

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。

目 次

| | |
|--|----|
| 摘 要 | i |
| 一、目 的 | 1 |
| 二、過 程 | 1 |
| 三、心 得 | 7 |
| (一) 『TIANJIN 2014 Symposium on Microgrids』國際會議開幕部分 | 7 |
| (二) 『TIANJIN 2014 Symposium on Microgrids』國際會議各國報告內容 | 10 |
| (三) 中新天津生態城參訪 | 55 |
| 四、建 議 事 項 | 60 |
| 五、附 錄 | 61 |

圖目錄

| | |
|--|----|
| 圖 1 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(1/5)..... | 2 |
| 圖 2 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(2/5)..... | 3 |
| 圖 3 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(3/5)..... | 4 |
| 圖 4 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(4/5)..... | 5 |
| 圖 5 『TIANJIN 2014 Symposium on Microgrids』國際會議議程(5/5)..... | 6 |
| 圖 6 『TIANJIN 2014 Symposium on Microgrids』國際會議全體人員合照 | 7 |
| 圖 7 『TIANJIN 2014 Symposium on Microgrids』國際會議會場照片 | 8 |
| 圖 8 會議主席美國 Berkeley Lab 的 Crisis Marney 致詞 | 8 |
| 圖 9 『TIANJIN 2014 Symposium on Microgrids』全體與會者名單 | 9 |
| 圖 10 趙波(Zhao Bo)進行南麂島微電網示範工程簡報 | 11 |
| 圖 11 南麂島的背景介紹..... | 11 |
| 圖 12 南麂島微電網系統的組成..... | 12 |
| 圖 13 南麂島微電網系統的設備..... | 12 |
| 圖 14 南麂島微電網系統架構..... | 13 |
| 圖 15 南麂島微電網監控介面..... | 13 |
| 圖 16 南麂島微電網控制系統架構..... | 14 |
| 圖 17 南麂島儲能系統最佳配置..... | 14 |
| 圖 18 南麂島微電網之系統穩定控制功能..... | 15 |
| 圖 19 南麂島微電網確實提高島上居民的穩定用電..... | 15 |
| 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 | 16 |

| | |
|---------------------------------------|----|
| 圖 21 大萬山島地理位置..... | 17 |
| 圖 22 大萬山島負載需求..... | 17 |
| 圖 23 大萬山島微電網系統設計..... | 18 |
| 圖 24 大萬山島微電網之分散式能源及其成本..... | 18 |
| 圖 25 大萬山島之再生能源與負載預測..... | 19 |
| 圖 26 大萬山島微電網系統之控制策略..... | 19 |
| 圖 27 大萬山島之微電網運轉評估(1/2)..... | 20 |
| 圖 28 大萬山島之微電網運轉評估(2/2)..... | 20 |
| 圖 29 大萬山島之微電網經濟效益評估..... | 21 |
| 圖 30 大萬山島之微電網經濟效益分析..... | 21 |
| 圖 31 大萬山島微電網系統之補助建議(1/2)..... | 22 |
| 圖 32 大萬山島微電網系統之補助建議(1/2)..... | 22 |
| 圖 33 黃磊(Lei Huang)進行東澳島微電網示範工程簡報..... | 23 |
| 圖 34 東澳島微電網地理位置圖..... | 24 |
| 圖 35 東澳島微電網系統架構..... | 24 |
| 圖 36 東澳島微電網研究議題..... | 25 |
| 圖 37 東澳島 BIPV..... | 25 |
| 圖 38 東澳島 PV..... | 26 |
| 圖 39 東澳島風力發電機..... | 26 |
| 圖 40 東澳島柴油發電機..... | 27 |
| 圖 41 東澳島微電網能源管理系統(1/2)..... | 27 |
| 圖 42 東澳島微電網能源管理系統(2/2)..... | 28 |

| | |
|--|----|
| 圖 43 東澳島雙向轉換器..... | 28 |
| 圖 44 東澳島微電網遠端即時監控系統(1/2)..... | 29 |
| 圖 45 東澳島微電網遠端即時監控系統(2/2)..... | 29 |
| 圖 46 Markson Tang 進行烏敏島微電網試驗場簡報..... | 30 |
| 圖 47 微電網建置前之烏敏島電力供應情形..... | 31 |
| 圖 48 第一階段已於烏敏島的 Jetty Area 建置微電網..... | 31 |
| 圖 49 烏敏島之太陽光電的建設(1/2)..... | 32 |
| 圖 50 烏敏島之太陽光電的建設(2/2)..... | 32 |
| 圖 51 張永瑞副組長進行台灣微電網研發現況簡報(1/2)..... | 33 |
| 圖 52 張永瑞副組長進行台灣微電網研發現況簡報(2/2)..... | 34 |
| 圖 53 姜政綸博士張貼本所微電網研發現況海報..... | 34 |
| 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..... | 36 |
| 圖 55 美國微電網計畫分布圖(受 DOE 或 DOD 補助)..... | 36 |
| 圖 56 美國 SPIDERS 微電網計畫..... | 37 |
| 圖 57 NJ TransitGrid 與 Hoboken ESDM 計畫..... | 37 |
| 圖 58 微電網的價值屬性..... | 38 |
| 圖 59 恢復力(Resilience)與可靠度(Reliability)的比較..... | 38 |
| 圖 60 2012 年 10 月珊迪(Sandy)颶風之路徑圖..... | 39 |
| 圖 61 珊迪(Sandy)颶風造成之影響..... | 39 |
| 圖 62 珊迪(Sandy)颶風造成 Hoboken 淹水的範圍..... | 40 |
| 圖 63 Hoboken 微電網之績效目標..... | 40 |
| 圖 64 Hoboken 雙微電網拓撲架構..... | 41 |

| | |
|---|----|
| 圖 65 Hoboken 微電網連接方式 | 41 |
| 圖 66 NJ TransitGrid 微電網系統示意圖 | 42 |
| 圖 67 NJ TransitGrid 微電網系統(建構前) | 42 |
| 圖 68 NJ TransitGrid 微電網系統(建構後) | 43 |
| 圖 69 Guillermo Jiménez Estévez 進行拉丁美洲之微電網研發現況簡報 | 44 |
| 圖 70 拉丁美洲的用電覆蓋率 | 44 |
| 圖 71 拉丁美洲進行微電網開發的地區 | 45 |
| 圖 72 智利適合發展獨立型微電網的數量 | 45 |
| 圖 73 Huatacondo 的微電網監控介面 | 46 |
| 圖 74 Huatacondo 的微電網能源管理系統 | 46 |
| 圖 75 自行開發之微變壓器 | 47 |
| 圖 76 自行開發之電動車 | 47 |
| 圖 77 微電網轉態切換示意圖 | 48 |
| 圖 78 微電網轉態切換測試 | 48 |
| 圖 79 Huatacondo 的微電網運轉測試 | 49 |
| 圖 80 Xavier Vallvé 進行 Chad 太陽光電微電網示範場域簡報 | 50 |
| 圖 81 Chad 的 Mombou 村落簡介 | 50 |
| 圖 82 Chad 的 Mombou 村落之預估負載量 | 51 |
| 圖 83 Mombou 村落的微電網單線圖 | 51 |
| 圖 84 Mombou 村落之分散式能源配置 | 52 |
| 圖 85 Mombou 村落之微電網技術規格 | 52 |
| 圖 86 柴油發電機與電池實景照 | 53 |

| | |
|-----------------------------|----|
| 圖 87 太陽能板實景照..... | 53 |
| 圖 88 負載、再生能源與電池 SOC 曲線..... | 54 |
| 圖 89 運用微電網系統供應路燈照明..... | 54 |
| 圖 90 中新天津生態城..... | 55 |
| 圖 91 中新天津生態城示範工程內容..... | 56 |
| 圖 92 中新天津生態城的太陽光電..... | 56 |
| 圖 93 中新天津生態城的風力發電機..... | 56 |
| 圖 94 中新天津生態城之微電網控制系統..... | 57 |
| 圖 95 智能供電營業廳內智慧電網組件展示..... | 57 |
| 圖 96 智能供電營業廳內模型展示..... | 58 |
| 圖 97 智能供電營業廳之動態解說..... | 58 |
| 圖 98 智能供電營業廳之多媒體互動..... | 59 |
| 圖 99 智能供電營業廳內電動車體驗..... | 59 |

表 目 錄

| | |
|--------------|---|
| 表 1 行程表..... | 1 |
|--------------|---|

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

| 行程 | | 公差地點 | | 工作內容 | |
|-----------------------|----|------|----|------|---|
| 日期 | 地點 | | 國別 | | 地名 |
| | 出發 | 抵達 | | | |
| 11/11(二) | 桃園 | 天津 | 大陸 | 天津 | 去程 |
| 11/12(三) | | | 大陸 | 天津 | 1. 會場海報布置 2. 口頭簡報資料準備 |
| 11/13(四)~ 11/16(日) | | | 大陸 | 天津 | 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 4. 資料整理 |
| 11/17(一) | 天津 | 桃園 | | | 回程 |



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, 2 nd floor |
| 09:00 - 09:15 | Zhipeng LIANG, National Energy Administration Welcome to Tianjin |
| 09:15 - 09:30 | Chris MARNAY, Berkeley Lab (Co-Chair: Ben KROPSKI, 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 |



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

| 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 Bldg. 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 Demand 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 |



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



[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 |

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

| 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 | Guxiu 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 |
| 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 Guxiu JIANG, Guangzhou Inst. of Enrg. Con. Tsal-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 | |
| 16:30 - 18:00 | |
| 18:00 - 18:30 | Chris, Farid, Hiroshi, Nikos, & Johan Retrospective: the First Decade of Microgrid Symposiums |

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

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



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 Symposium 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 |
| Dionizio Paschoarelli Júnior | Universidade Estadual Paulista |
| Dong Jun Won | Inha university |
| Duo Luo | XingYe Solar Energy Technology |
| Farid Katraei | Quanta Technology |
| Fengyan (Wendy) Zhang | Xiamen University |
| Gengfeng Li | Xi'an Jiaotong University |
| Gonçalo Mendes | Technical University of Lisbon |
| Guillermo Jimenez | University of Chile |
| Gulixu 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. |
| Kilchiro Tsuji | Osaka University |
| Kumudhini Ravindra | PRDC Infotech |
| Lecai Zeng | Shanghai Electric R&D Center |
| Lef Huang | Chinese Academy of Sciences |
| Liang Tao | SIEMENS |
| Lingwei Zheng | Hangzhou Dianzi University |
| Luchen Chang | University of New Brunswick |

| 2014 Tianjin Symposium 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 Hatzilargyriou | 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 |
| Ryolchi 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 TechnoAmbiental (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

Background(1)




1、南麂島--海上仙山，貝藻王國，遠離大陸，柴發供電，用電困難。
 Nanji Island—a fairy mountain on the sea, serious electricity shortage with few diesel generators

2、海上可再生能源充足，以此建設一個清潔、高效、經濟的小型獨立電網—南麂島微電網示範工程。
 Based on the abundant renewable resources, a clean, efficient, economical isolated grid is established—Nanji Island microgrid demonstration project

3、南麂島微電網屬於含多種分布式電源的非網型示範工程，是浙江省電力公司承擔的國家863計劃“含分布式電源的微電網關鍵技術研發”課題中兩個示範工程之一。
 With multiple distributed generations, Nanji microgrid is one project of the national development program(863 program) taken by Zhejiang Power Grid, China

圖11 南麂島的背景介紹

Integration of the microgrid(1)

南麂微电网系统组成 System structure of the microgrid on Nanji Island



圖12 南麂島微電網系統的組成

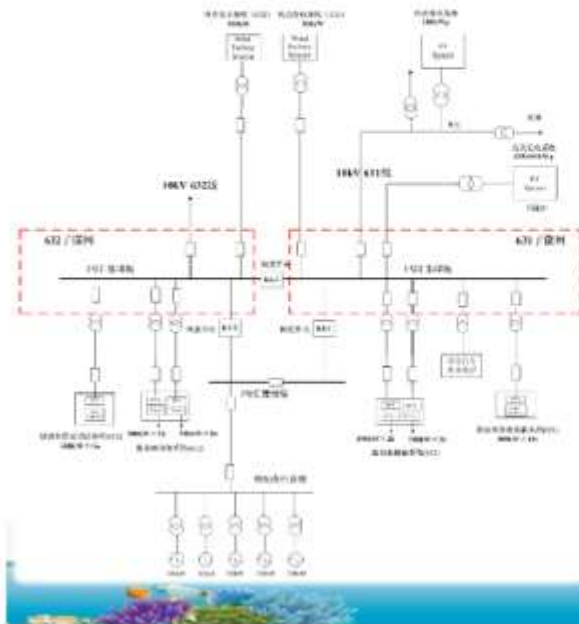
Integration of the microgrid(5)



圖13 南麂島微電網系統的設備

Integration of the microgrid(3)

南麂微电网系统设计图 System design



结构特点

- ✓ 离网型微电网 stand-alone
- ✓ 多子微网结构 multiple subsystems
- ✓ 可再生能源集中与分布式接入相结合 integration of centralized and distributed accesses
- ✓ 电动汽车充换电站接入 filling stations of EVs
- ✓ 多达7种运行控制模式 7 operation modes

圖14 南麂島微電網系統架構

Integration of the microgrid(4)

南麂微电网主监控界面 Main monitoring interface

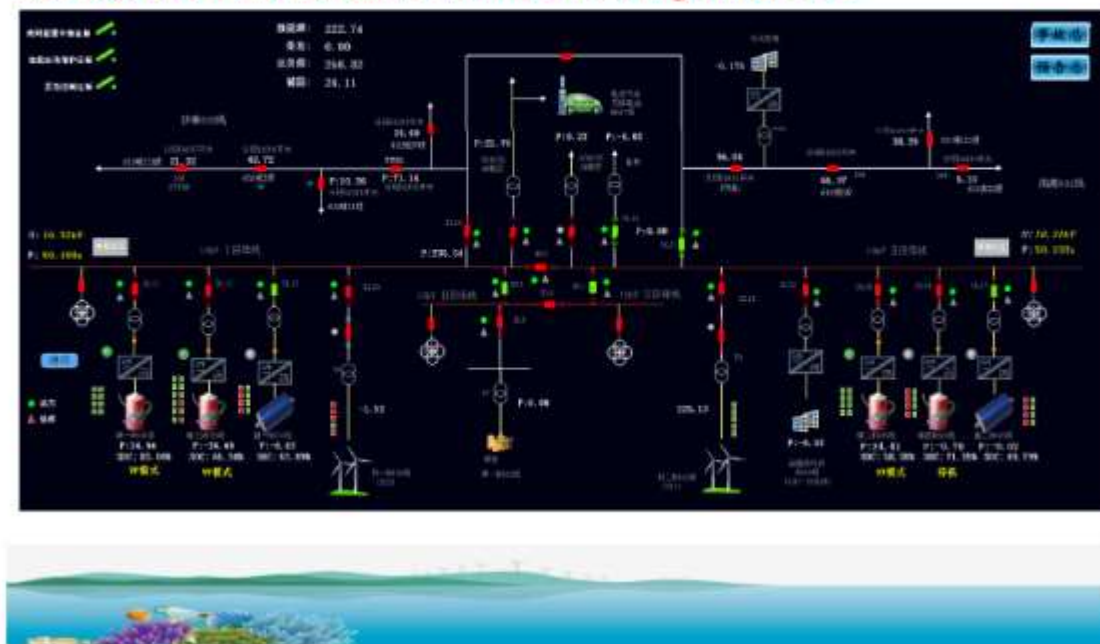


圖15 南麂島微電網監控介面

Key technology research(2)

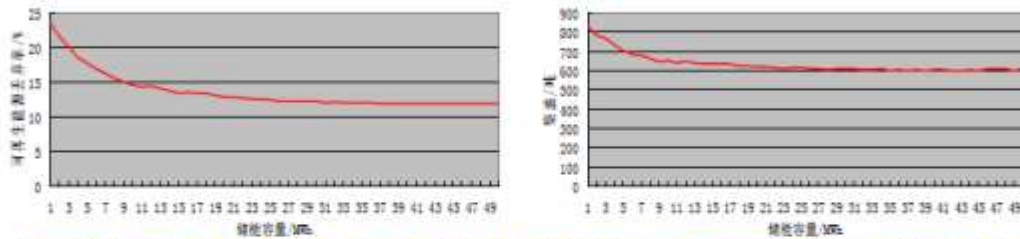
南麂微电网控制系统结构图 Control structure



圖16 南麂島微電網控制系統架構

Key technology research(1)

南麂島儲能優化配置 Optimal configuration of storage system



南麂島秋冬季节负荷较低，低负荷不足以使得储能系统中的电能得到及时和完全释放，从而造成可再生能源的丢弃。

In cold days, surplus energy in storage system(SE) is abandoned due to low load demand

柴油发电机在春夏季节运行较多，储能系统自身并没有发电能力，它只是转移可再生能源和柴油发电机的电能，可再生能源并没有富余的电能给储能系统进行充电，增加储能系统容量的作用逐渐减小。

In hot days, with high load demand, no extra renewable energy is available for SE. So the storage capacity should be optimized based on the upper figures.

