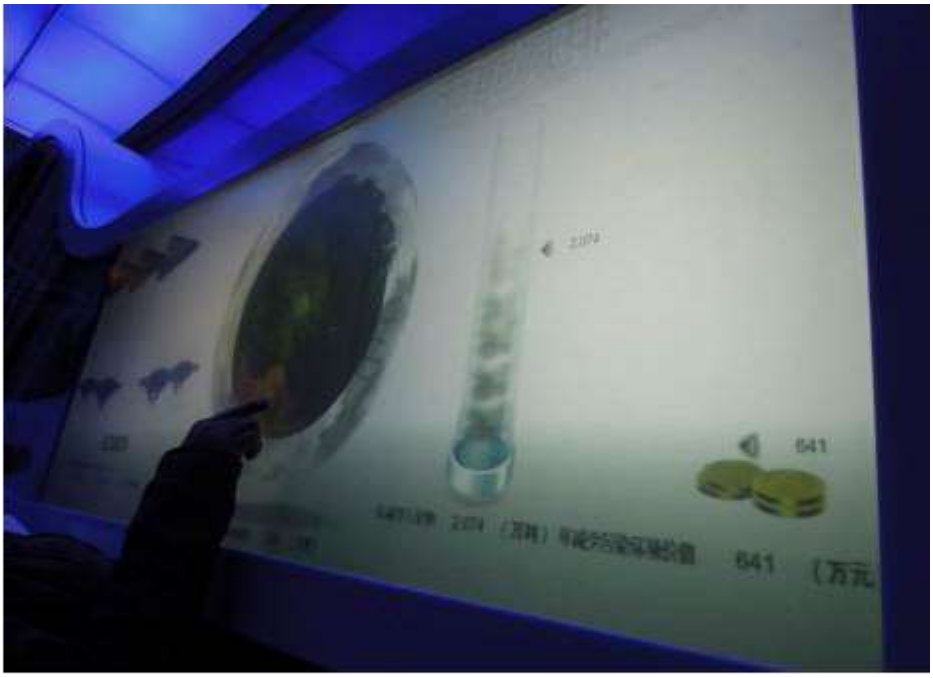


圖98 智能供電營業廳之多媒體互動


圖99 智能供電營業廳內電動車體驗

四、建　議　事　項

(一) 本次前往天津參加『TIANJIN 2014 Symposium on Microgrids』國際會議，該會議為各國主要負責 Microgrid 之專家學者參加，可主導國際微電網技術與產業發展方向，值得每年定期參加，本所除獲邀出席外，並特邀張副組長進行台灣微電網技術研發現況之簡報，以及張貼本所微電網技術發展之海報，用以說明本所自主式分散型區域電力與微電網技術之研發情形，以及台灣未來規劃方向，使國際瞭解台灣技術能量，以利產業推廣，並藉此引進國際先進技術，拓展台灣能見度。

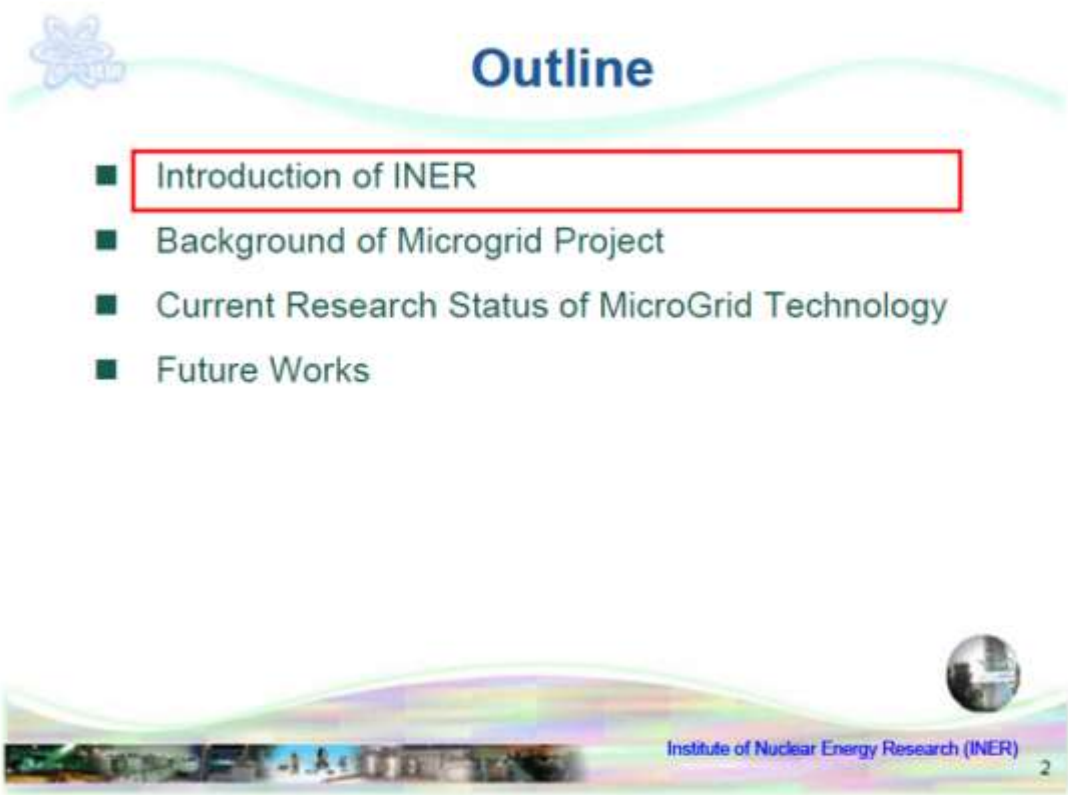
(二) 發展獨立型微電網為世界趨勢，多國皆投入大筆經費進行實際場域的建置，及相關技術驗證與測試，建議我國宜加速離島微電網的建設，並實際進行相關技術測試與穩定運轉，建立運轉實績，便可扶植國內廠商將產品推廣至國內外市場中。

(三) 微電網系統建置前，建議應先進行分散式能源建置與儲能系統容量的評估與規劃，且同時考量不同區域之氣候特性與用電情形，方能盡可能地減少過度建置而造成之浪費。此外，為能使廠商一同參與微電網建置與開發，建議應有適當之誘因，才能促進廠商的投資，並且微電網關鍵技術的開發，需仰賴產學研的合作，方可使產品具有國際競爭力，當產品量產穩定便能降低生產成本，開拓更廣大的國內外市場。

(四) 智慧電網為改善電力系統的重要方法，各國多已投入國家資源進行研發，而微電網為其重要基礎，故亦可看到各個試驗場域或實際應用如雨後春筍般冒出，顯現各國重視程度。尤以美國新澤西州遭受珊迪(Sandy)颶風破壞後，選擇以微電網作為重建重點，著重其恢復力，更顯其重要性。因此本所應持續發展微電網與分散式能源之關鍵技術，未來可應用於台灣本島與離島之電力系統，提高再生能源的占比與發電量，進而達到提昇電力品質、降低離島發電成本、及減少碳排放量等目標。

