行政院及所屬各機關出國報告

（出國類別：）研究

（裝訂線）

2003.8.14 美加大停電的研究

服務機關　：台灣電力公司
出國人職稱：八等電機工程師
姓　　名　：陳政宏

出國地區　：美國、加拿大
出國日期　：93 年 09 月 07 日至 93 年 11 月 04 日
報告日期　：94 年 1 月 3 日

行政院及所屬各機關出國報告提要

出國報告名稱： 2003.08.14 美、加大停電之研究

頁數 63 含附件：□是■否

出國計畫主辦機關/聯絡人/電話

台灣電力公司/陳德隆/(02)23667685

出國人員姓名/服務機關/單位/職稱/電話

陳政宏/台灣電力公司/電力調度處/電機工程師/(02)2366-7453

出國類別：□1 考察□2 進修■3 研究□4 實習□5 其他

出國期間：93.09.07-93.11.04　　出國地區：美國、加拿大

報告日期：94.1.3

分類號/目

關鍵詞：2003.8.14 美加大停電、安大略省電力調度中心(IMO)、紐約調度中心(NYISO)

內容摘要：(二百至三百字)

奉派赴至美、加地區實際參訪於 2003.8.14 北美大停電中受波及區域內的電力機關，從事研究與資料蒐集的工作。報告人具備台灣電力公司中央調度室調度員的經驗，整理並比較取得的資訊後，提出本件『美加大停電』研究報告。

本文電子檔已傳至出國報告資訊網(http：//report.gsn.gov.tw)

行政院及所屬各機關出國報告審核表

出國報告名稱：2003.08.14 美、加大停電的研究	
出國計畫主辦機關名稱：台灣電力公司	
出國人姓名/職稱/服務單位：（若二人或以上，則列　　等　　人） 陳政宏/電機工程師/台灣電力公司	
出國計畫主辦機關審核意見	☑1. 依限繳交出國報告 ☑2. 格式完整 ☑3. 內容充實完備. ☑4. 建議具參考價值 ☐5. 送本機關參考或研辦 ☐6. 送上級機關參考 ☐7. 退回補正，原因： ☐(1)不符原核定出國計畫 ☐(2)以外文撰寫或僅以所蒐集外文資料為內容 ☐(3)內容空洞簡略 ☐(4)未依行政院所屬各機關出國報告規格辦理 ☐(5)未於資訊網登錄提要資料及傳送出國報告電子檔 ☐8. 其他處理意見
層轉機關審核意見	☐同意主辦機關審核意見 ☐全部　☐部分＿＿＿＿＿＿（填寫審核意見編號） ☐退回補正，原因：＿＿＿＿＿＿（填寫審核意見編號） ☐其他處理意見：

說明：

一、出國計畫主辦機關即層轉機關時，不需填寫「層轉機關審核意見」。

二、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

三、審核作業應於報告提出後二個月內完成。

單位	主管處	總經理
報告人： 主管：	主管：	副總經理：

目 錄：

壹、摘要

2003 年 8 月 14 日,美加地區發生了史上最嚴重的停電事故,造成北美洲東北地區，美國八個州及加拿大兩個省，共五千萬人的大停電，停電規模達61800MW，約為全台灣裝置容量的兩倍，造成的經濟損失難以計算，影響之鉅大，世界震撼。事後經美加大停電聯合專案調查小組的調查，及北美電力可靠度理事會(NERC)的協助分析，所得的事故原因及報告已向世人揭露：電力系統彼此權責的不清，電能管理系統的部分功能瑕疵、系統運轉人員的素質不齊、系統分析能力的不足、及制度上的溝通協調不夠，都是引發此大停電極主要的因素。此次的大停電，大家一致認同是因電網局部系統有事故發生，進而破壞電網的穩定度，造成電壓崩潰與電網瓦解，最後為大規模的停電。為找出引發事故的原因，美加兩國政府機關與學術機構專業及專責人員，除積極投入此次事故的研究外，並舉辦有多次技術研討會與公聽會，且提出許多相關改善建議。此外，集合各方意見的美加大停電聯合專案調查小組「期末調查報告」也在期末呈送兩國政府作為避免大停電再發生之改善對策，其中，有許多值得我們參考借鏡之處。本出國研究計劃在於前往美、加地區，進行實地研究及蒐集相關單位的改善措施及後續實施情況後，加以整理並比較，以期收前車之鑑；此外，並與各國實際運轉或分析系統的工程師，交換心得與經驗，作為借鏡並增廣新知，找出本公司運轉上可能未注意的盲點，提供作為參考，使未來本公司在運轉觀念上能更與世界先進國家接軌，讓本公司電力系統更穩定與可靠。