圖17 南麂島儲能系統最佳配置

Key technology research(4)

南麂微电网稳定控制 Stability control

功能模块



- ✓ 微电网电压稳定控制
voltage stability
- ✓ 微电网频率稳定控制
frequency stability
- ✓ 通过超级电容平抑可再生
能源出力波动
alleviating fluctuation of
renewable energy
- ✓ 系统紧急控制
emergency control



圖18 南麂島微電網之系統穩定控制功能

Conclusion



混合储能系统与电动汽车充电站相结合，能使多余可再生能源得到充分利用
Hybrid storage system combined with EV filling stations, taking full use of surplus renewable energy



灵活的多微网结构和多运行模式的无缝切换，显著提高南麂岛负荷的供电可靠性
Flexible structure with multiple microgrids and seamless mode switching, increasing the power supply reliability remarkably.



多种绿色能源，结合电动汽车充电站，智能电表、用户交互等先进智能电网技术，建成后将成为一座标志性的绿色能源综合利用智能岛屿
Green energy, EVs, smart meters and user interaction together forming an iconic clean-energy-integrated smart island



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

Overview



Dawanshan Island

- ◆ Located to the southeast of Xiangzhou (39km), Zhuhai, Guangdong, China
- ◆ The area of the island is 8.1 km², and the population is 300.
- ◆ Main industries: fishing and tourism
- ◆ Relied on diesel generation with high cost and low reliability



Tianjin 2014 Symposium on Microgrids

圖21 大萬山島地理位置

Resources & Demand



Load Demand

- ◆ Mainly at: Wanshan, southwest and northwest of the island
- ◆ Load changes with tourism:
High-season: May – Oct;
Low-season: Jan-April, Nov-Dec
- ◆ Peak load: 810kW; 59% of load is 200kW-400kW

| | | |
|-----------------------|-----------------|---|
| Wind Resource | Abundant | Average wind speed: 6.89 m/s ~ 7.58 m/s at the height 10m ~ 70m |
| | | Average wind power density: 426.1 W/m ² ~ 444.3 W/m ² |
| | | Average wind speed: Winter > Summer |
| Solar Resource | Medium | Average annual solar radiation: 4996.25 MJ/m ² |
| | | Typical year solar radiation: 4975 MJ/m ² |
| | | Solar radiation is high from May to October |

Tianjin 2014 Symposium on Microgrids

圖22 大萬山島負載需求

System Design



Objective Function:

Net Income

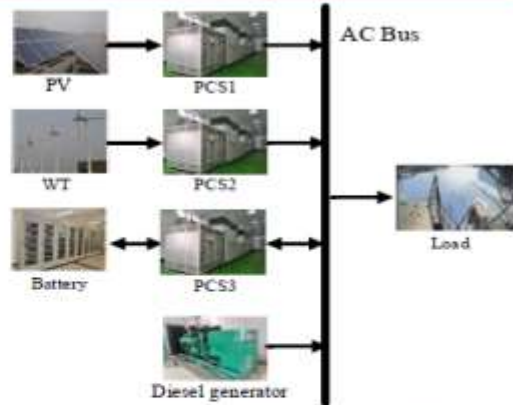
$$\max f = B_{net}^{pre} - C_{TEI}^{pre}$$

Total Income

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

Cost

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



Constraints:

System Structure of Dawanshan Microgrid

| 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 |

Tianjin 2014 Symposium on Microgrids

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 |

Tianjin 2014 Symposium on Microgrids

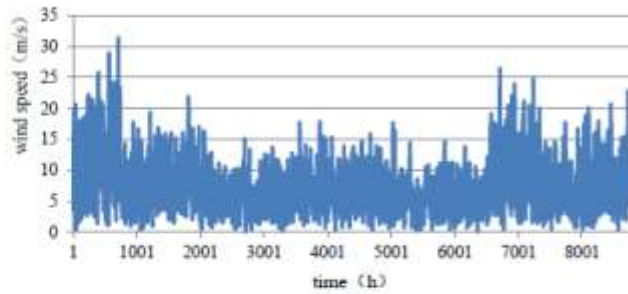
圖24 大萬山島微電網之分散式能源及其成本

Resource/Load Data

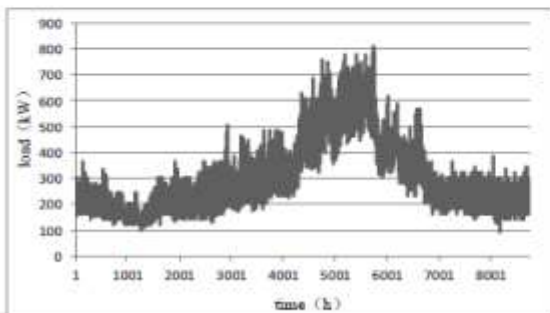


Solar/Wind/Load Data:

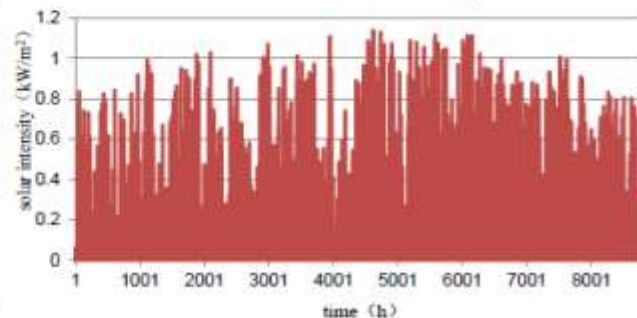
According to the solar and wind resources of Dawanshan Island, data needed in the optimization model was generated by HOMER.



Forecast Results of Wind Speed



Load Forecast Results



Forecast Results of Solar Radiation

Tianjin 2014 Symposium on Microgrids

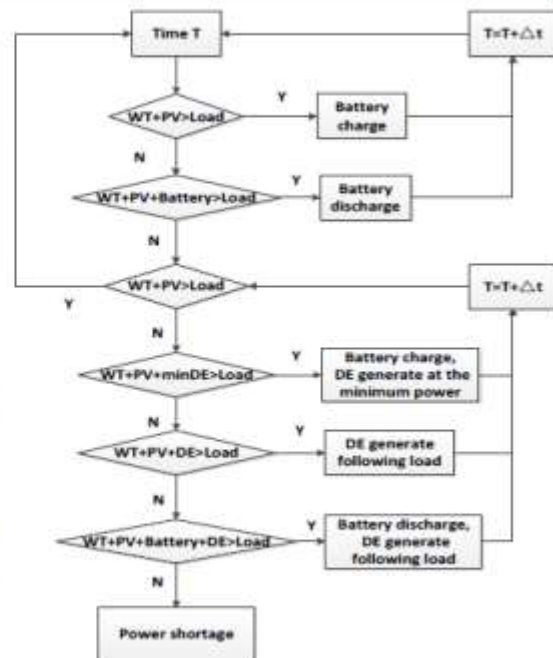
圖25 大萬山島之再生能源與負載預測

Control Strategies



Load Following Strategy

- ◆ Use WT/PV/ESS first, and take ESS as main power Source;
- ◆ When $WT+PV+ESS > Load$, ESS would be charged by WT/PV;
- ◆ When $WT+PV+ESS < Load$, DE would be started to supply load along with ESS;
- ◆ When $WT+PV > Load$, DE would be shut down, and load would be supplied by WT/PV/ESS.



Flow Chart of Load Following Strategy

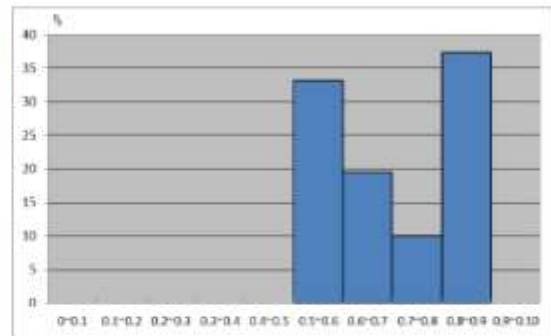
Tianjin 2014 Symposium on Microgrids

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

- ◆ 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.

Generation of Power Sources in a Year

Tianjin 2014 Symposium on Microgrids

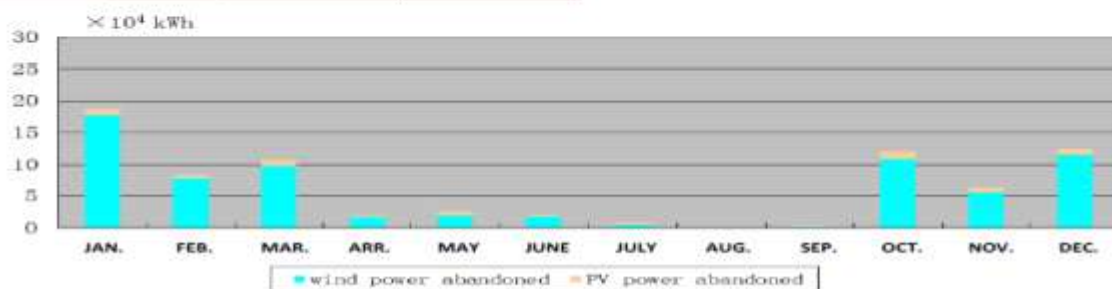
圖27 大萬山島之微電網運轉評估(1/2)

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

Tianjin 2014 Symposium on Microgrids

圖28 大萬山島之微電網運轉評估(2/2)

Economic Evaluation



| Basic Information | Unit | Value | Economic Indices | Unit | Value |
|--------------------------|----------|-----------|-----------------------------------|------|----------|
| Project Cycle | year | 25 | Annual Operation Cost | USD | 560,000 |
| Initial Investment | USD | 2,780,000 | Annual Income Selling Elec. | USD | 850,000 |
| Discount Rate | % | 8 | Annual Net Income | USD | 290,000 |
| User Electricity Price | USD/year | 0.33 | Net Present Value of Total Income | USD | -200,000 |
| Capital Ratio | \ | 0.3/0.7 | Internal Rate of Return | % | 5.925 |
| | | | Payback Period | year | >25 |
| 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 | | | |

Tianjin 2014 Symposium on Microgrids

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.

Tianjin 2014 Symposium on Microgrids

圖30 大萬山島之微電網經濟效益分析

Policy Proposal



For Dawanshan Case:

- ◆ **Subsidy Principles:** With subsidies, the internal rate of return should be no less than 8%, and years of investment recovery should be around 7 to 8 years. According to this principle, subsidy regulation and level can be made.
- ◆ Subsidies can be provided in forms of **initial investment** or **electricity price**.
- ◆ Subsidy Level:

| | Initial Investment | Electricity Price |
|---|---------------------------|-------------------|
| Subsidy Level | 70% of initial investment | 0.065 USD/kWh |
| Internal Rate of Return (With Subsidies) | 29.3% | 26.3% |
| Years of Investment Recovery (With Subsidies) | 8.15 years | 8.31 years |
| Subsidy Period | \ | 10 years |

Tianjin 2014 Symposium on Microgrids

圖31 大萬山島微電網系統之補助建議(1/2)

Policy Proposal



For Future Development of Island Microgrid in China:

- ◆ Provide **subsidies** for **initial investment** of island microgrid
- ◆ Provide **subsidies** for **electricity price** of areas supplied by island microgrid
- ◆ Encourage **more stakeholders** to participate in the construction and operation of island microgrid
- ◆ Provide **integrated energy service** to satisfy users' demand for electricity, heating and cooling, to improve the energy efficiency.
- ◆ Offer **subsidies** to **device manufacturers**, especially to those who produce **wind turbines and batteries of medium/small capacity**

Tianjin 2014 Symposium on Microgrids

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



Dong'ao Island Microgrid Overview

- Geographic location
- Resources
- Power supply
 - Wind: 50kW
 - PV: 1MW
 - Diesel: 1000kW
 - Storage:
 - lead-acid battery: 1500kWh
 - ice machine: 100kW

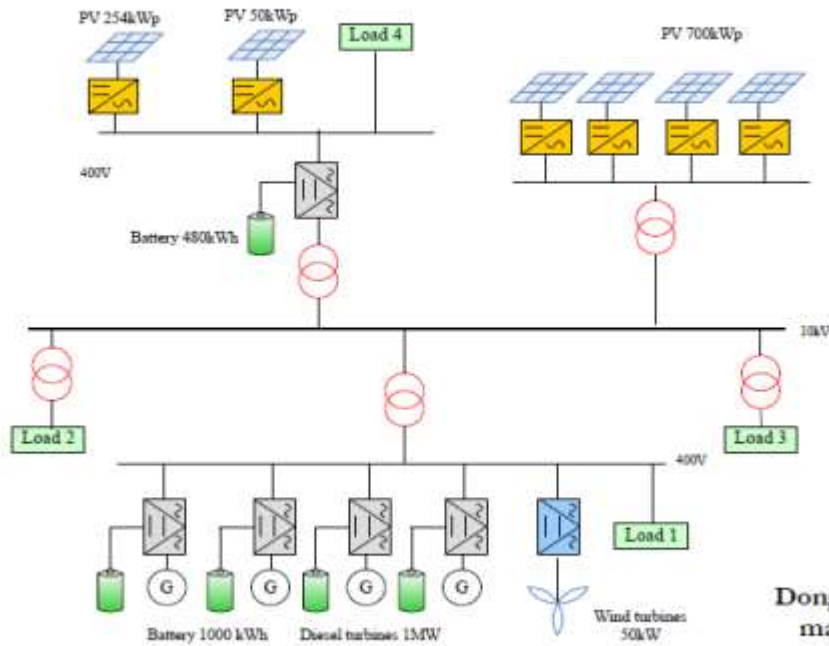


Page 2

圖34 東澳島微電網地理位置圖



Wind-PV-diesel hybrid microgrid optimized planning

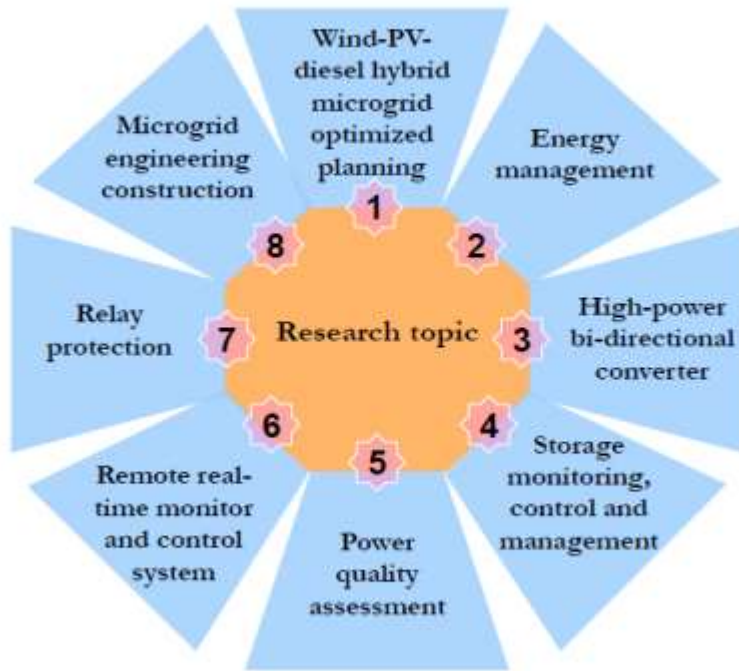


Page 13

圖35 東澳島微電網系統架構



Dong'ao island microgrid research



Page 3

圖36 東澳島微電網研究議題



Dong'ao island microgrid construction - PV system

Sub-microgrid in culture center



Building attached photovoltaic: 254kWp
 PV grid-integrated inverters: 10kVA*8
 PV grid-integrated inverters: 30kVA*5
 lead-acid battery: 2V/1000Ah*240
 Bi-directional converter: 250kVA
 PV system connected directly to inner bus
 Inner bus connected to higher level microgrid through bi-directional converter

- 50kWp building attached photovoltaic
- 100kVA grid-integrated inverter
- PV system directly connected to inner bus of the sub-microgrid in culture center



PV system in multifunctional building

Page 5

圖37 東澳島 BIPV



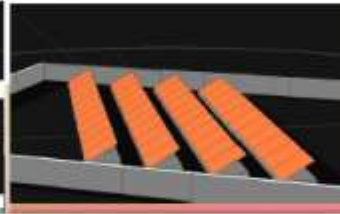
Dongao island microgrid construction - PV system