五、附　錄

(一) 本所口頭簡報資料：



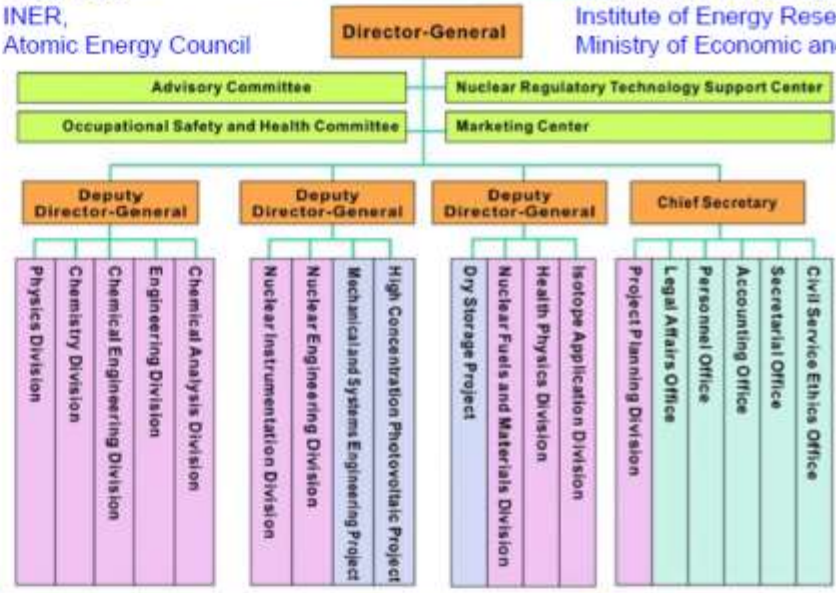
Location of INER

http://www.iner.gov.tw

Organization Chart of INER

Since 1968 ~
INER,
Atomic Energy Council

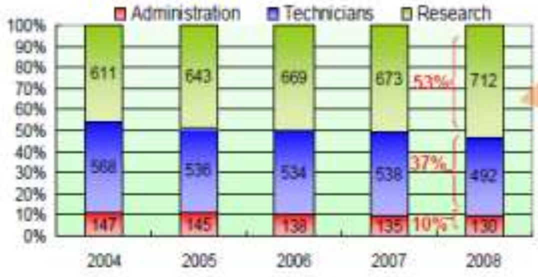
In Jan. 2015 will be renamed by
Institute of Energy Research,
Ministry of Economic and Energy Affairs



Institute of Nuclear Energy Research (INER)

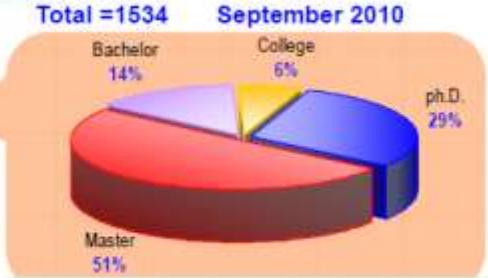
Profile of INER

Profile - Staff



Job Attributes

Total =1534 **September 2010**



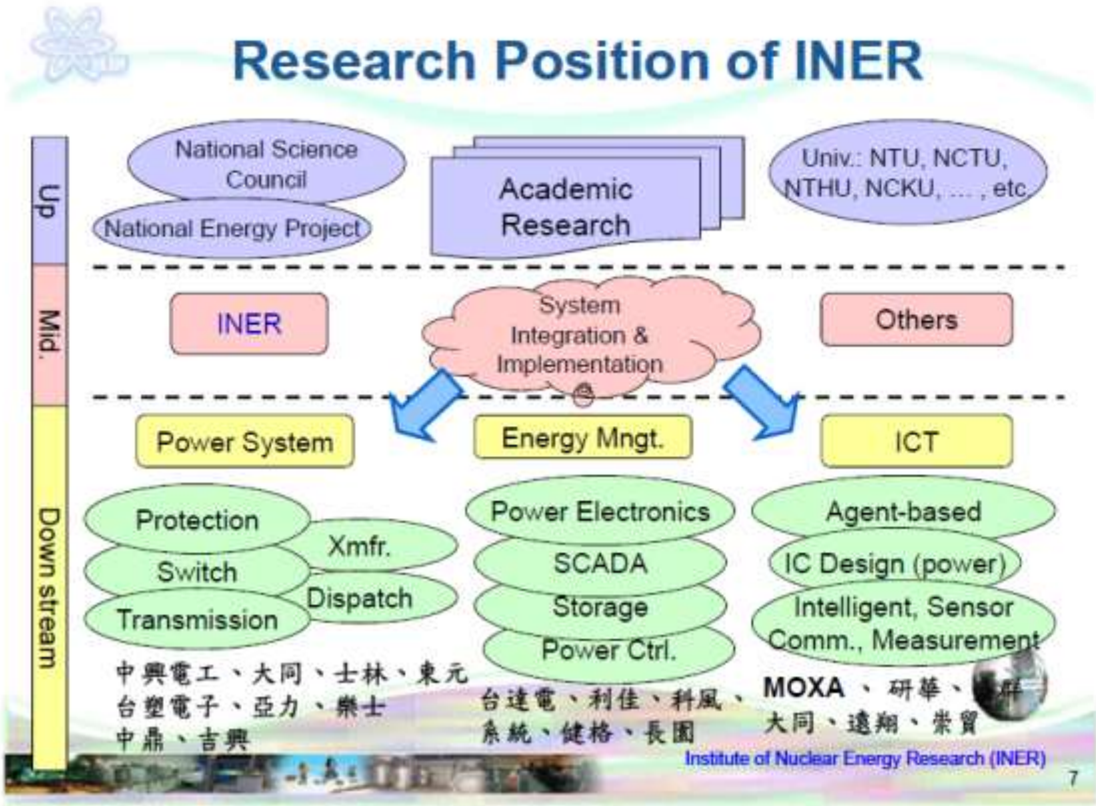
Educational background of research staff