貳、北美地區電力產業簡介

北美電力產業的最重要組織係北美電力可靠度理事會NERC(North American Electric Reliability Council)，在1968年由電力工業界，為了促進北美電力供應的穩定而成立的非營利組識，NERC的成員包括十個區域可靠度委員會和一個由幾乎是全北美電力供應者所組成的組織。這些委員會的成員來自電力供應界的各階層:投資者, 聯邦政府, 電力公司, 州立/市立，及省立的公用事業機構，獨立發電業者，電力市場參與者等。

NERC 的執掌為：

一、 北美電力系統計劃及可靠運轉標準的建立。

二、 監視及評估是否符合北美電力系統可靠度標準。

三、 提供提昇北美電力系統可靠度所需之教育及訓練資源。

四、 評估、分析及報告電力系統的適當性及表現。

五、 與十個區域可靠度委員會及其他未加入的組織作協調。

六、 協調電力系統可靠度運轉應用分析工具的提供。

七、 認証工作。

八、 負責電力系統的基礎保護協調的工作。

NERC 下屬組織及權限：

NERC 旗下共分十個區域可靠度委員會(Regional Reliability Council)，並再區分為三大電力互連系統，彼此以直流系統互連，但不作潮流的融通，僅作為系統的連接，如圖 2.1 所示。

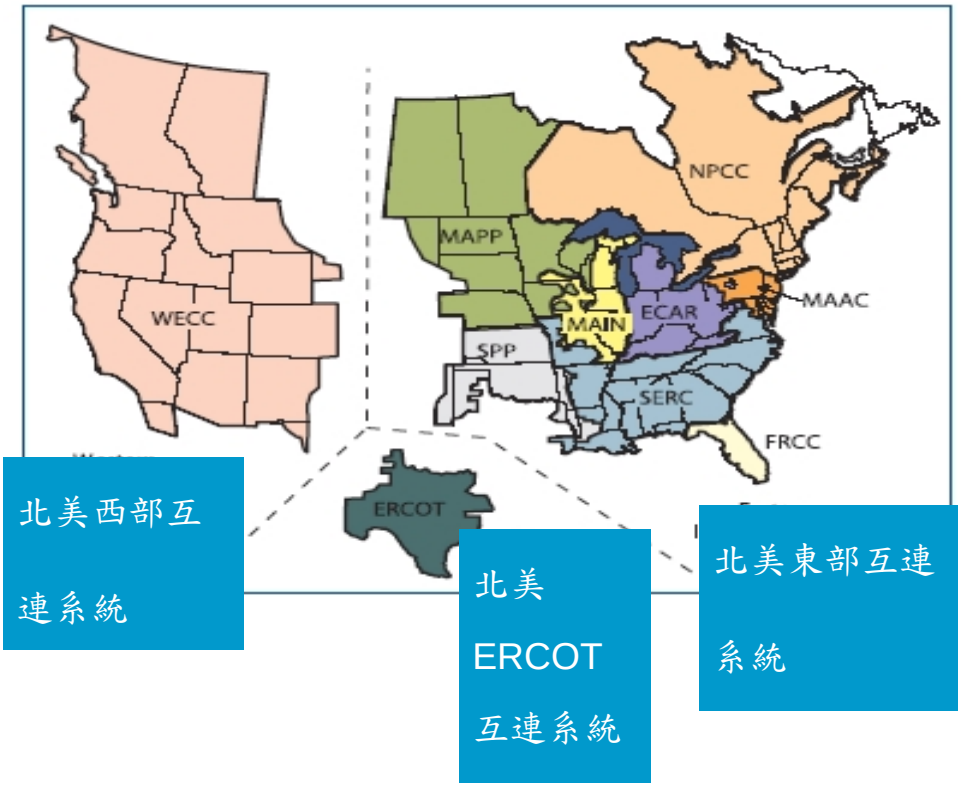


圖 2.1 NERC 下的三大互連系統圖

西部互連系統僅一個 WECC 區域可靠度委員會。
(WECC)Western Electricity Coordinating Council

德州互連系統僅一個 ERCOT 區域可靠度委員會。
(ERCOT)Electric Reliability Council of Texas

東部互聯系統有 MAAC、MAIN、MAPP、NPCC、SERC、SPP、FRCC、ECAR 等共八個區域可靠度委員會。

(MAAC)Mid-Atlantic Area Council;
(MAIN)Mid-America Interconnected Network;
(MAPP)Mid-Continent Area Power Pool;
(NPCC)Northeast Power Coordinating Council;
(SERC)Southeastern Electric Reliability Council;
(SPP)Southwest Power Pool;
(FERC)Federal Energy Regulatory Commission ;
(ECAR)East Central Area Reliability Coordination Agreement; and
(ASCC, Affiliate)Alaskan Systems Coordination Council.