- PV module design
south facing, inclination angles of 25°
- Grid integrated design
400V/10kV

Shading analysis



12.22 9am



12.22 3pm

Voltage of PV string within MPPT of inverter



Ground Mounted PV System

700kWp PV system on mountain

- Amorphous and polycrystalline silicon photovoltaic cell
- Connected directly to 10kV power transmission line through inverter

Operation

- Each technical index meets design requirement
- Remote control function

圖38 東澳島 PV



Dong'ao island microgrid construction - wind turbines



Wind turbines

•50kW wind power generation(five 10kW wind turbines)

- Located on the top of a hill
- connected to a low-voltage AC bus
- with battery near the coupling point

•AC-DC-AC inverter

- three phase integrated method
- remote monitoring and control



Grid-connected inverter for wind turbine



•Unload device

- To improve operation condition under strong wind and slight load

圖39 東澳島風力發電機



Dong'ao island microgrid construction - diesel generation

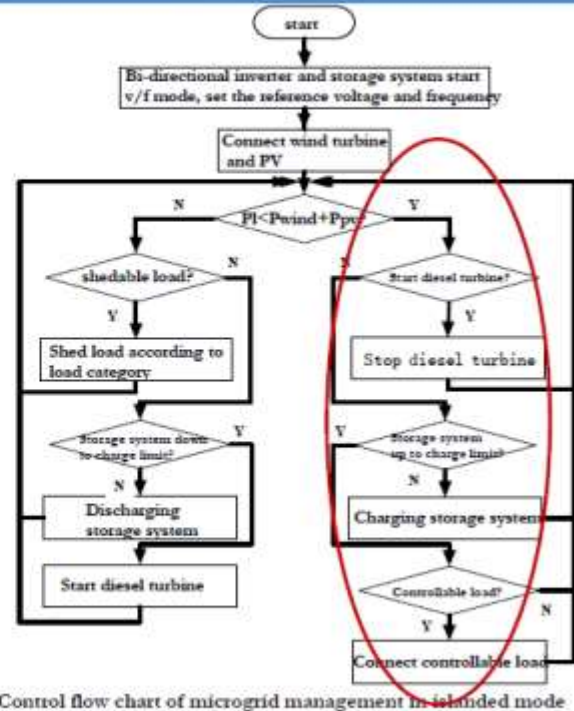


1000kW diesel generation units

圖40 東澳島柴油發電機



Dong'ao island microgrid energy management



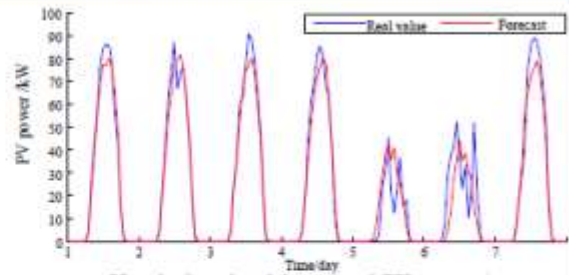
Control flow chart of microgrid management in islanded mode

圖41 東澳島微電網能源管理系統(1/2)

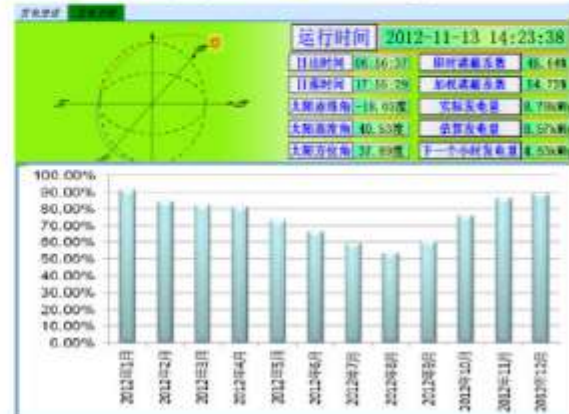


Dong'ao island microgrid energy management

- 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%



Hourly day-ahead forecast of PV generation



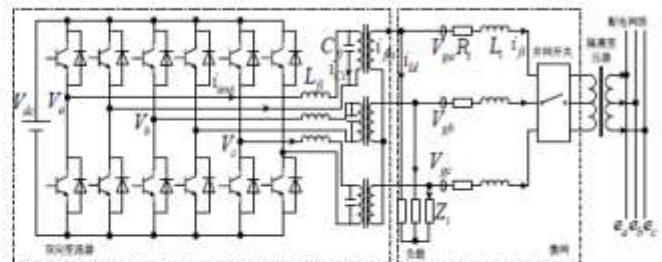
Page 16

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



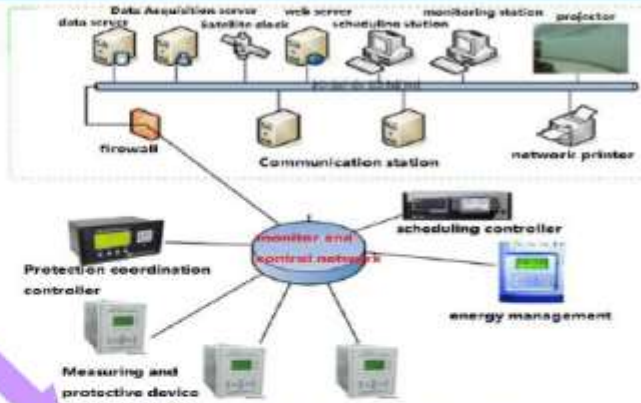
Page 17

圖43 東澳島雙向轉換器



Real-time remote monitoring and control system

- Real-time monitor
 - Ethernet, GPRS
 - Key parameters
- Operation status analysis
- Fault detection, alert and Emergency measures



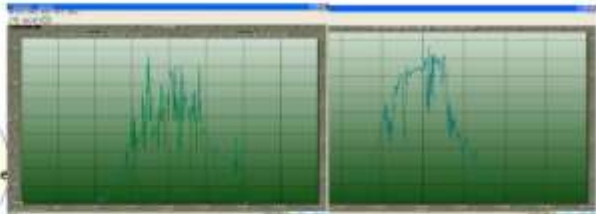
Microgrid scheduling and control system

- ZK2012 developed in this project
 - A microgrid intelligent scheduling and control system
 - Real-time monitor and control
 - Friendly interface, easy to maintain, convenient to extend, independent of hardware platform and easy configuration

圖44 東澳島微電網遠端即時監控系統(1/2)



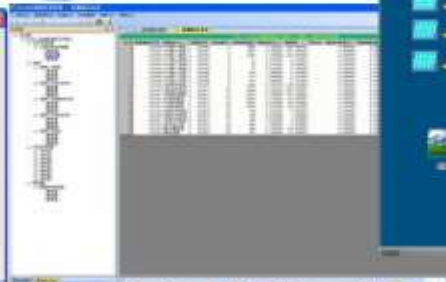
Real-time remote monitoring and control system



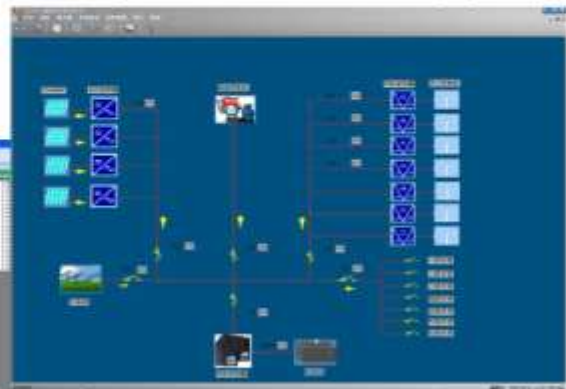
Query interface of historical data/graph



Manual control interface



Query interface of Real-time data



Real-time monitor interface

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

Solar energy produced during the day are charged into the battery bank.



Hours of electricity usage was supported from the battery bank during night time, for residents to enjoy the quietness without darkness.

圖49 烏敏島之太陽光電的建設(1/2)



The solar energy generated is also used to maintain the necessary connections for the residents and visitors, as the Telecommunication Towers and phone lines are supported by the Micro Grid.

The Police Station, the street lights at the ferry pier, the water pumped from the wells for the washrooms, are all powered by the Micro Grid now.



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)

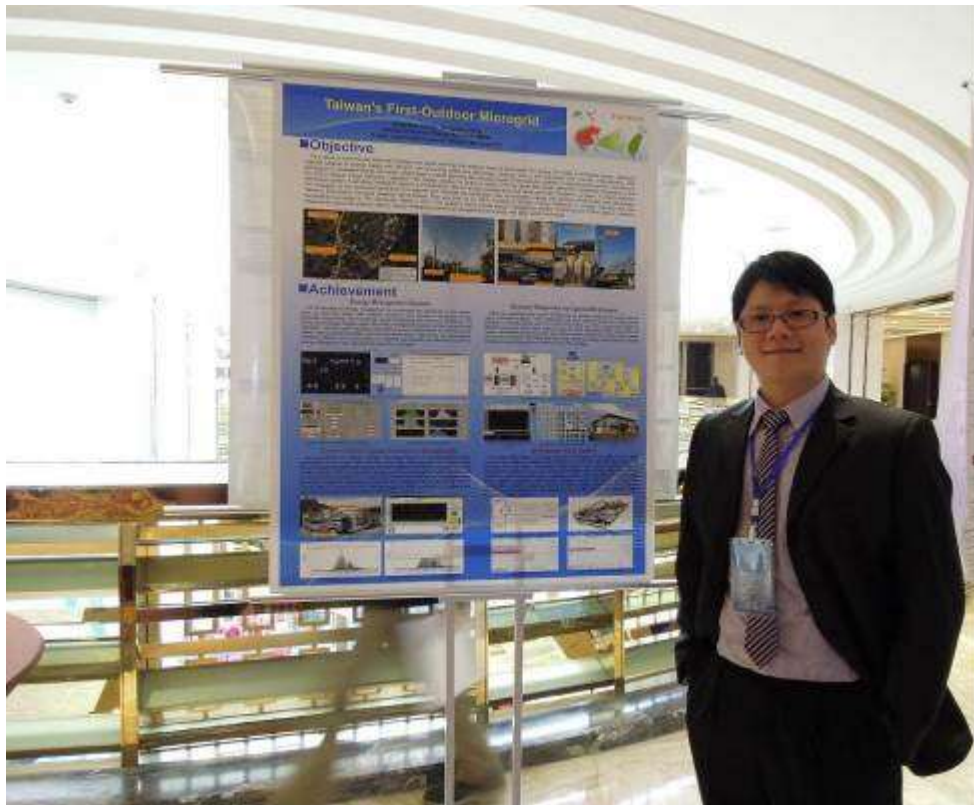


圖53 姜政綸博士張貼本所微電網研發現況海報

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

Selected Energy Surety Microgrid Projects (Funded by DOE OE, DOE FEMP, and DoD)

DOE and DOD jointly fund Sandia National Laboratory to work with military bases to develop energy surety microgrid conceptual designs

| Conceptual Designs/Assessments | Small Scale Microgrid Demos | Large Scale Microgrid Demos | Operational Prototypes |
|---|---|--|--|
| <ul style="list-style-type: none"> • Philadelphia Navy Yard – FY11, DOE OE/PIDC • Camp Smith – FY10, DOE FEMP • West Point FY12, DoD/DOE • Indian Head NWC – FY09, DOE OE/DoD • Ft. Sill – FY08, Sandia LDRD • Ft. Bliss – FY10, DOE FEMP • Ft. Carson – FY10, DOE FEMP • Ft. Devens (99th ANG) – FY09, DOE OE/DoD • Ft. Belvoir – FY09 DOE OE/FEMP • Cannon AFB – FY11, DOE OE/DoD • Vandenberg AFB – FY11, DOE FEMP • Kirtland AFB – FY10, DOE OE/DoD • Maxwell AFB – FY09, DoD/DOE | <ul style="list-style-type: none"> • Maxwell AFB – FY09, DoD • Ft. Sill – FY09, DoD w/ SNL ser' advisor | <ul style="list-style-type: none"> • SPIDERS JCTD – FY11, DOE/DoD <ul style="list-style-type: none"> • Camp Smith | <ul style="list-style-type: none"> • H.R. 5136 National Defense Authorization Act |
| | | | |

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



5

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**



10

圖57 NJ TransitGrid 與 Hoboken ESDM 計畫

Summary of Microgrid Value Attributes

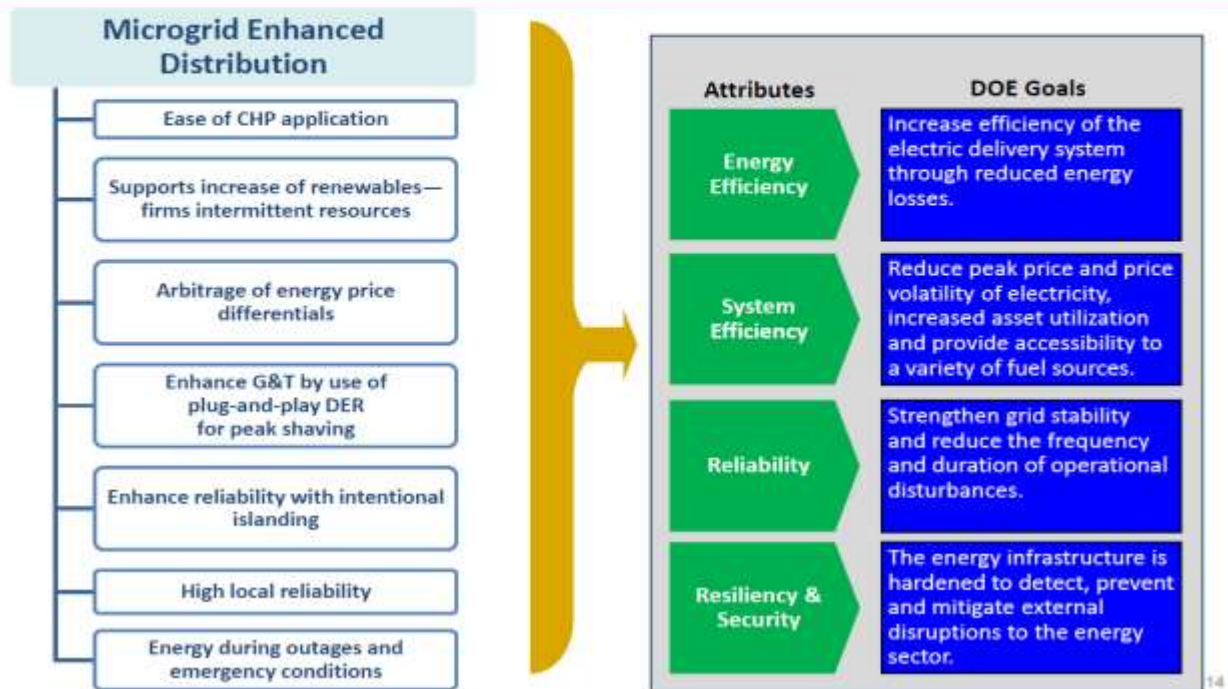


圖58 微電網的價值屬性

Resilience versus Reliability



Separating reliability and resilience is important

- Reliability is compulsory
- Reliability is related to rate recovery
- Adoption of resilience metrics will be easier if reliability definitions remain as-is

| Reliability | Resilience |
|--|--|
| High Probability, Low Consequence (SAIDI/SAIFI exclude storm data) | Low Probability, High Consequence |
| Not risk based | Risk Based, includes: Threat (you are resilient to something) System Vulnerability (~reliability) Consequence (beyond the system) |
| Operationally, You are reliable, or you are not [0 1]. Confidence is unspecified | Resilience is a continuum, confidence is specified |
| Focus is on the measuring impact to the system | Focus is on measuring impact to humans |

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

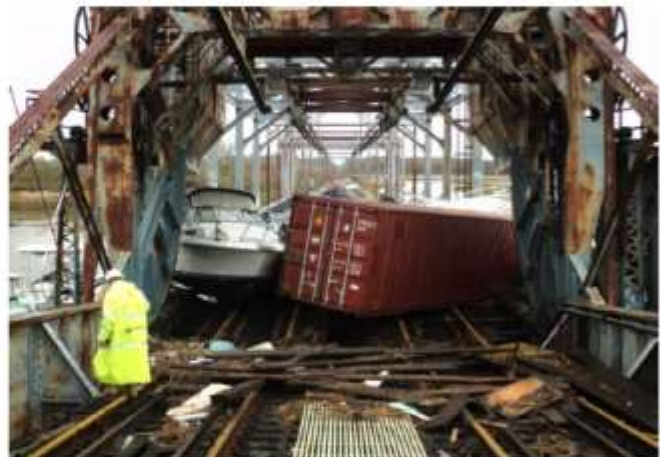
Impact of Superstorm Sandy



- Superstorm Sandy caused major disruption to critical infrastructure in NY & NJ
- Impact to economy and cost of repairs are in the \$Billions
- Re-build efforts emphasize resilience