Profile - Budget

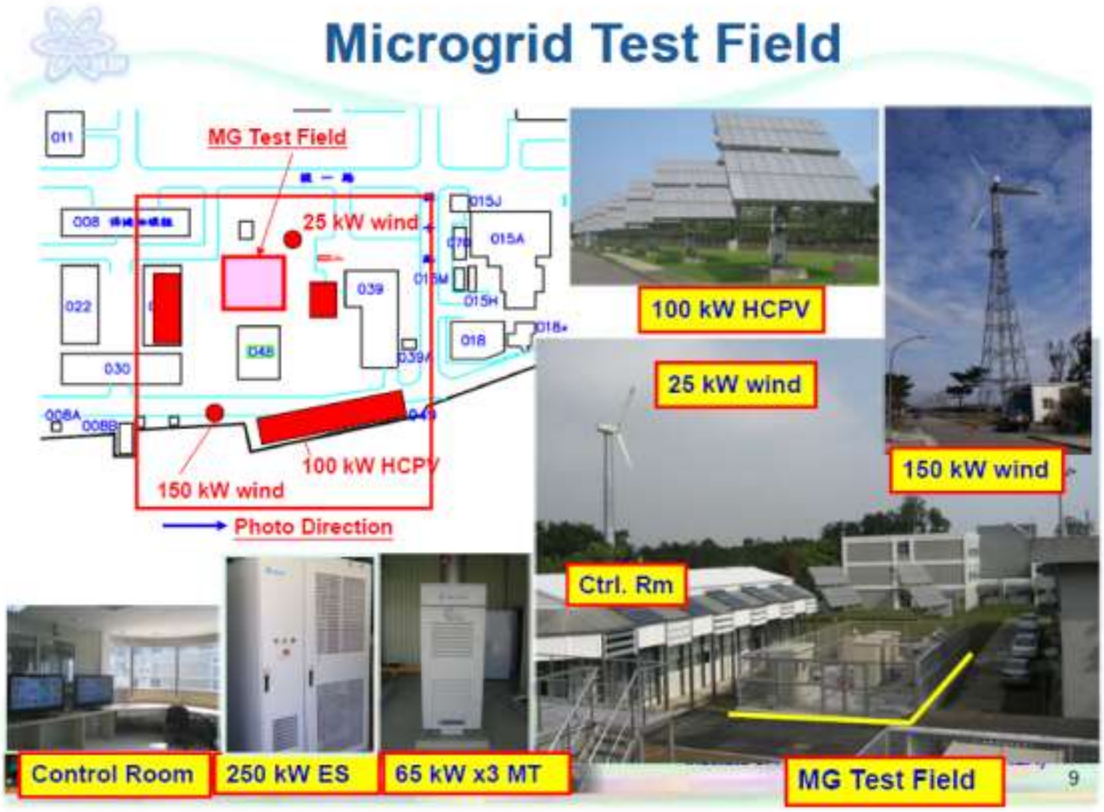
- In 2010, INER has an annual research budget of 3,063M NTD, equivalent to about 100M USD.
- The annual budget includes administrative expenses supported by the central government and R&D funds for contracted projects

Outline

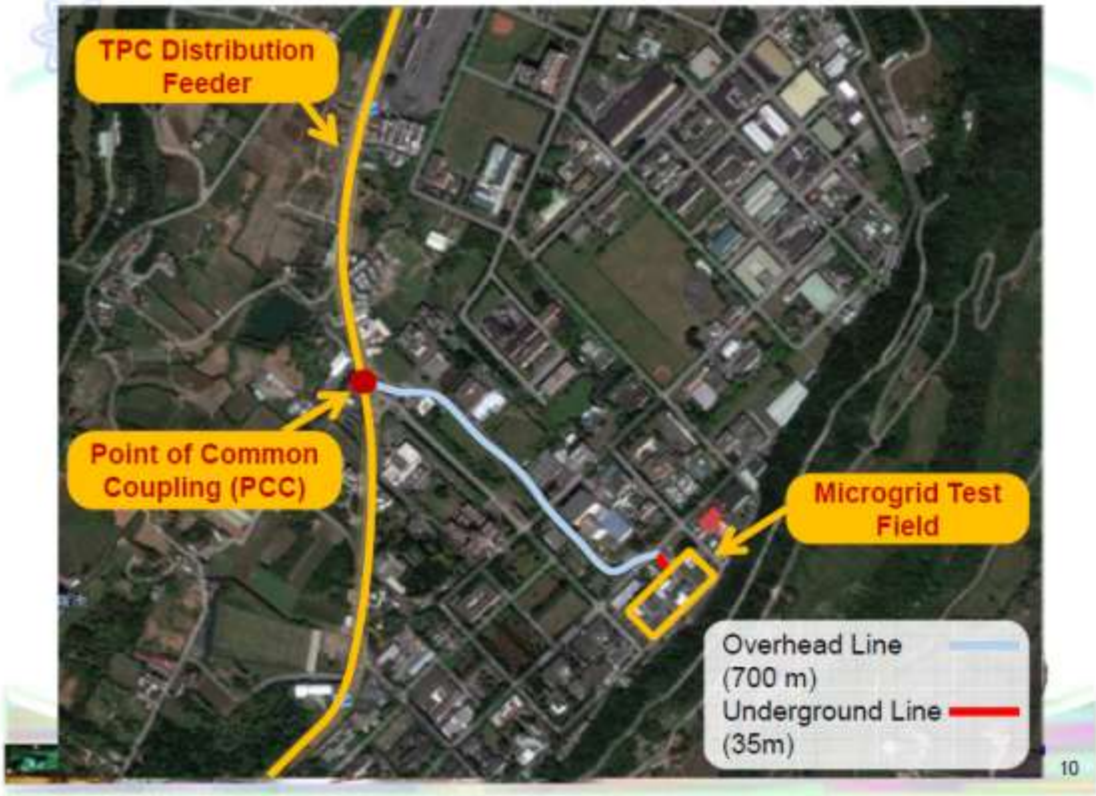
- Introduction of INER
- Background of Microgrid Project
- Current Research Status of MicroGrid Technology
- Future Works


Research Position of INER
Up
Mid.
Down stream
National Science Council
National Energy Project
Academic Research
Univ.: NTU, NCTU, NTHU, NCKU, ... , etc.
INER
System Integration & Implementation
Others
Power System
Energy Mngt.
ICT
Protection
Xmfr.
Switch
Dispatch
Transmission
Power Electronics
SCADA
Storage
Power Ctrl.
Agent-based
IC Design (power)
Intelligent, Sensor
Comm., Measurement
中興電工、大同、士林、東元
台塑電子、亞力、樂士
中鼎、吉興
台達電、利佳、科風、
系統、健格、長園
MOXA 、研華、
大同、遠翔、崇貿
Institute of Nuclear Energy Research (INER)
7


DG Units at INER
100 kW HCPV
1 MW HCPV
25 & 150 kW Wind Turbine
2 kW SOFC
Institute of Nuclear Energy Research (INER)
8