NERC 並有十八個電力可靠協調中心(Reliability Coordinator)，即大家所熟悉的 ISO(Independent System Operator)，如圖 2.2 所示：

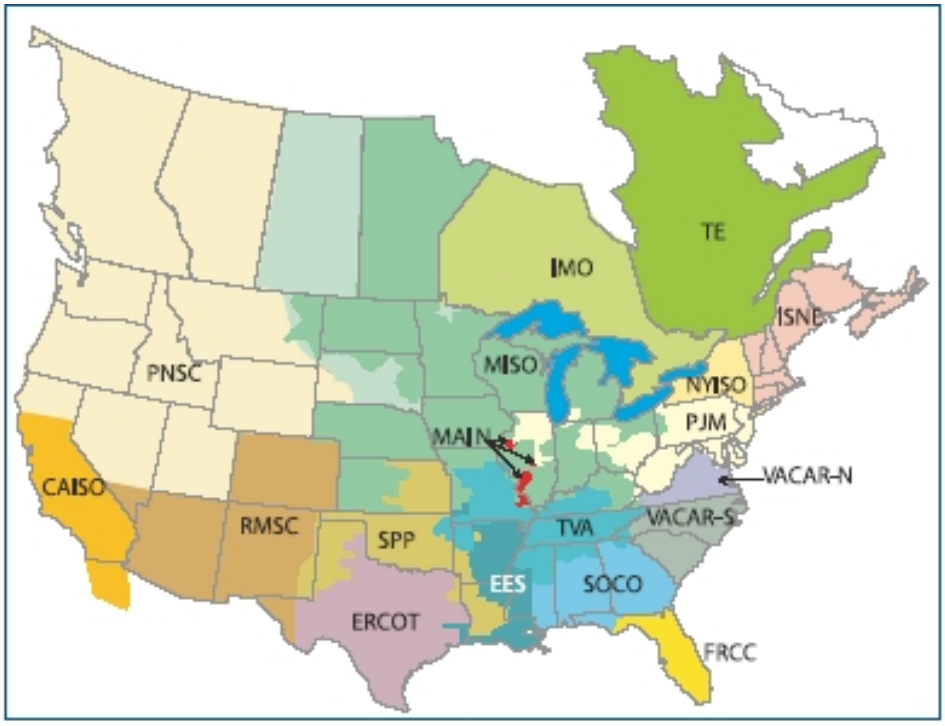


圖 2.2 NERC 下的區域電力可靠協調中心分佈圖

參、2003.8.14 美加大停電介紹

2003.8.14 的美加大停電發生在美東時間下午 4 時 11 分,事故發生的 3 分鐘內，包括 9 座核能發電廠在內的 21 座電廠發生跳脫，隨後美國及加拿大共有包含 22 座核能發電廠在內的 256 座電廠 508 部發電機陸續解聯，負載損失 61800MW，停電範圍為 9300 平方英里，共有加拿大魁北克省、安大略省，及美國密西根州、俄亥俄州、紐約州、賓夕法尼亞州、新澤西州、麻薩諸塞州、康乃狄克州、佛蒙特州等八個州共約五千萬人用電受到影響；事故面積及規模之大，是北美地區前所未有的。雖然事故當時，有各種事故原因的說法傳出，但最後一致的結論是：美、加地區大區域的停電，是因局部電力網故障，控制區的電力公司未及時查覺，且責任區的可靠度委員會(MISO)未能提供分析上的協助，進而擴大到電網不穩定，電壓崩潰，電力網瓦解，最後演變成大規模的嚴重停電的事故。