City of Hoboken, New Jersey



New Jersey Transit Rail System

圖61 珊迪(Sandy)颶風造成之影響

Flood Maps for Hoboken

FEMA 100 Year Flood + 2.5 Feet



Business Sensitive

圖62 珊迪(Sandy)颶風造成 Hoboken 淹水的範圍

Hoboken Performance Objectives

- 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

Hoboken Microgrid Solution

Dual Microgrid Topology, 54 Buildings



圖64 Hoboken 雙微電網拓撲架構

Facility Connections

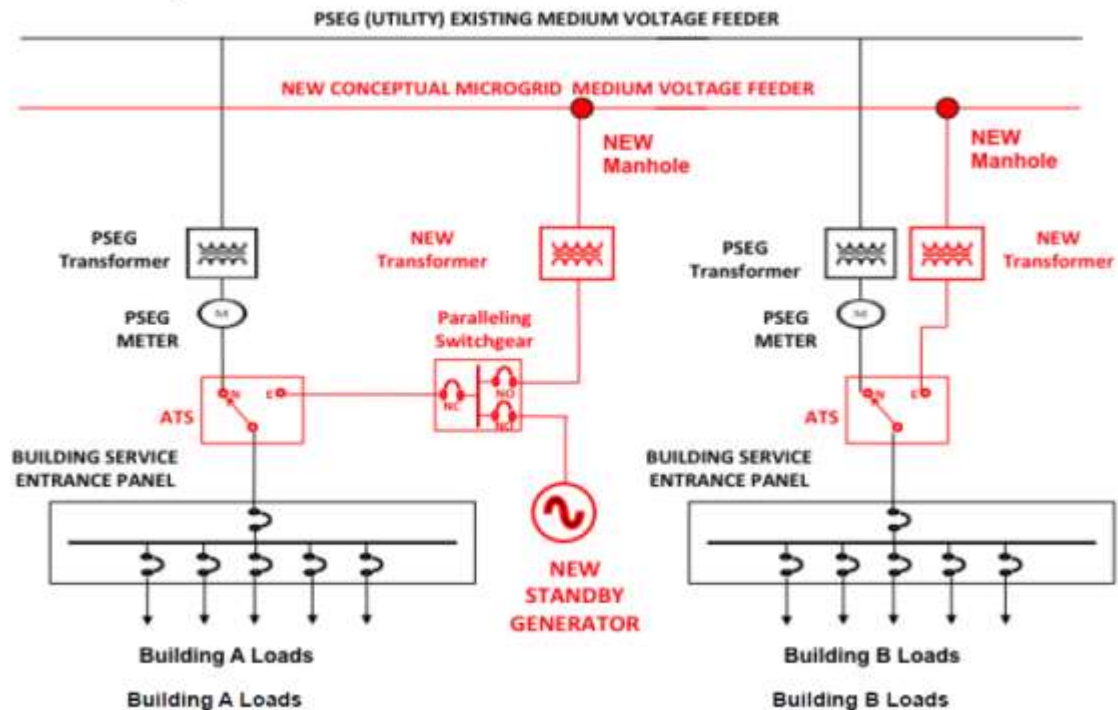
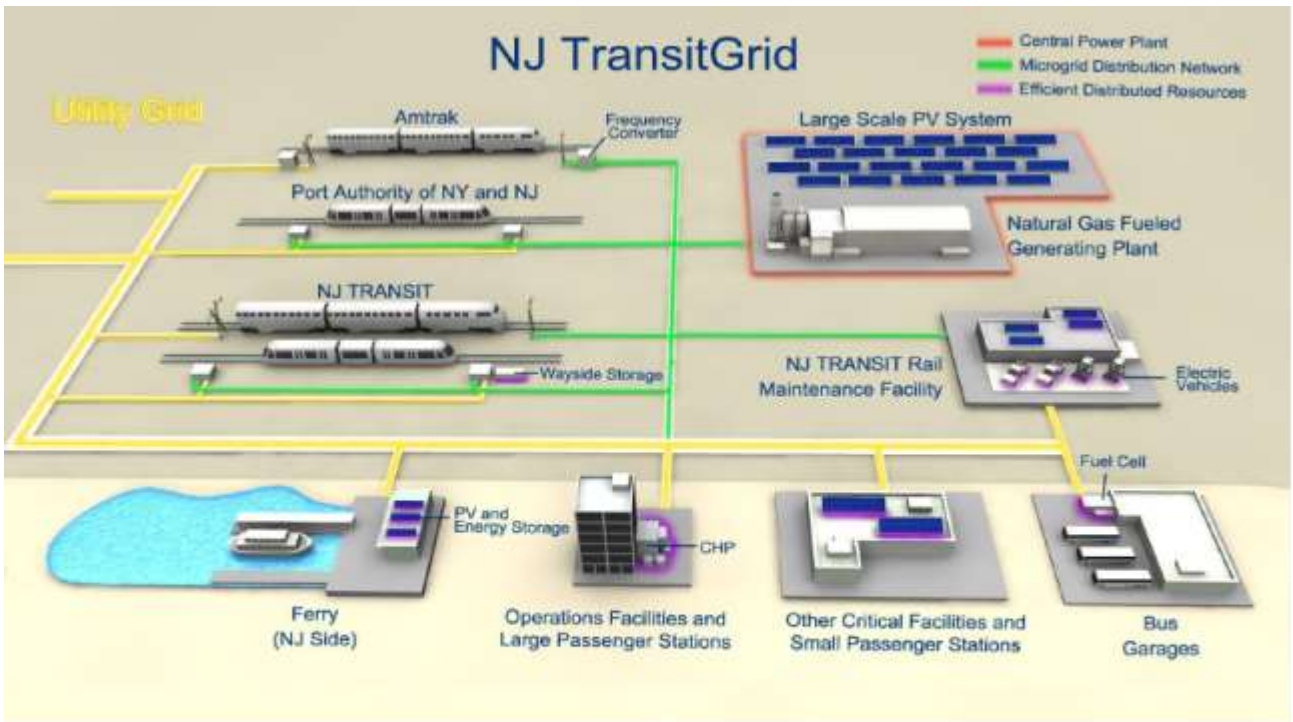


圖65 Hoboken 微電網連接方式



5/16/2014

16

圖66 NJ TransitGrid 微電網系統示意圖

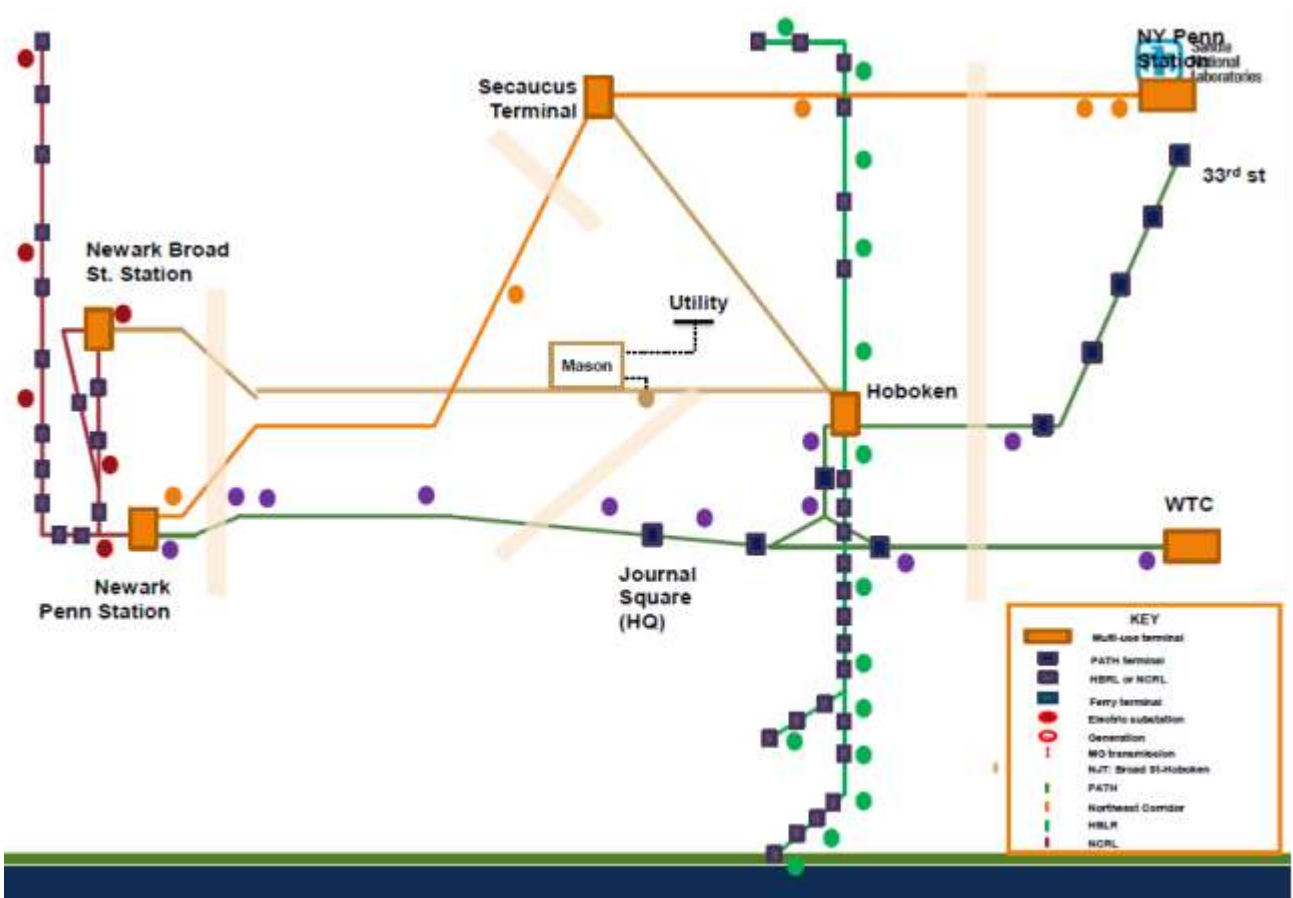


圖67 NJ TransitGrid 微電網系統(建構前)

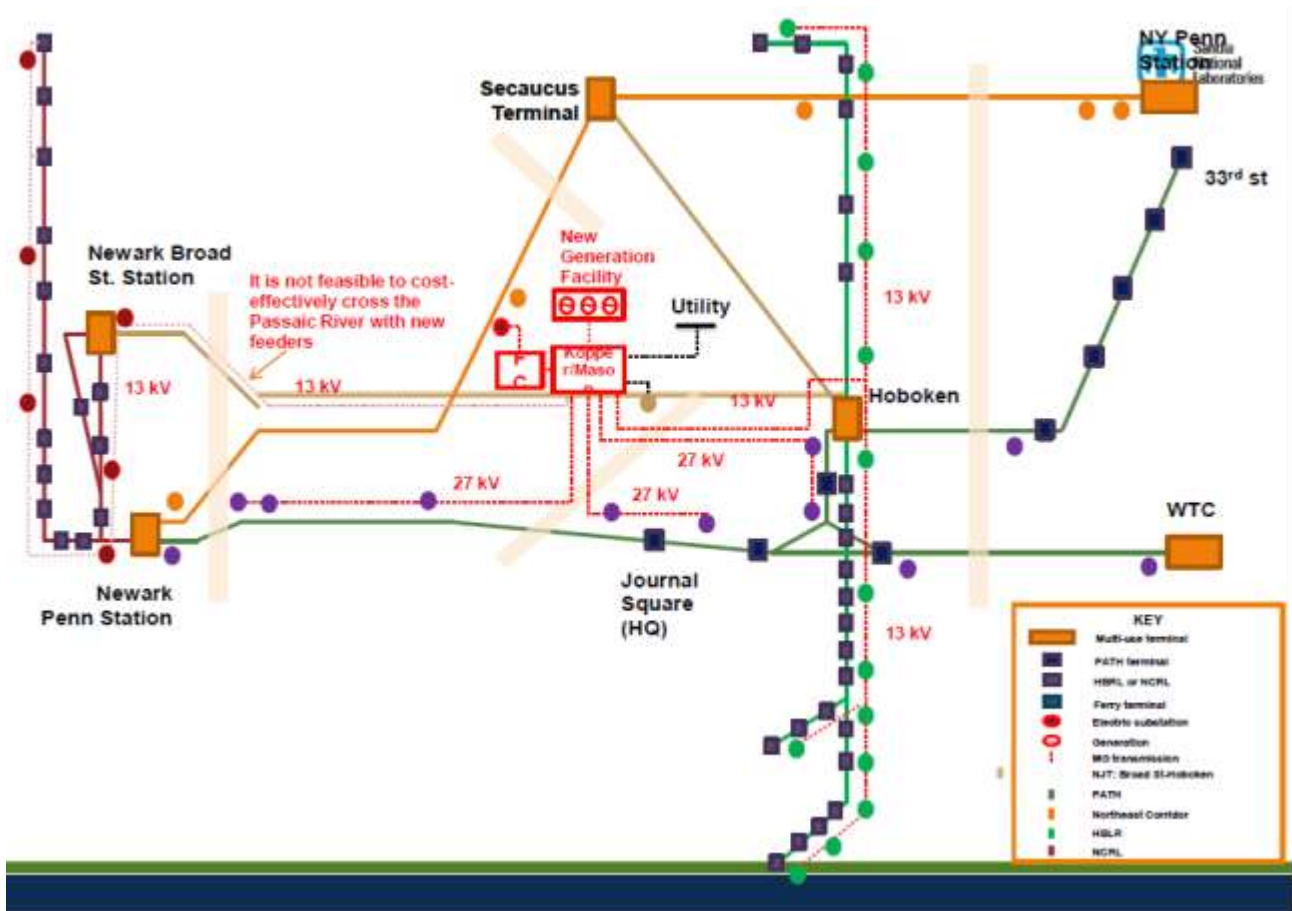


圖68 NJ TransitGrid 微電網系統(建構後)