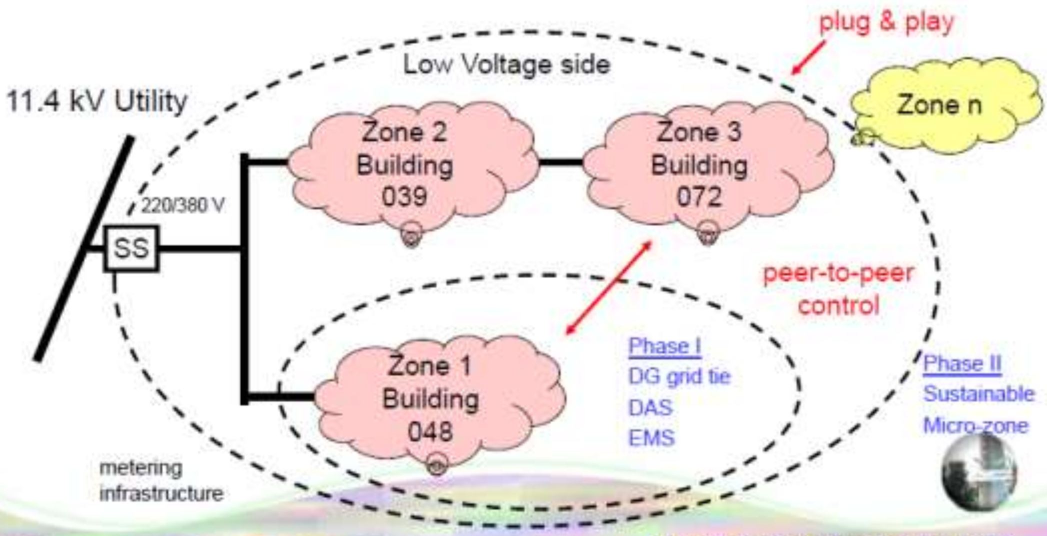


Microgrid Test Field
MG Test Field
25 kW wind
100 kW HCPV
150 kW wind
Photo Direction
100 kW HCPV
25 kW wind
150 kW wind
Ctrl. Rm
Control Room
250 kW ES
65 kW x3 MT
MG Test Field
9



TPC Distribution Feeder
Point of Common Coupling (PCC)
Microgrid Test Field
Overhead Line (700 m)
Underground Line (35m)
10

Target:
Developing power control and management technology for low voltage side of smart microgrid in which 20% of total energy comes from renewable energy.



Institute of Nuclear Energy Research (INER) 11

Microgrid Development Roadmap

2010 → 2011 → 2012 → 2013 → 2014 → 2015~2020

Phase	System Planning & Core Technology Development	System Integration & Implementation	Pilot Operation & Performance Improvement
Target	■ Power Analysis for Seamless Islanding Operation ■ Smart Control & Measurement ■ Advanced Power Electronics ■ Energy Management ■ Energy Storage	■ Increase the renewable energy penetration rate of regional power grid up to 10%	■ Increase the renewable energy penetration rate of regional power grid up to 20%

Institute of Nuclear Energy Research (INER) 12

Outline

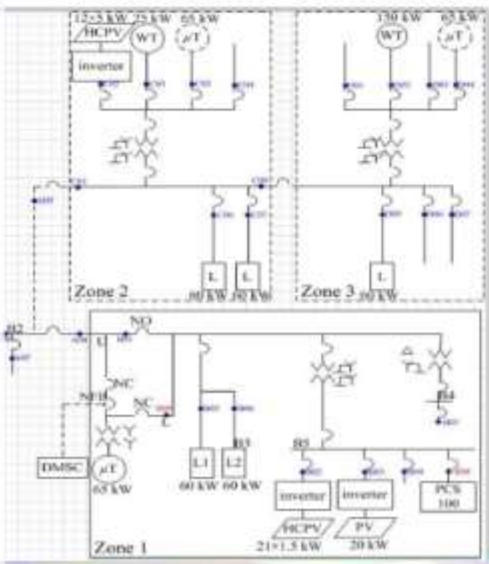
- Introduction of INER
- Background of Microgrid Project
- Current Research Status of MicroGrid Technology
- Future Works

Microgrid Technology Development

(1) Power System Technology
- Operation Scenarios Design & Testing
- System Stability Analysis
- Protection Coordination for MG
- Microgrid Power Quality Analysis

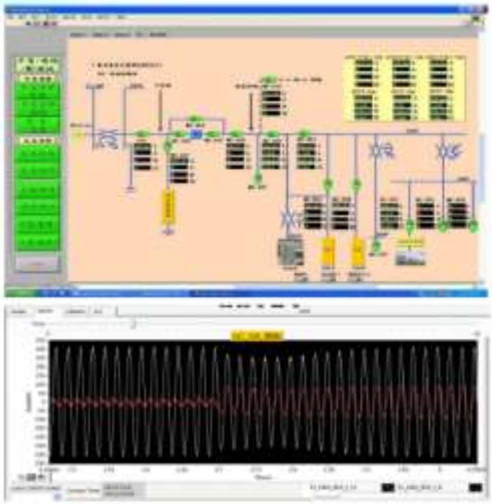
(2) Power Electronics Technology
- Static Switch and Islanding Detection
- Smooth Switching Inverter
- Active/Reactive Power Control
- Droop Control
- Low Voltage Ride Through

(3) Intelligent control and EMS
- Energy Management System
- Power Flow Analysis
- Generation & Load Prediction
- DAQ and Time Synchronization



(1) Power System Technology

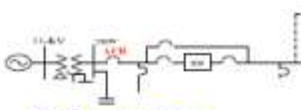
- Operation Scenarios Design & Testing
  - A. Microturbine Test
    - A1. Transition between Grid-tied and stand alone operation
    - A2. Stand alone operation with HCPV
    - A3. Stand alone operation with WTG
    - A4. Load following control
  - B. Static Switch Test
    - B1. Synchronized control
    - B2. Loss of utility and restoration
    - B3. Reverse power
    - B4. Microgrid energized
  - C. Microgrid Protection Test
    - C1. Three phase short circuit at B5
    - C2. Single line to ground fault at B5
    - C3. Three phase short circuit at B2
    - C4. Single line to ground fault at B2
  - D. Subsystem Test
    - D1. Initial voltage control
    - D2. Three phase unbalance