(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。

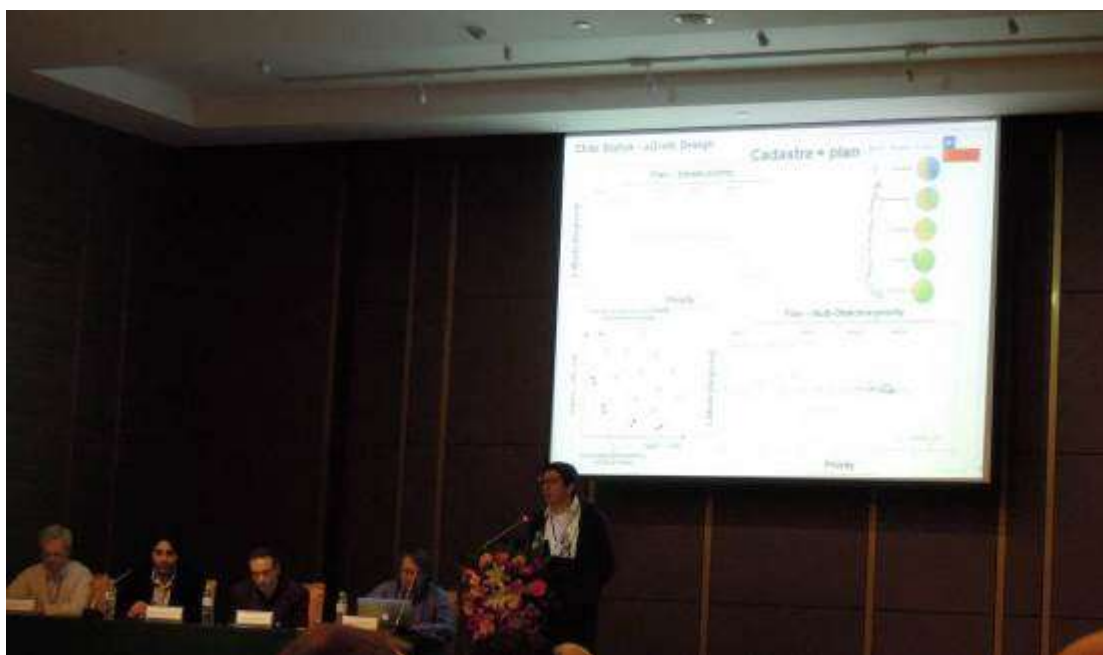


圖69 Guillermo Jiménez Estévez 進行拉丁美洲之微電網研發現況簡報

Microgrids opportunities in the region

Electricity Coverage in Latin America

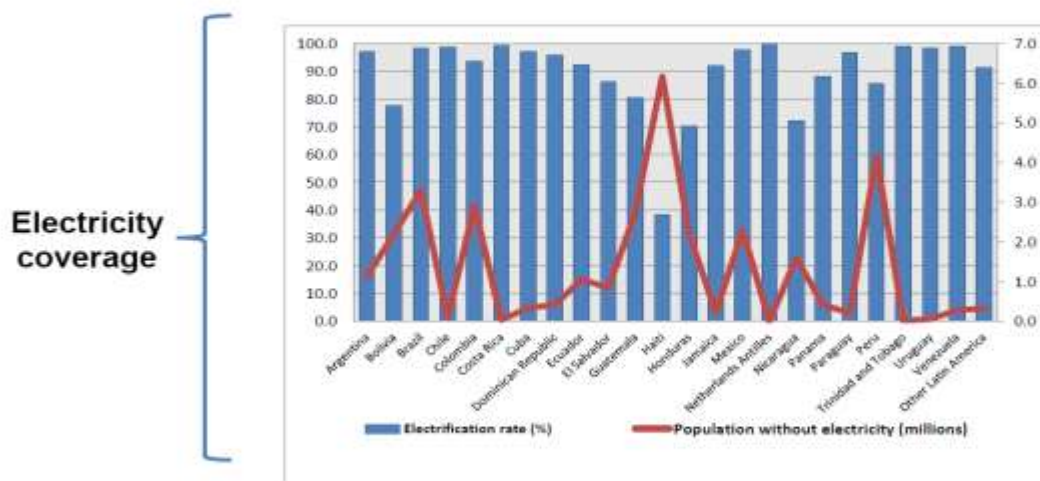


圖70 拉丁美洲的用電覆蓋率

Microgrids opportunities in the region

Some Microgrid developments in LA



圖71 拉丁美洲進行微電網開發的地區

Microgrids opportunities in the region

Chile: Number of feasible isolated MG opportunities

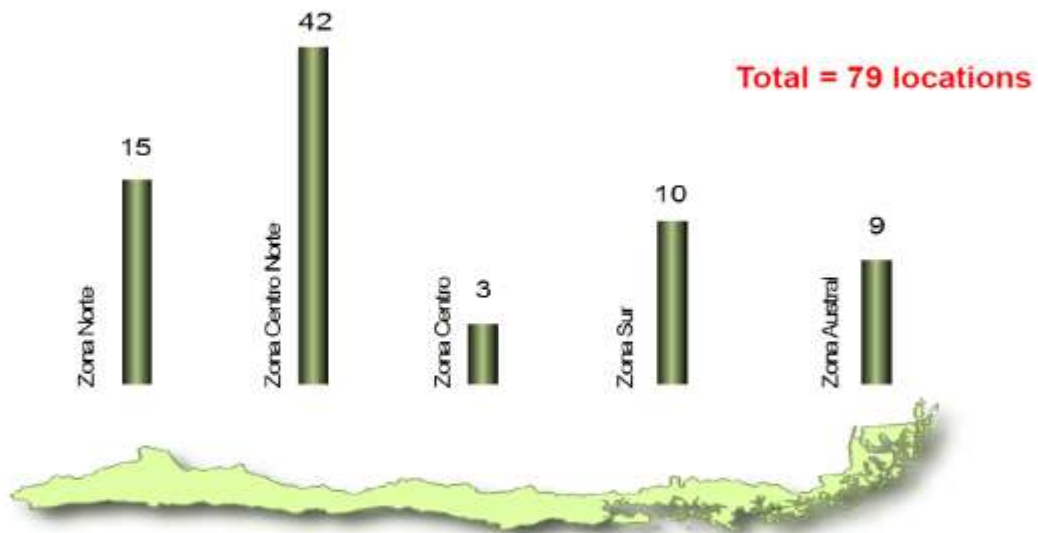


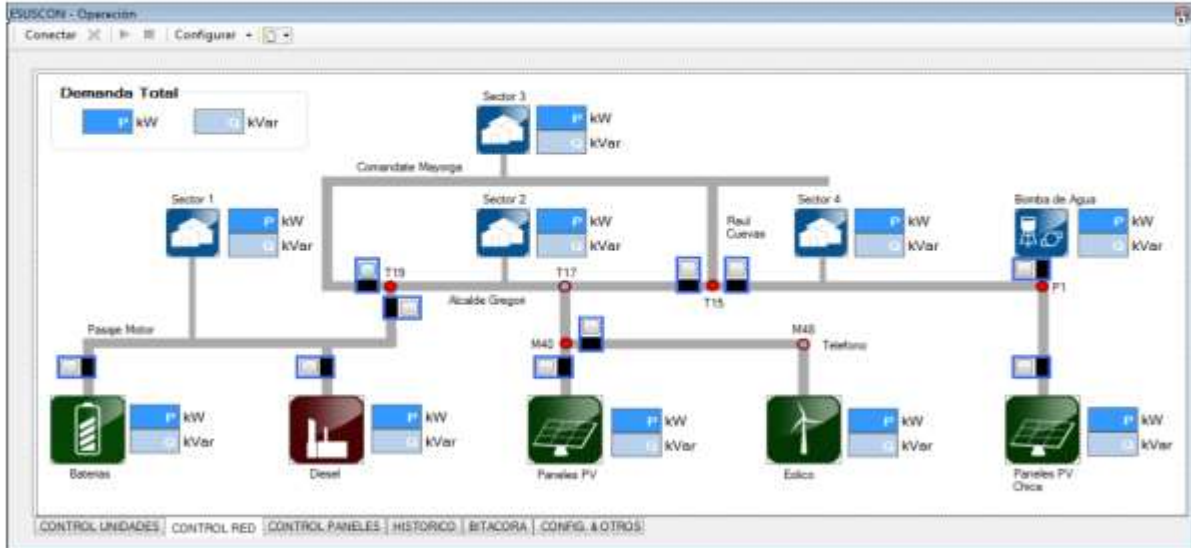
圖72 智利適合發展獨立型微電網的數量

Control software

Huatacondo

.NET application -> "Operación Huatacondo"

µGrid monitoring and control



15

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

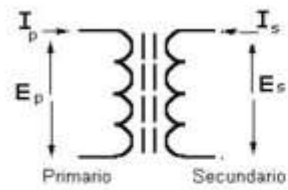
GenSet configuration:

- Consumption curve
- Pmax, Pmin
- Start-up costs, Diesel
- Operational constraints
- Diesel fuel storage

16

圖74 Huatacondo 的微電網能源管理系統

Micro-formers



Low voltage transmission

| | | |
|---|--|---|
| <p>Pros</p> <ul style="list-style-type: none"> • Easy to build • No transformer needed • Consumers and producers easily connected | <p>Cons</p> <ul style="list-style-type: none"> • Expensive, thick copper wire • High distribution losses, low efficiency • 100 meter range | <p>Quality: </p> <p>Cost: </p> <p>Efficiency: </p> |
|---|--|---|

High voltage transmission

| | | |
|--|---|---|
| <p>Pros</p> <ul style="list-style-type: none"> • Low distribution losses, high efficiency • Thin wires • High power capacity (typical) • 10 to 100 km range | <p>Cons</p> <ul style="list-style-type: none"> • Expensive, bulky transformers • Expensive poles • Added complexity in connecting consumers and producers | <p>Quality: </p> <p>Cost: </p> <p>Efficiency: </p> |
|--|---|---|

Microformer transmission

| | | |
|---|---|---|
| <p>Pros</p> <ul style="list-style-type: none"> • Easy, low-cost construction • Consumers and producers easily connected • Low system losses, average to high efficiency | <p>Cons</p> <ul style="list-style-type: none"> • Modest amounts of power • 1 to 5 km range | <p>Quality: </p> <p>Cost: </p> <p>Efficiency: </p> |
|---|---|---|

圖75 自行開發之微變壓器

Electric Vehicle

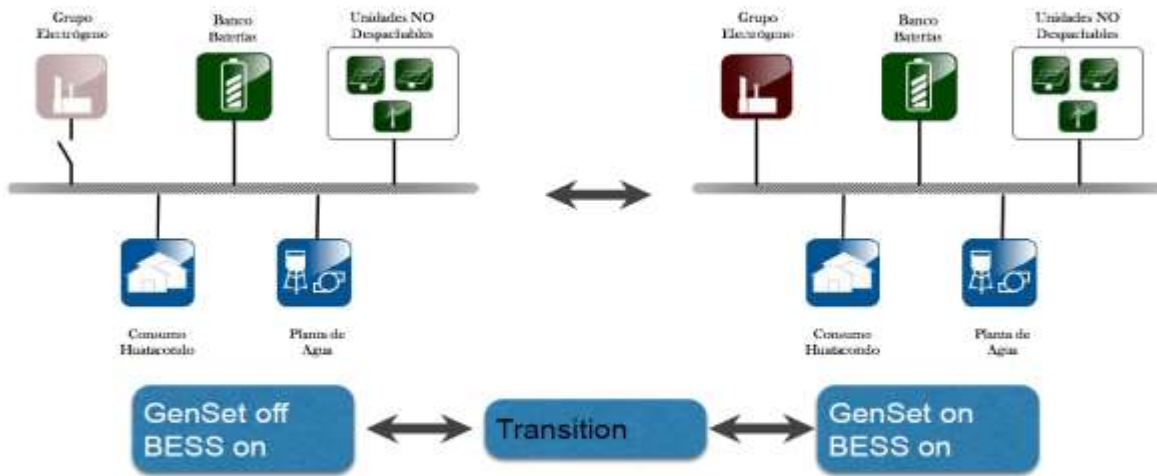


圖76 自行開發之電動車

Control software

Huatacondo

Transitions: GenSet On/Off



BESS controls frequency and voltage.

GenSet controls frequency and control, I BESS is dispatched.

圖77 微電網轉態切換示意圖

Control software

Huatacondo

Transitions —> GenSet goes on

Frequency and active power

Voltage and reactive power

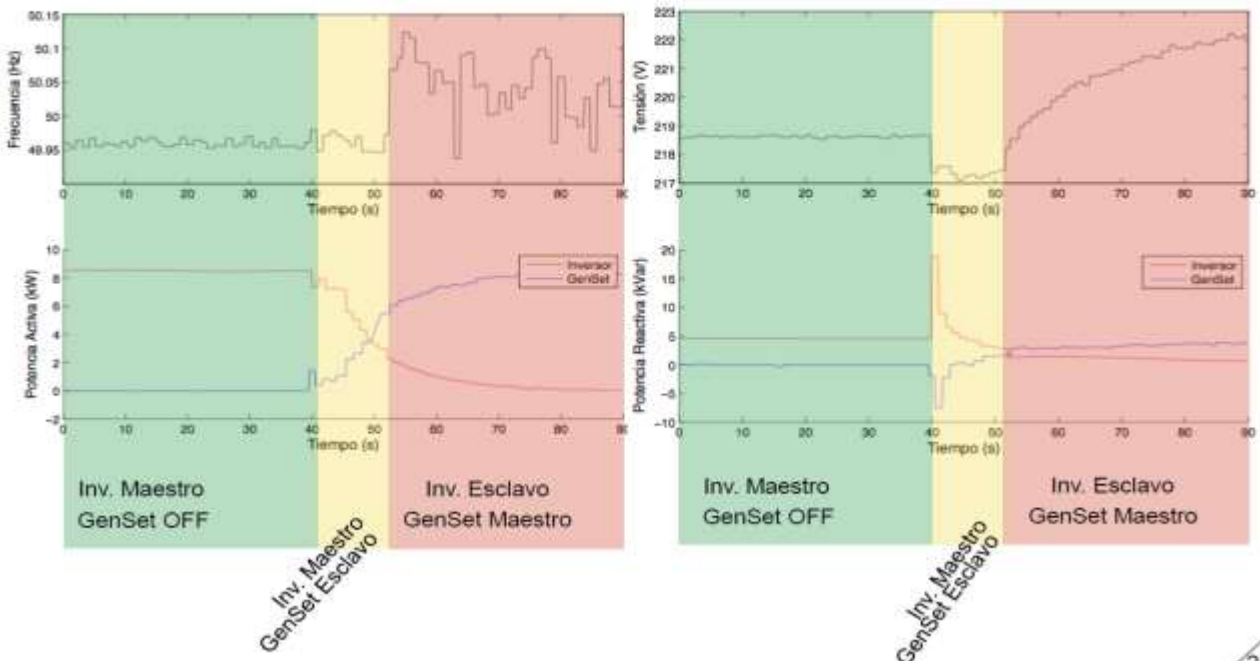


圖78 微電網轉態切換測試

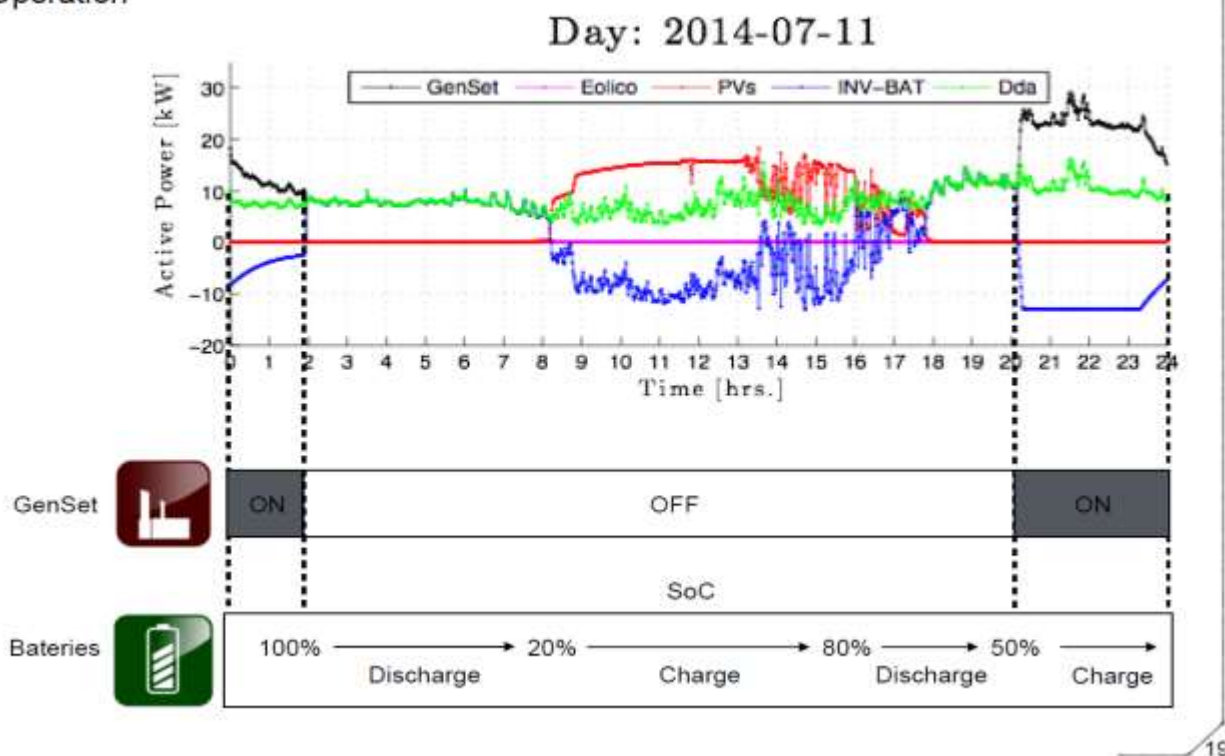


圖79 Huatacondo 的微電網運轉測試

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

Mombou: the village



- Remote in semiarid climate
- 800 people and an additional 200 from hamlets nearby, main income generating activity is cattle
- 135 buildings (129 connected), school, medical centre, mosque, small shops
- several small shops, water pumps for vegetable gardening
- Deferrable load: water pumping for irrigation
- PV electricity since June 2014

圖81 Chad 的 Mombou 村落簡介

Needs Assessment

Estimated Load profile - Dry season (October - June)