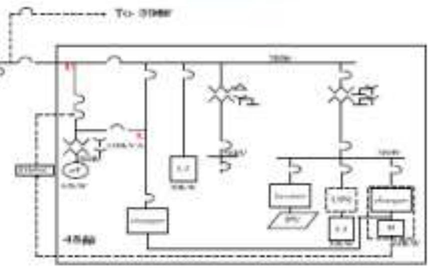
Grid-connected & Islanding

(1) Power System Technology

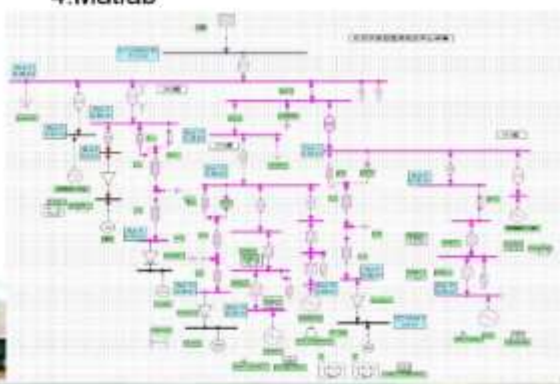
- System Stability Analysis

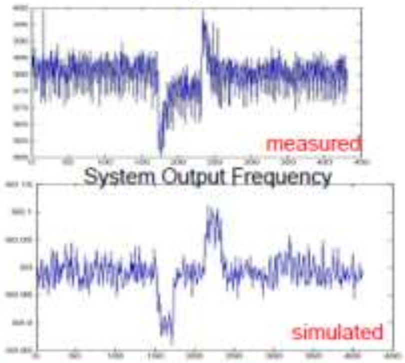


-Software Tools
1. PSCAD
2. CYME/PSAF
3. NEPLAN
4. *Matlab*



-System Analysis
1. System Planning
2. Modelling
3. Power Flow
4. Fault Current
5. Impact Analysis
6. Scenarios Design
:



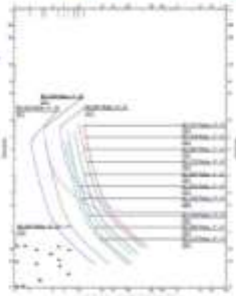


(1) Power System Technology

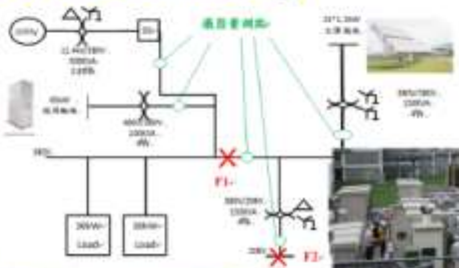
■ Protection Coordination for MG

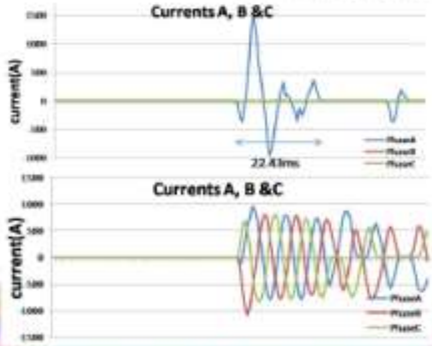
➢ Protection coordination analysis

- Fault current calculation & parameter selection and design for protection decision-making algorithm
- Action analysis for (NFB & OC Relay)

➢ Artificial fault testing



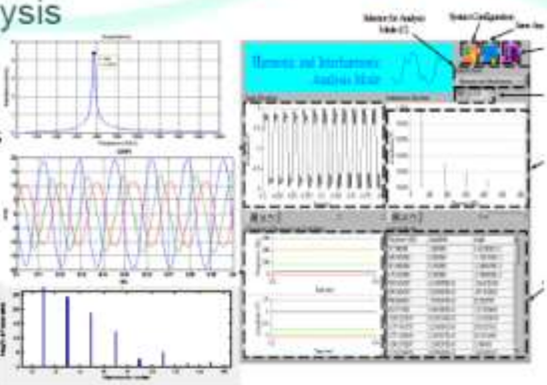
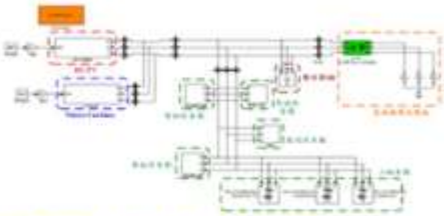
Measurement of fault current

(1) Power System Technology

■ Microgrid Power Quality Analysis

➢ Power quality analysis

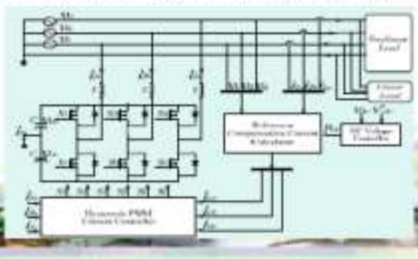
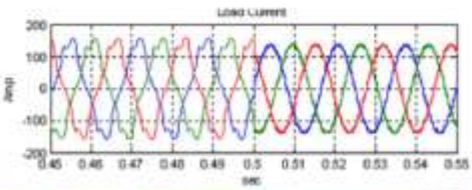
- Harmonic modeling of microgrid component
- Harmonic power flow and unbalance analysis

Power quality analysis of grid-tied/islanding

➢ Power quality improvement

- Active/passive power filter analysis & design

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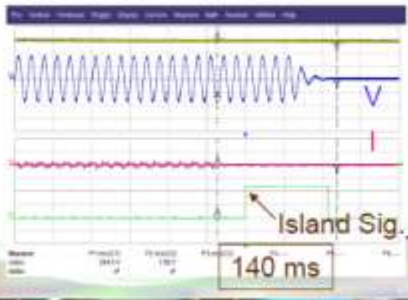
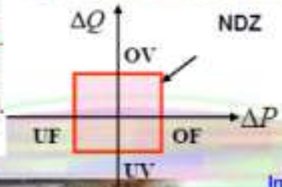
(2) Power Electronics Technology

■ Static Switch & Islanding Detection

➢ Active islanding detection

- AFD, slip-mode (SMS)
- Voltage-Pulse Perturbation, Voltage Correlation
- Active/reactive power perturbation
- Sandia frequency shifting
- Impendence, Current injection





電壓範圍	解聯時間(秒)
V<50	0.16
50≤V<88	2.00
110<V<120	1.00
120≤V	0.16

頻率範圍		解聯時間(秒)
≤30kW	>60.5	0.16
	<59.3	0.16
>30kW	>60.5	0.16
	<{59.8~57.0}	0.16~300
	<57.0	0.16

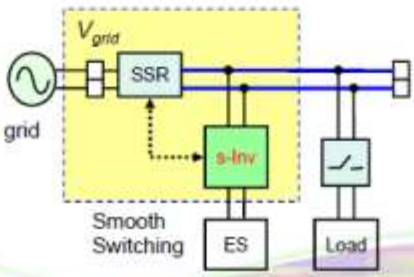
IEEE 1547 standard

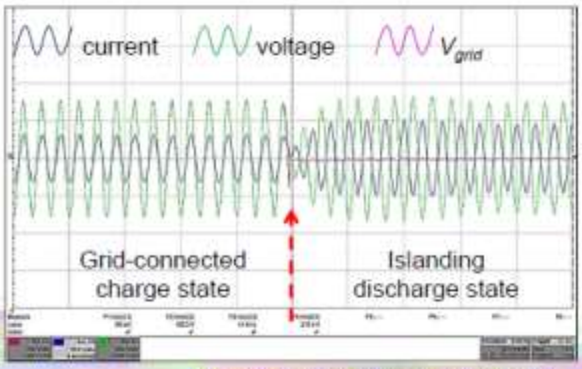
(2) Power Electronics Technology

■ Smooth Switching Inverter

Smooth Switching Inverter

- In grid-tied, S-inverter is a CS
  In islanding, S-inverter is a VS
- Smooth switching capability within two cycle
- "Energy Storage Systems for Seamless Mode Transfer in Microgrid", *IEEE PEDS Conference*, Dec. 2011.