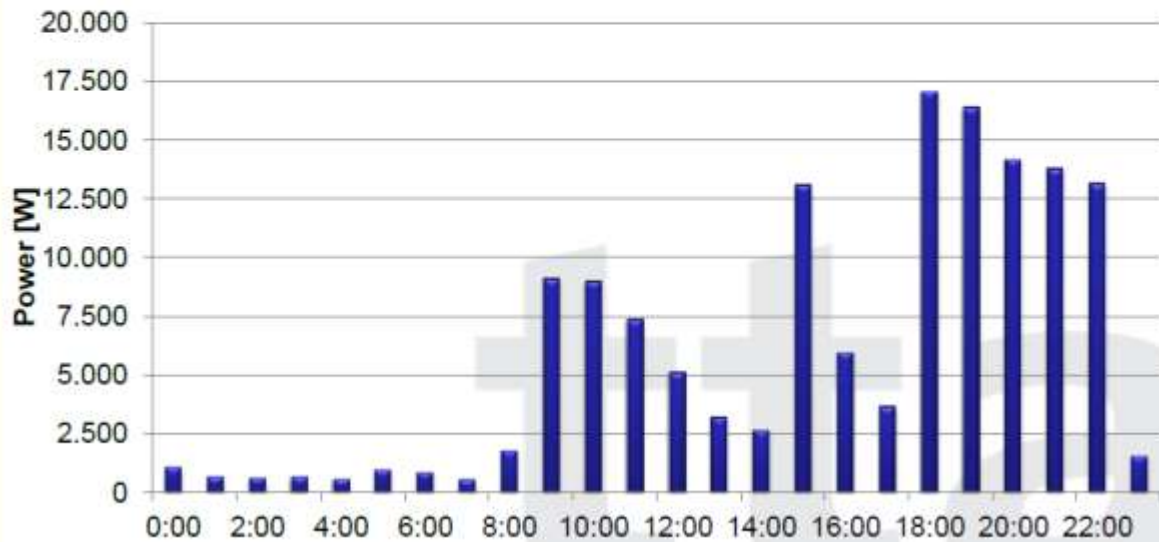


圖82 Chad 的 Mombou 村落之預估負載量

Electrical diagram

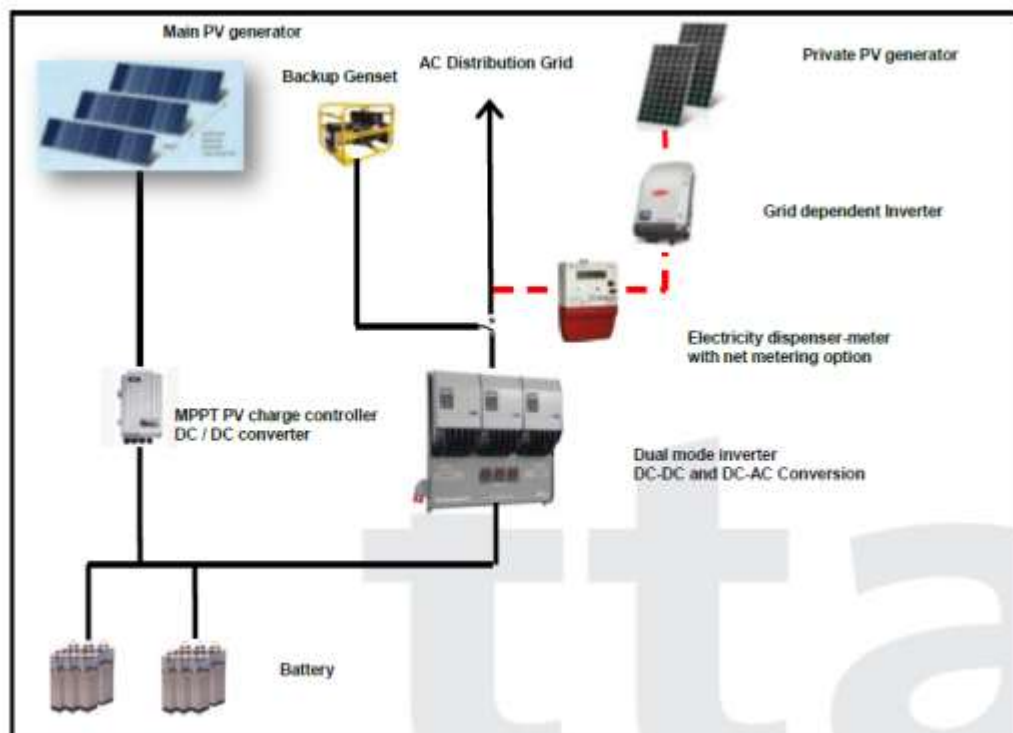


圖83 Mombou 村落的微電網單線圖

Distribution grid layout

Mombou, Chad

Reseau de distribution

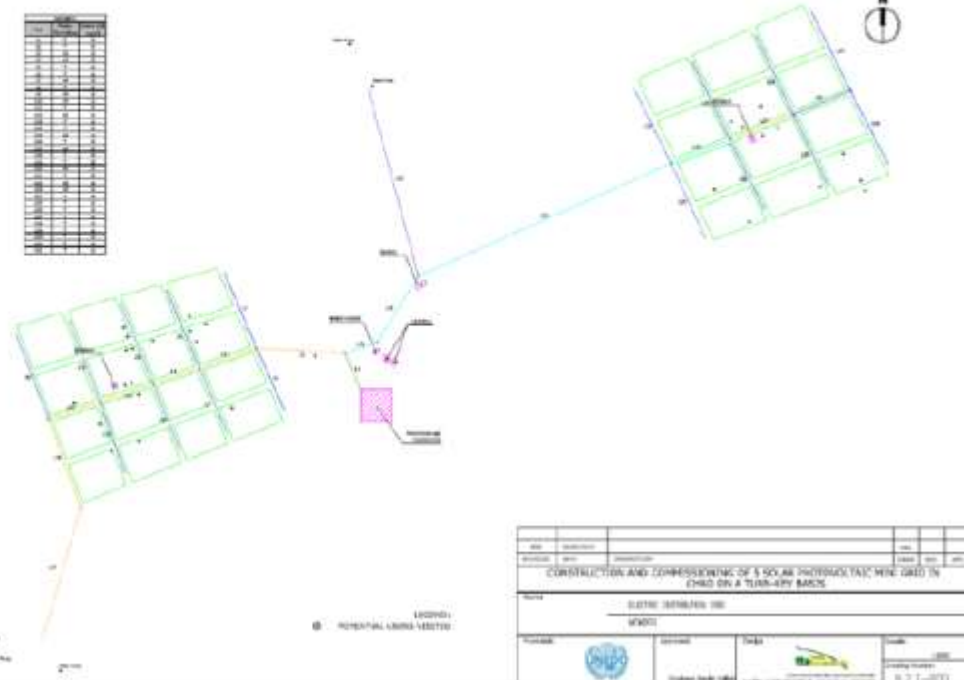


圖84 Mombou 村落之分散式能源配置

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 HP5 |
| PV GENERATOR | |
| Total PV capacity (STC) | 39.600 kWp |
| Type of PV module / capacity STC | polycrystalline / 240 W _p |
| Brand and Model | REC140PE |
| Number of PV module | 165 |
| Inclination / orientation | 10° / +25° 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 ₂₀)) | 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

Technical solution: mechanical room



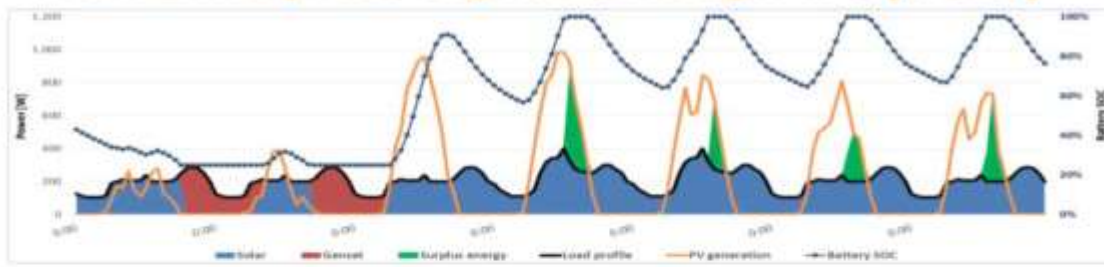
圖86 柴油發電機與電池實景照

Added value solution: local capacity building



圖87 太陽能板實景照

Real time price signal through frequency



tta

圖88 負載、再生能源與電池 SOC 曲線

Start up: Let there be light!

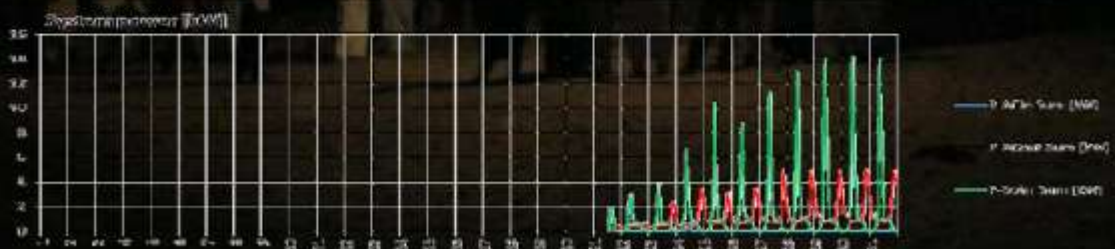


圖89 運用微電網系統供應路燈照明

(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

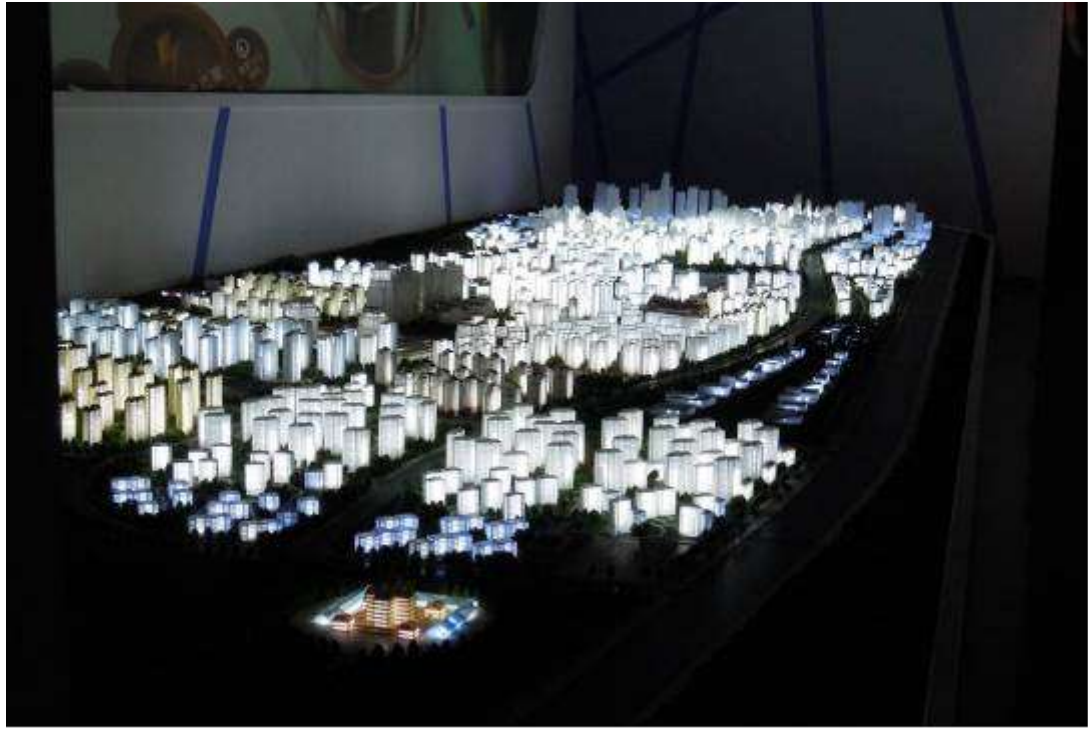


圖96 智能供電營業廳內模型展示



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



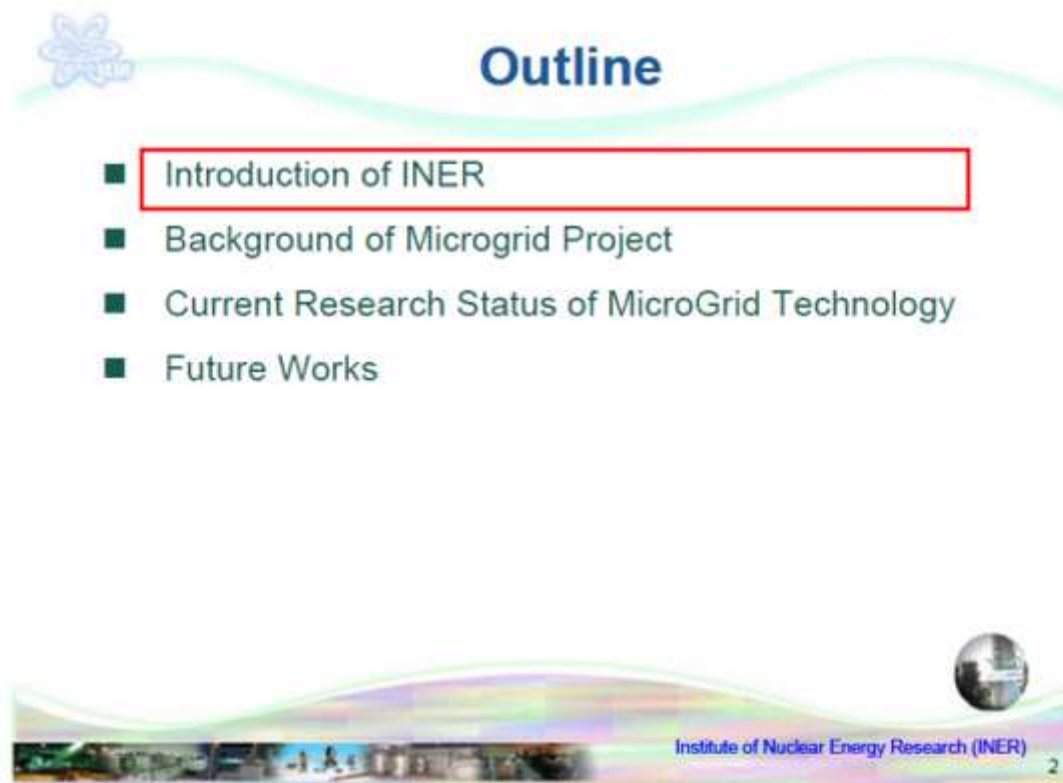
圖99 智能供電營業廳內電動車體驗

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

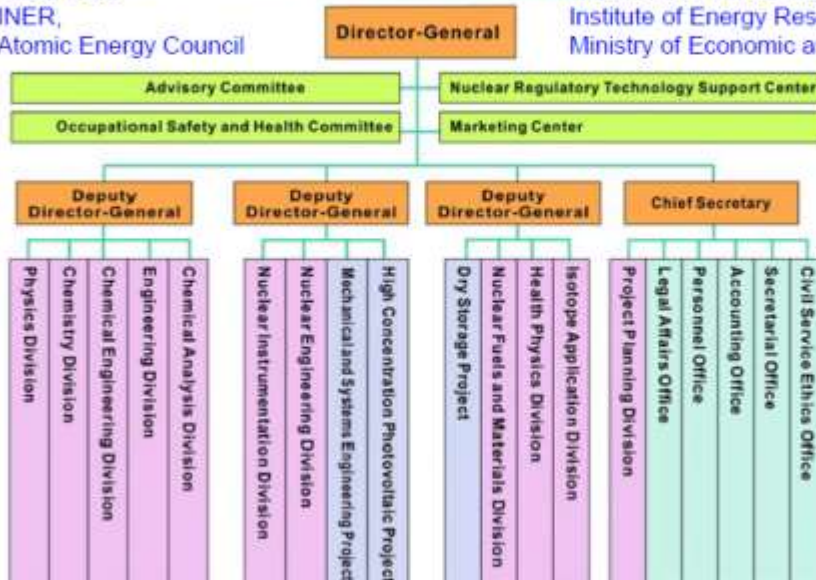
<http://www.iner.gov.tw>



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

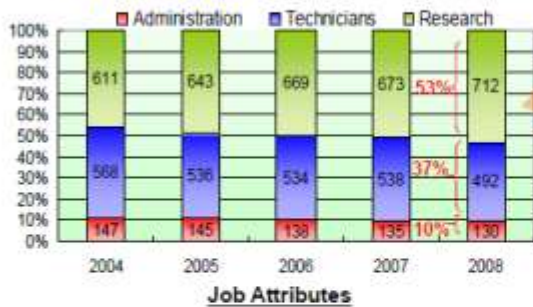


Institute of Nuclear Energy Research (INER)

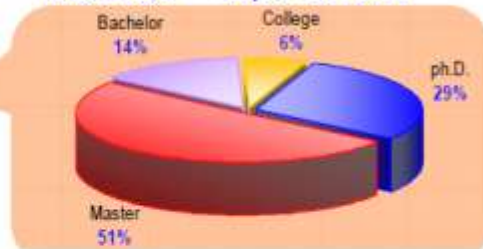


Profile of INER

Profile - Staff

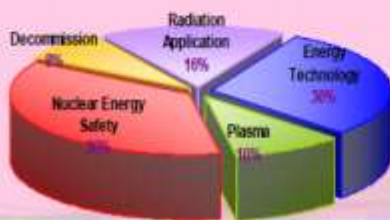


Total = 1534 September 2010



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

Institute of Nuclear Energy Research (INER)