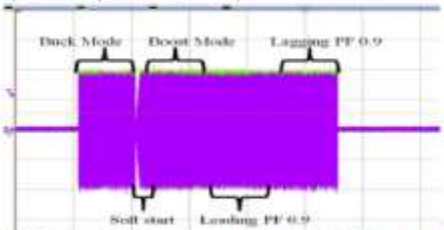




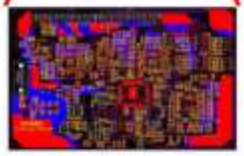
(2) Power Electronics Technology

- Bi-directional inverter for energy storage with active/reactive power control

	Spec.	Note
Vac	3ϕ3W -Δ 220v/60 Hz	
Vdc	380 ± 20 V	
PF	>0.99	Charger mode
	-0.9~1~0.9	Discharger mode
Freq.	>96%	Highest efficiency
Rating	250 kVA	Discharger with active/reactive control
Comm.	Can-bus	



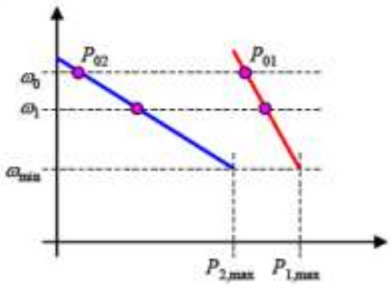
Measured waveform in four-quadrant operation


DSP controller layout


250 kW bi-directional inverter

(2) Power Electronics Technology

- Frequency-Droop Control
  - In islanding operation
  - Fast response requirement (using power electronics locally instead of receiving commands from EMS)
  - Traditional control may not work in low voltage microgrid (short distance means that impedance comes from resistance more than inductance, high R/X ratio)



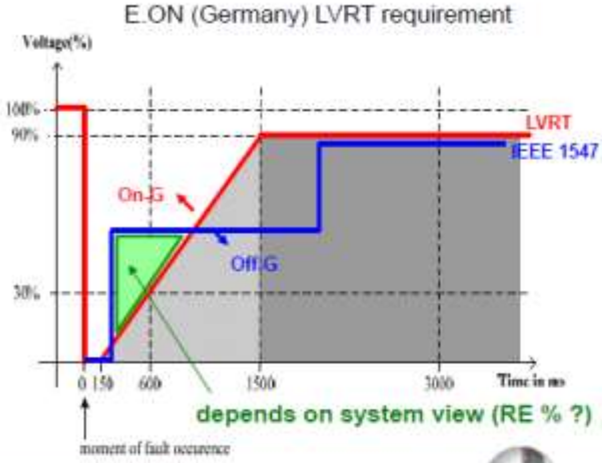
(2) Power Electronics Technology

■ Low Voltage Ride Through

- When voltage sag occurs, WT should provide reactive power to support grid voltage instead of only just trips for self-protection.

- E.ON (Germany) LVRT requirement
  Type 1:Traditional SG
  Type 2: WT, PV

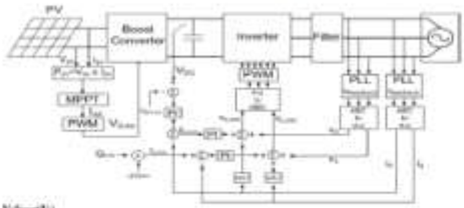
E.ON (Germany) LVRT requirement

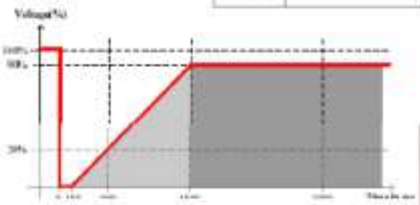


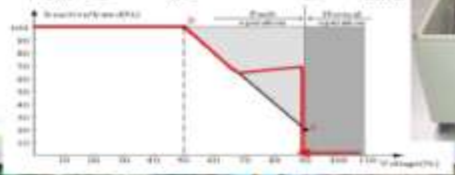
(2) Power Electronics Technology

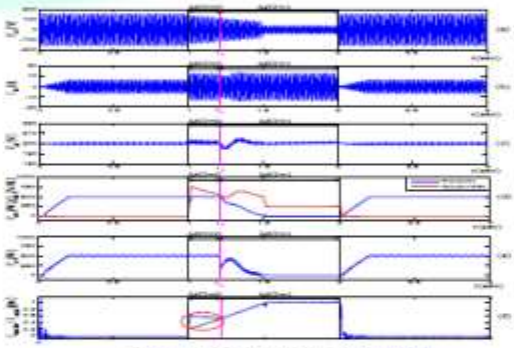
■ Low Voltage Ride Through

- Simulation platform for LVRT

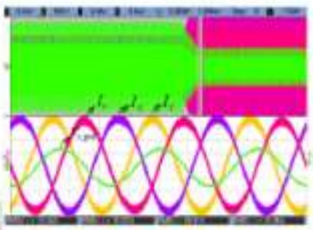






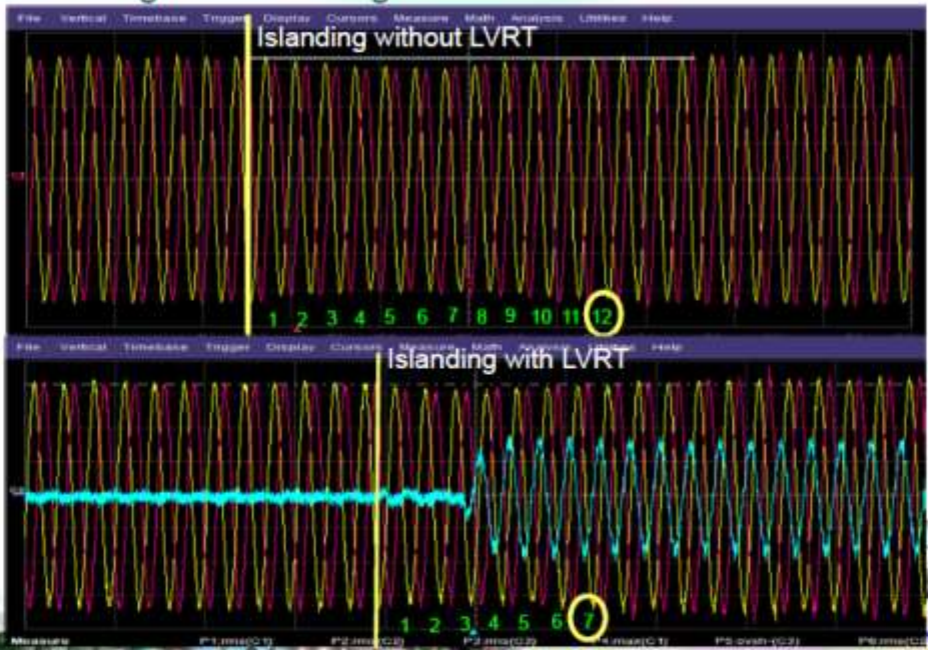


simulation platform for LVRT



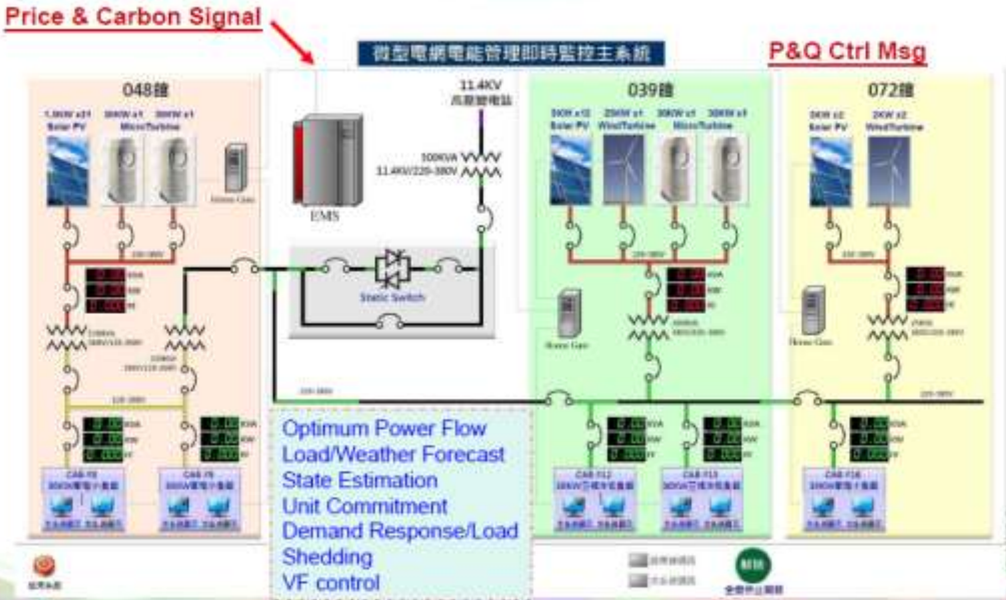
(2) Power Electronics Technology

- Low Voltage Ride Through



(3) Intelligent control and EMS

- Energy Management System

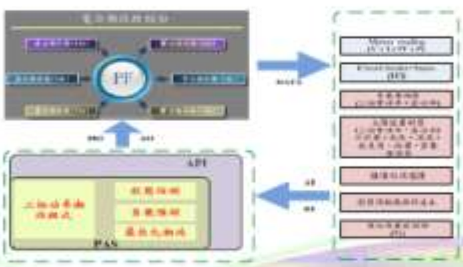


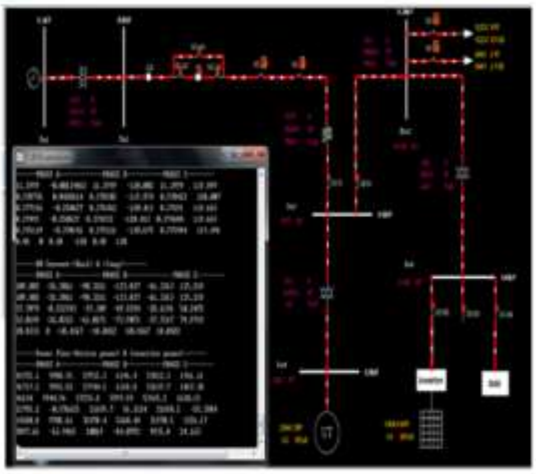
(3) Intelligent control and EMS

(3) Intelligent control and EMS

■ Three Phases Power Flow Analysis

- Real-time three-phase power flow analysis algorithm for microgrid
- Good convergence for multiple DGs and high R/X ratio in low voltage system
- ZLoop Method
- Capable for 100 nodes in 1 sec.

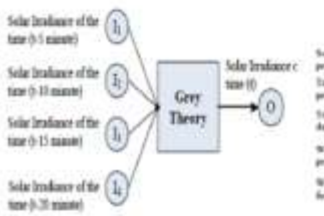


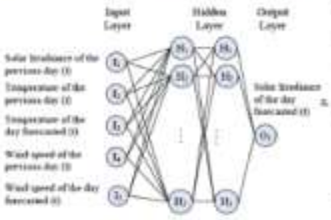


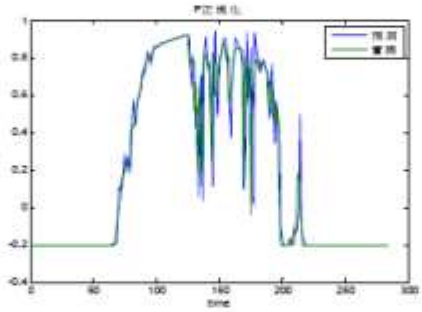
(3) Intelligent control and EMS

- Generation prediction for renewable energy

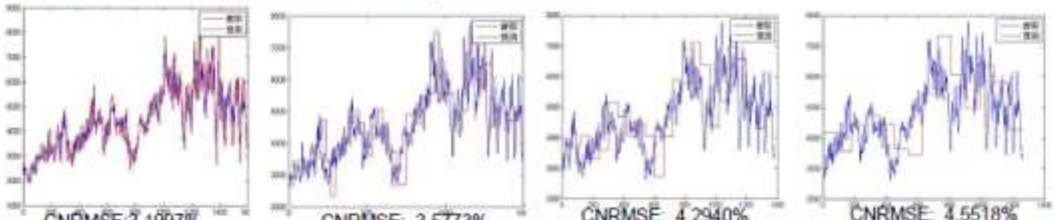
Extreme short-term forecast – GT   Short-term forecast – BNN