5



Outline

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

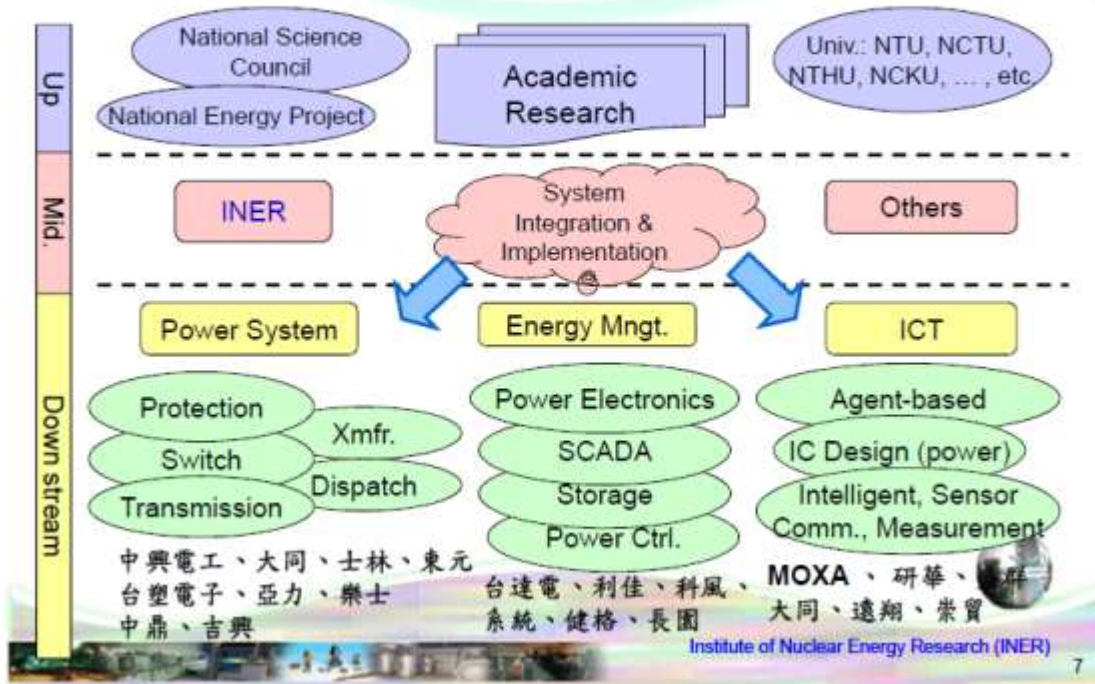


Institute of Nuclear Energy Research (INER)

6



Research Position of INER



DG Units at INER





Microgrid Test Field

The composite image includes a site map and several photographs. The site map shows the layout of the test field with various components labeled: 25 kW wind, 100 kW HCPV, 150 kW wind, and 100 kW HCPV. A blue arrow indicates the 'Photo Direction'. The photographs show: 100 kW HCPV (High Concentration Photovoltaic) panels, a 25 kW wind turbine, a 150 kW wind turbine, a Control Room (Ctrl. Rm) with computer monitors, 250 kW ES (Energy Storage) units, and 65 kW x3 MT (Micro Turbine) units. A yellow box labeled 'MG Test Field' is overlaid on the bottom right of the photograph area.

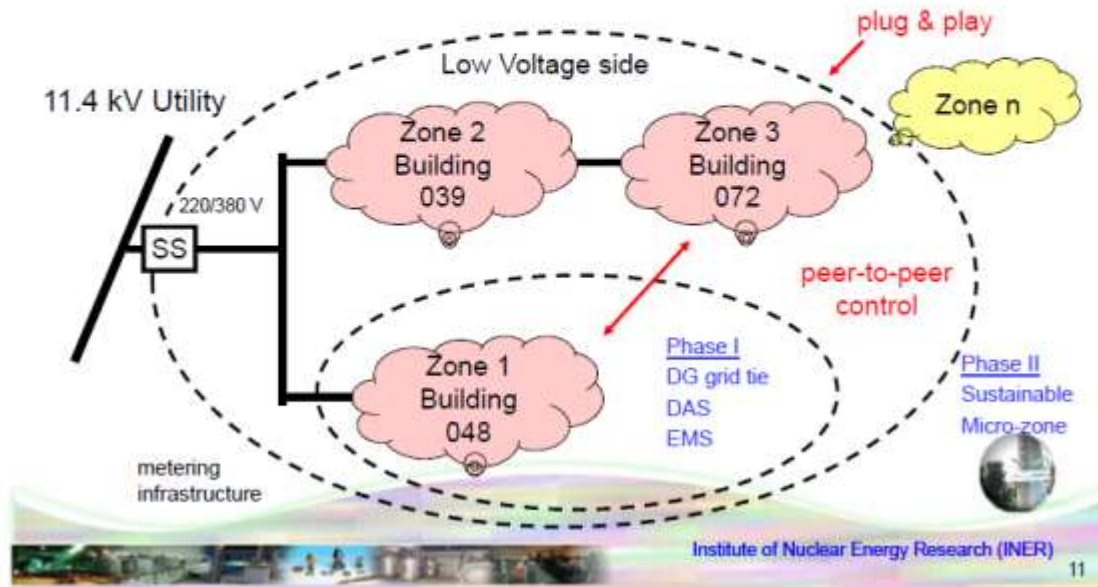
9

The aerial map shows the location of the Microgrid Test Field. A yellow line represents the TPC Distribution Feeder. A red dot marks the Point of Common Coupling (PCC). A blue line represents the Overhead Line (700 m) connecting the PCC to the Microgrid Test Field. A red line represents the Underground Line (35m) connecting the PCC to the Microgrid Test Field. A legend in the bottom right corner identifies the line types and lengths.

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.



Microgrid Development Roadmap



| Phase | 2010 | 2011 | 2012 | 2013 | 2014 | 2015-2020 |
|--------|---|------|---|------|---|-----------|
| Phase | System Planning & Core Technology Development | | System Integration & Implementation | | Pilot Operation & Performance Improvement | |
| Target | <ul style="list-style-type: none"> Power Analysis for Seamless Islanding Operation Smart Control & Measurement Advanced Power Electronics Energy Management Energy Storage | | <ul style="list-style-type: none"> Increase the renewable energy penetration rate of regional power grid up to 10% | | <ul style="list-style-type: none"> Increase the renewable energy penetration rate of regional power grid up to 20% | |



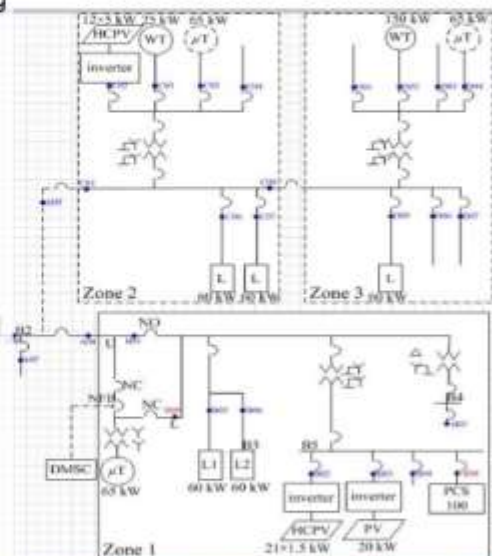
Outline

- 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

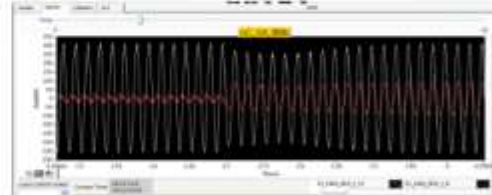
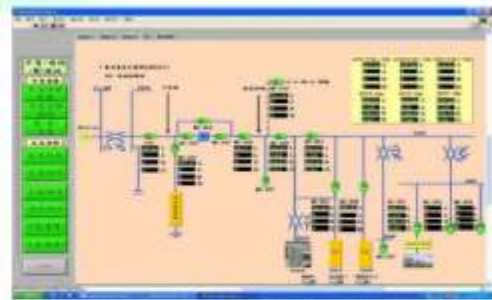




(1) Power System Technology

■ 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

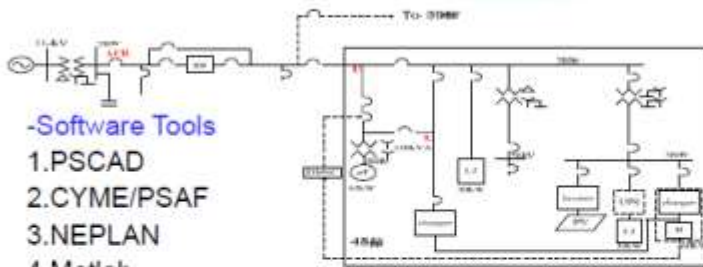


Grid-connected & Islanding



(1) Power System Technology

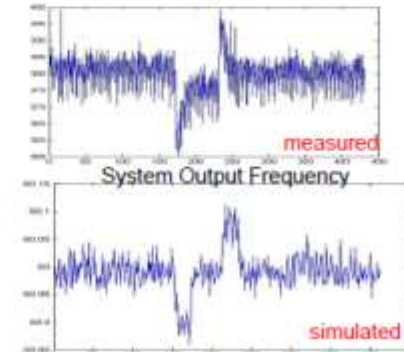
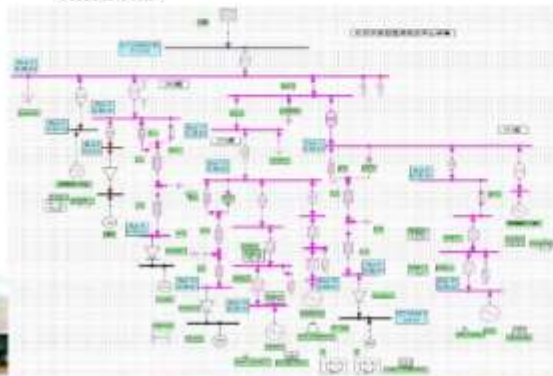
■ System Stability Analysis



- 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



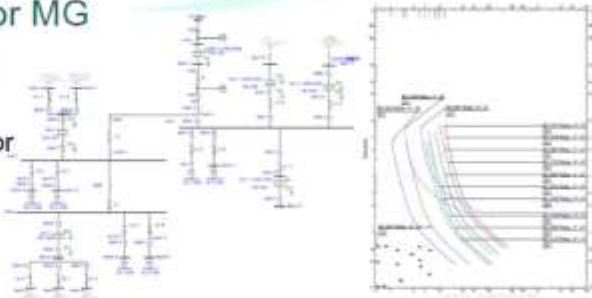


(1) Power System Technology

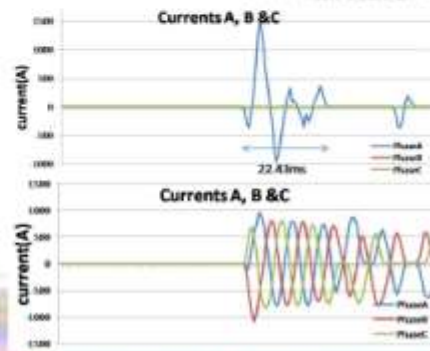
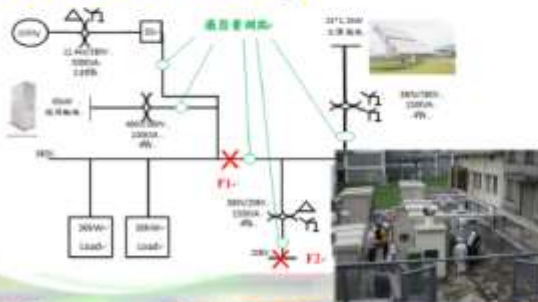
■ Protection Coordination for MG

➢ 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

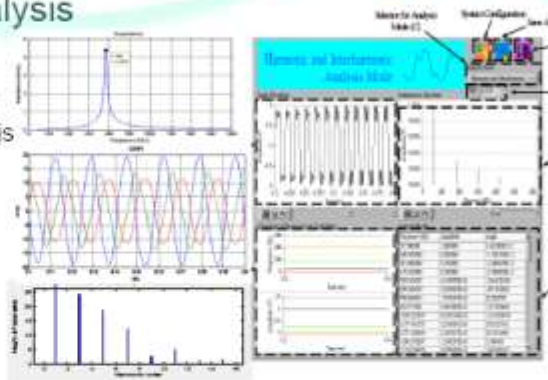
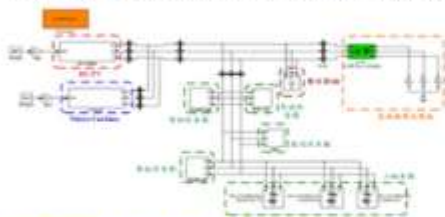


(1) Power System Technology

■ Microgrid Power Quality Analysis

➢ Power quality analysis

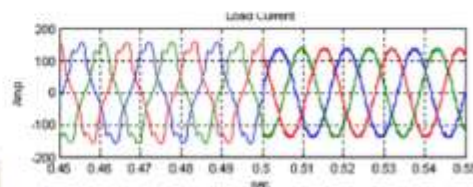
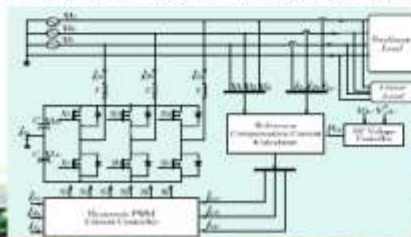
- Harmonic modeling of microgrid component
- Harmonic power flow and unbalance analysis



Power quality analysis of grid-tied/islanding

➢ Power quality improvement

- Active/passive power filter analysis & design



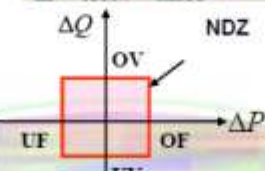
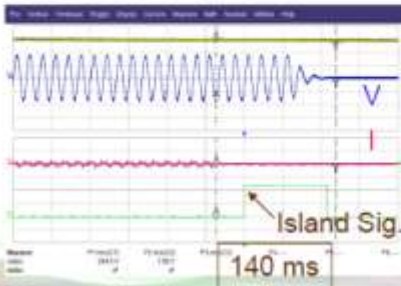


(2) Power Electronics Technology

■ Static Switch & Islanding Detection

➤ Active islanding detection

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



| 電壓範圍 | 解聯時間(秒) |
|------------------|---------|
| $V < 50$ | 0.16 |
| $50 \leq V < 88$ | 2.00 |
| $110 < V < 120$ | 1.00 |
| $120 \leq V$ | 0.16 |

| 頻率範圍 | 解聯時間(秒) | |
|--------------------|----------------------|----------|
| $\leq 30\text{kW}$ | > 60.5 | 0.16 |
| | < 59.3 | 0.16 |
| $> 30\text{kW}$ | > 60.5 | 0.16 |
| | $\{59.8 \sim 57.0\}$ | 0.16~300 |
| | < 57.0 | 0.16 |

IEEE 1547 standard



Institute of Nuclear Energy Research (INER)

19

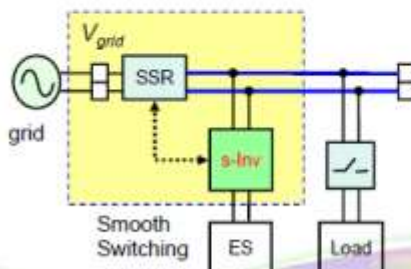


(2) Power Electronics Technology

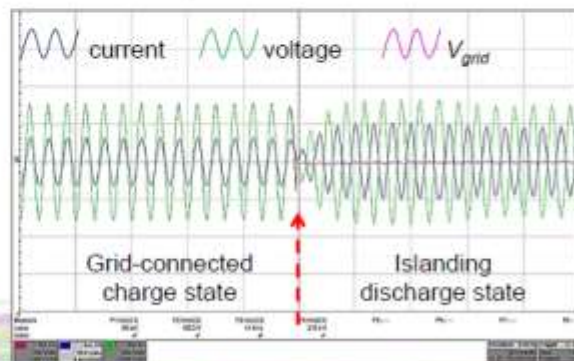
■ Smooth Switching Inverter



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.