- 1, 5, 10, 15 min-ahead load prediction



CNRMSE:3.1997%
NMBE :10.6733%
MAPE :10.3065%

CNRMSE: 3.5773%
NMBE : 11.9459%
MAPE : 11.9657%

CNRMSE: 4.2940%
NMBE : 15.9084%
MAPE : 16.0081%

CNRMSE: 4.5518%
NMBE : 16.[illegible]%
MAPE : 16.5805%

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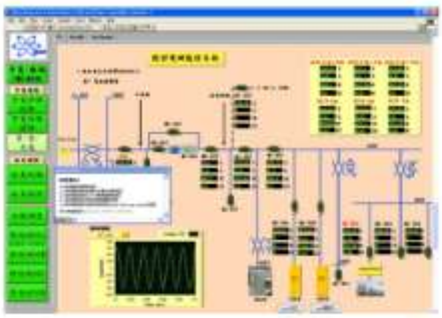
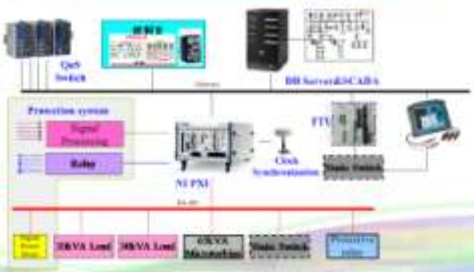
(3) Intelligent control and EMS

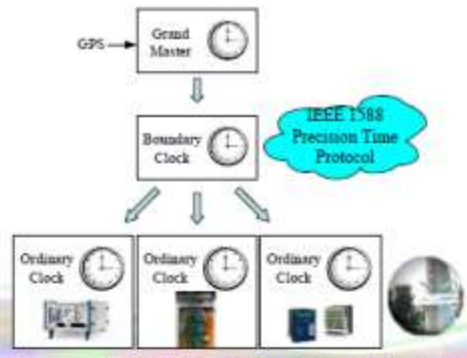
- DAS and Time Synchronization





IEEE1588 V2 time synchronization (PTP)

- Proper to distributed multi-nodes system
- Precision < 1 ms
- Easy for implementation in network



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(3) Intelligent control and EMS

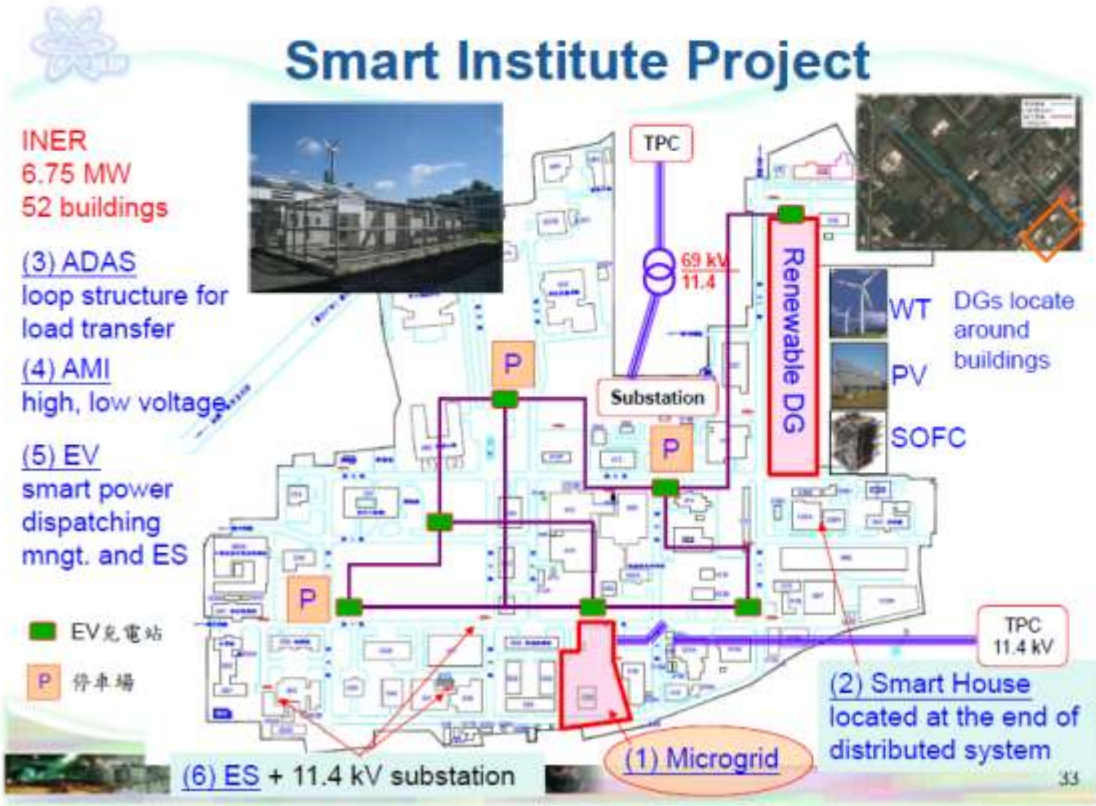
■ Other Energy Storage

Vanadium Redox Battery (under testing)

- Monitoring and testing platform.
- Charge/discharge characteristic analysis

Outline

- Introduction of INER
- Background of Microgrid Project
- Current Research Status of MicroGrid Technology
- Future Works


Smart Institute Project
INER
6.75 MW
52 buildings
(3) ADAS
loop structure for load transfer
(4) AMI
high, low voltage
(5) EV
smart power dispatching mngt. and ES
EV充電站
P 停車場
TPC
69 kV
11.4
Substation
Renewable DG
WT
PV
SOFC
DGs locate around buildings
TPC
11.4 kV
(2) Smart House located at the end of distributed system
(1) Microgrid
(6) ES + 11.4 kV substation
33


Water Park of Pingtung Microgrid
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Microgrid on Penghu Island
4.8 MW
5.4 MW
All possible types of international collaboration are welcomed !
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(二) 本所展示之海報資料：


Taiwan's First-Outdoor Microgrid
TAIWAN
Yung-Ruei Chang, Jheng-Lun Jiang
Institute of Nuclear Energy Research (INER)
E-mail: raymond@iner.gov.tw, jhenglun@iner.gov.tw
Objective
As a result of conventional fossil fuel shortage and global warming, the research trend of world goes into raising the usage of renewable energy, stabilizing regional balance of energy supply and demand, and promoting smart grid technology. However, due to the intermittent and uncertain characteristics, high penetration of renewable energy will cause voltage sags or swells and bring the dramatic impact to the operation stability of regional power system. According to the TPC's (Taiwan Power Company) regulation, the voltage variation is limited to below 2.5% for renewable power generation equipment connecting to the distribution system. It will affect installation capacity and penetration ratio of the solar systems and wind power generation systems in a region. In order to enhance the integration of the distributed generation into regional grid, increase the penetration ratio of renewable energy, and develop virtual power plant technology, Taiwan's first-outdoor microgrid research demonstration field was built up by INER (Institute of Nuclear Energy Research) in Longtan township and was successfully connected to TPC distribution feeder in 2013. The research topics include energy management system, monitoring and control platform, demand response by OpenADR scheme, electric vehicle intelligence operational management technology, and static switch technology.
Achievement
Energy Management System
Demand Response by OpenADR Scheme
Electric Vehicle Charge Scheduling Management
SCR-Based Static Switch