Institute of Nuclear Energy Research (INER)

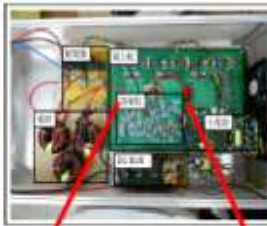
20



(2) Power Electronics Technology

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

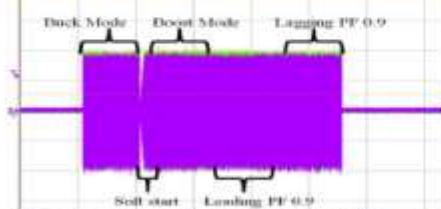
| | Spec. | Note |
|--------|-------------------------------------|---|
| Vac | 3 ϕ 3W- Δ 220V/60 Hz | |
| Vdc | 380 \pm 20 V | |
| PF | > 0.99 | Charger mode |
| | -0.9~1~0.9 | Discharger mode |
| Freq. | > 96% | Highest efficiency |
| Rating | 250 kVA | Discharger with active/reactive control |
| Comm.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



DSP controller layout



250 kW bi-directional inverter



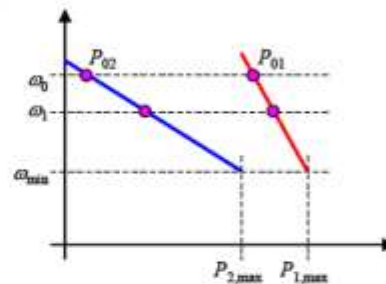
Measured waveform in four-quadrant operation



(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)

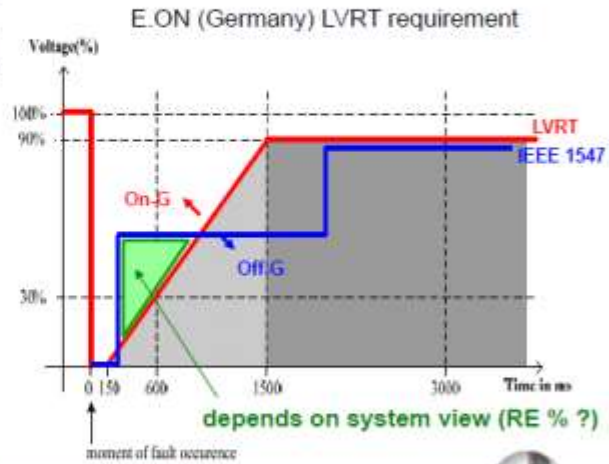




(2) Power Electronics Technology

■ 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



Institute of Nuclear Energy Research (INER)

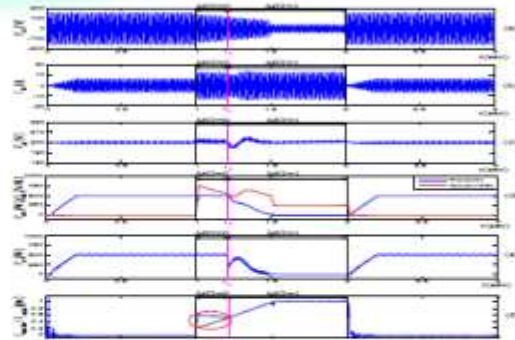
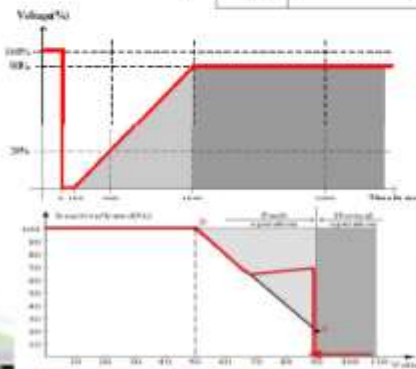
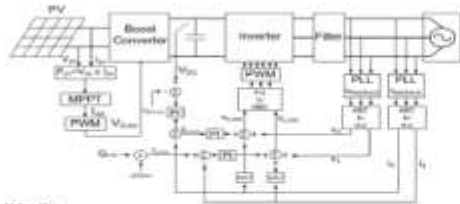
23



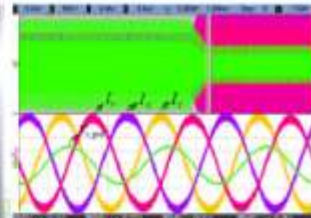
(2) Power Electronics Technology

■ Low Voltage Ride Through

- Simulation platform for LVRT



simulation platform for LVRT



Institute of Nuclear Energy Research (INER)

24



(2) Power Electronics Technology

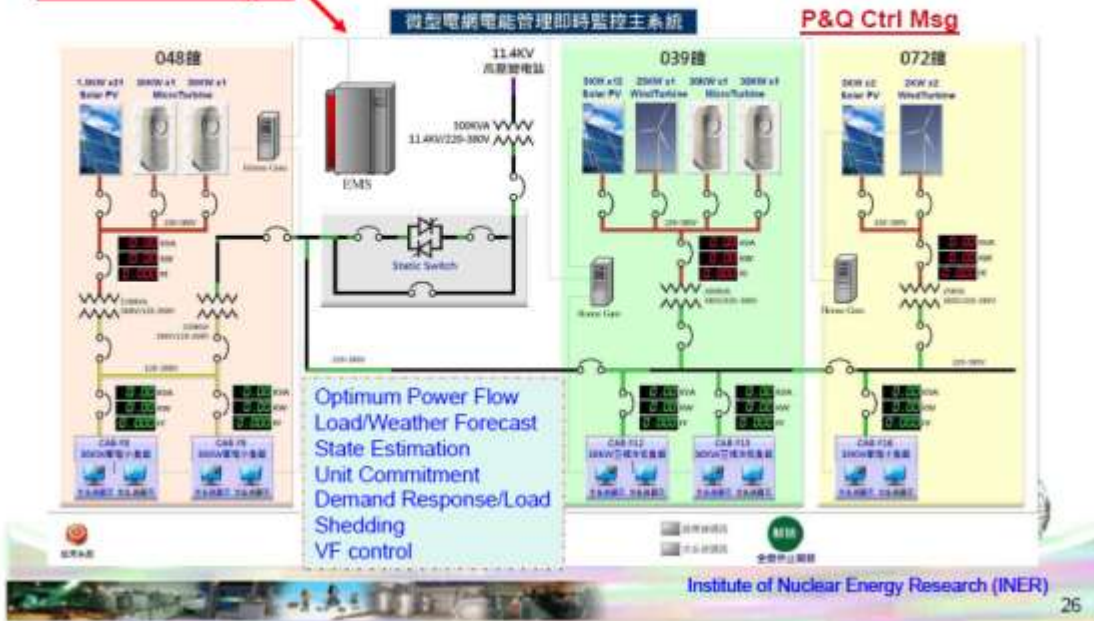
Low Voltage Ride Through



(3) Intelligent control and EMS

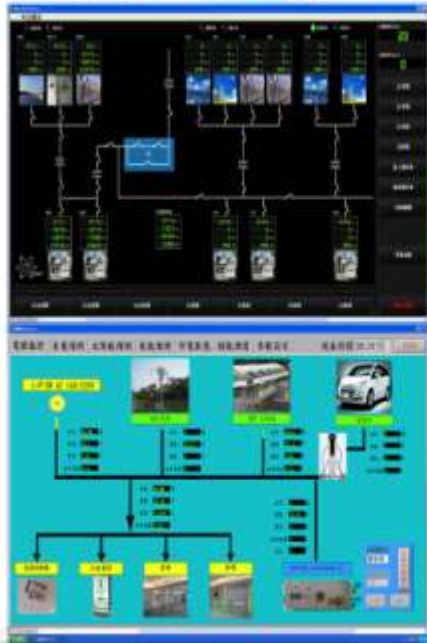
Energy Management System

Price & Carbon Signal





(3) Intelligent control and EMS



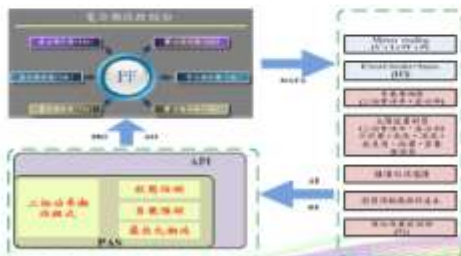
Institute of Nuclear Energy Research (INER)



(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.



Institute of Nuclear Energy Research (INER)

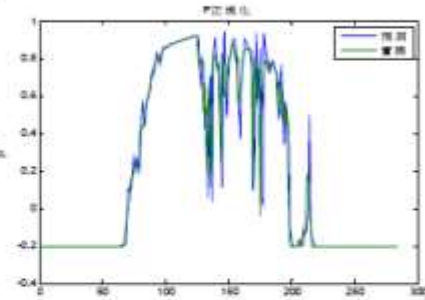
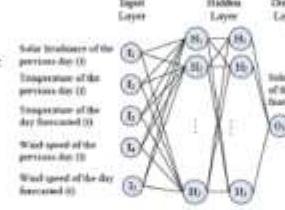
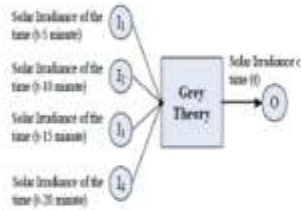


(3) Intelligent control and EMS

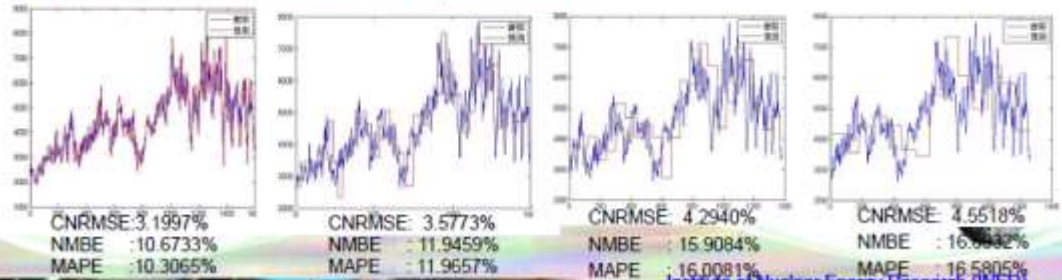
■ Generation prediction for renewable energy

Extreme short-term forecast – GT

Short-term forecast – BNN



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

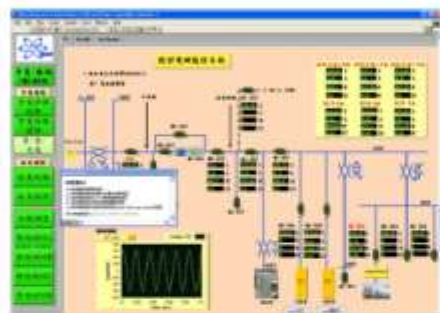


Institute of Nuclear Energy Research (INER)



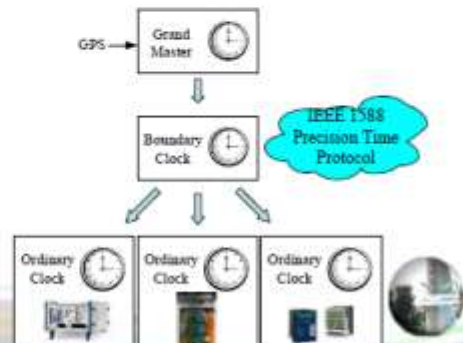
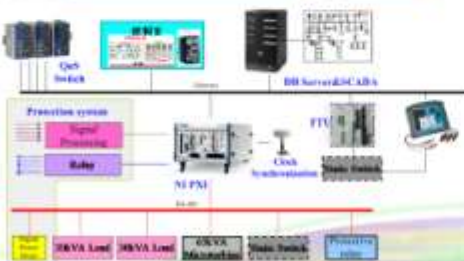
(3) Intelligent control and EMS

■ DAS and Time Synchronization



IEEE1588 V2 time synchronization (PTP)

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



Institute of Nuclear Energy Research (INER)



(3) Intelligent control and EMS

■ Other Energy Storage

Vanadium Redox Battery (under testing)

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



Institute of Nuclear Energy Research (INER)

31



Outline

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



Institute of Nuclear Energy Research (INER)

32



Smart Institute Project

INER
6.75 MW
52 buildings

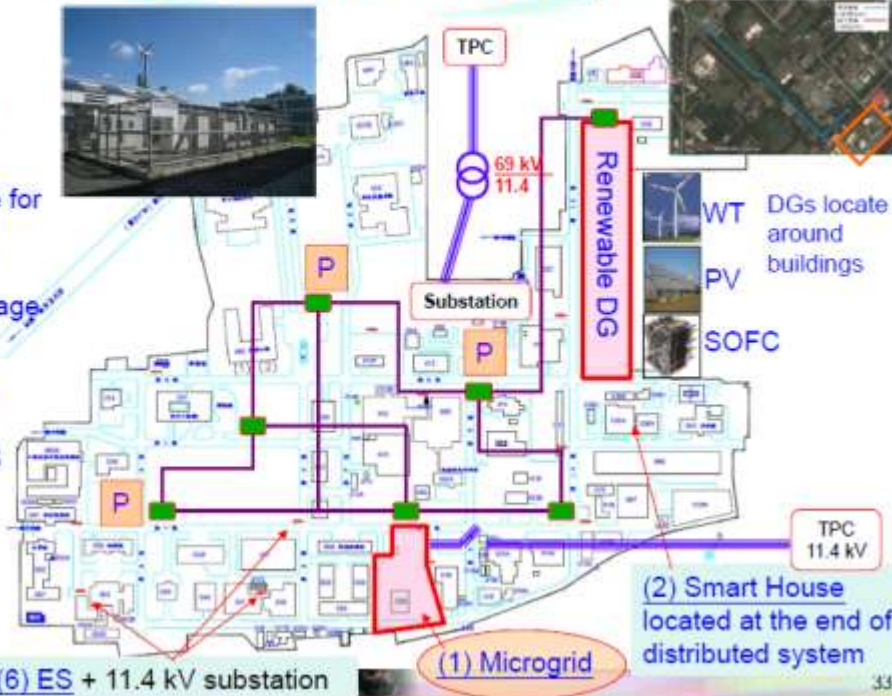
(3) ADAS
loop structure for
load transfer

(4) AMI
high, low voltage

(5) EV
smart power
dispatching
mngt. and ES

EV充电站

停車場



WT DGs locate
around
buildings

PV

SOFC

(2) Smart House
located at the end of
distributed system

(6) ES + 11.4 kV substation

(1) Microgrid

33



Water Park of Pingtung Microgrid



Institute of Nuclear Energy Research (INER)

34



Microgrid on Penghu Island



All possible types of international collaboration are welcomed !

(二) 本所展示之海報資料：

Taiwan's First-Outdoor Microgrid

Yung-Ruei Chang, Jheng-Lun Jang
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

Full functionality of energy management for a microgrid are developed in this system, such as real time power flow analysis, long-term and short-term renewable energy generation forecasting, load forecasting, power dispatching and economic dispatching. By taking use of energy storage system, the energy management system carries out real power regulation, reactive power regulation and reactive power compensation to maintain power output, reduce voltage fluctuation and improve power factor, respectively. Two subsystems, monitoring platform and control platform, cooperate harmonically and efficiently to perform energy management and cost-effective target for a microgrid.



Demand Response by OpenADR Scheme

INER has established the system architecture for demand response of a microgrid by using OpenADR protocol, which distributes real time electricity price and utility power demand to terminal device via VTN (Virtual Top Node) and VEN (Virtual End Node) in different substations. Once each substation gets the price information from OpenADR, for some cost-effective purposes, they can reduce power demand and shed some loads, such as air conditioner, light lamp and electricity stored by bidding mechanism and BEMS (Building Energy Management System) in an office building.



Electric Vehicle Charge Scheduling Management

As the growth of EV (Electric Vehicle), the power peak in a community will increase dramatically in the future. When all EVs come back home and go their charging state simultaneously, the power peak may be over the limitation of transformer capacity and cause a disaster. INER has developed charge scheduling management system for microgrid by considering EV's parking time, power needs, feeder load forecast and renewable energy generation forecast to dynamically optimize all EV's charging schedule and satisfy all EV's charge needs. Of course, the most important target we have to achieve is to suppress the peak load and keep the health of electricity facility in a community.



SCR-Based Static Switch

The static switch system is located between a microgrid and the utility. When a fault occurs in the utility, the static switch should be turned off very fast and isolate the microgrid from the utility. Conventional BMS switch may require one-half cycle to complete the isolation process and sometimes for safety issue, brings some latency. This latency is close to the peak point of voltage variation. The proposed SCR-based static switch system coordinate with Energy Storage Inverter (ESI), which provides the commutation current to speed up the trip of SCR residues. Controller of the EVs for efficient operation modes are also designed to ensure the stability of microgrid voltage during the isolation process.