詳細介紹如下：

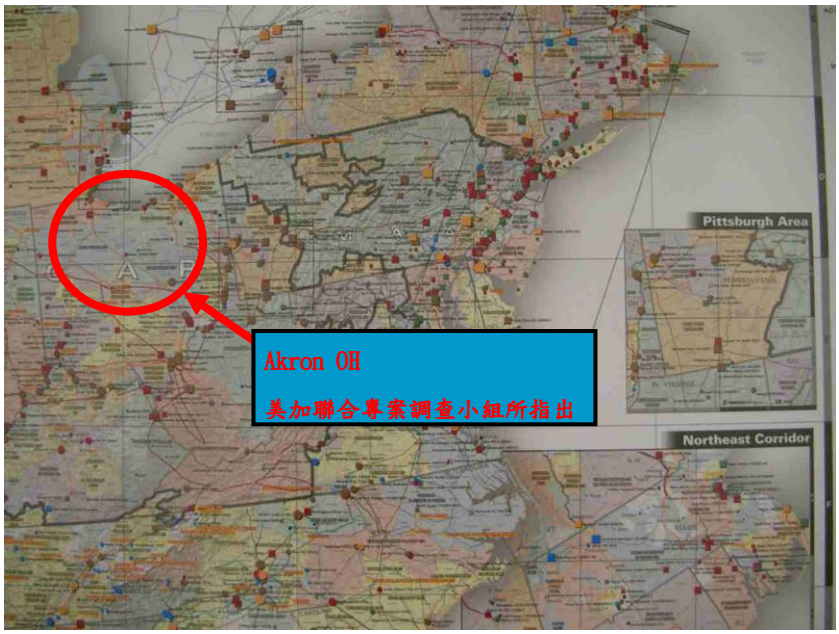


圖 3.1 大停電肇始區位置圖

圖 3.1 所示為此次北美東北部地區，大停電的肇始地區，即俄亥俄州的埃克隆(Akron)，此區之重載地區為克里夫蘭(Cleveland)。

圖 3.2 為 2003.8.14 當日 15:05 分，Harding Chamberlin 345KV 線跳脫前的電力潮流狀況。失去這一條線(Harding Chamberlin 345KV)，MISO 的系統再也無法承受任何系統 N-1 事故;由此圖可大概瞭解當日潮流在各電力公司間的流動情形，並可了解重載區所在，即圖中所繪大量潮流流入的地區。此地區類似台灣，重載區位於北邊，潮流由南往北送;另外，電業自由化後，

組織架構變複雜，造成管理複雜且難度增加，如圖 3.2 中，一控制區中有許多電力公司，此時的責任劃分及運轉監督和協調就十分重要;但在運轉上，各公司都視自己內部的線路及發電機狀況為機密，因此盲點甚多，責任區也不容易畫分清楚。

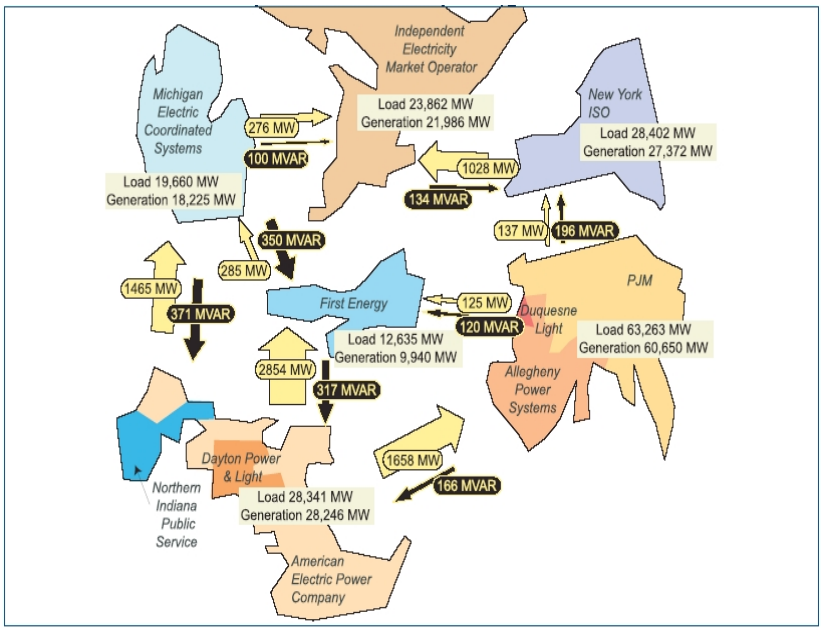


圖 3.2 當日下午 15:05 肇事地區潮流狀況

圖 3.3 則為肇始地區。幾間電力公司的地理相關位置及轄區範圍圖，其中之重點區為第一能源公司 (First Energy)。

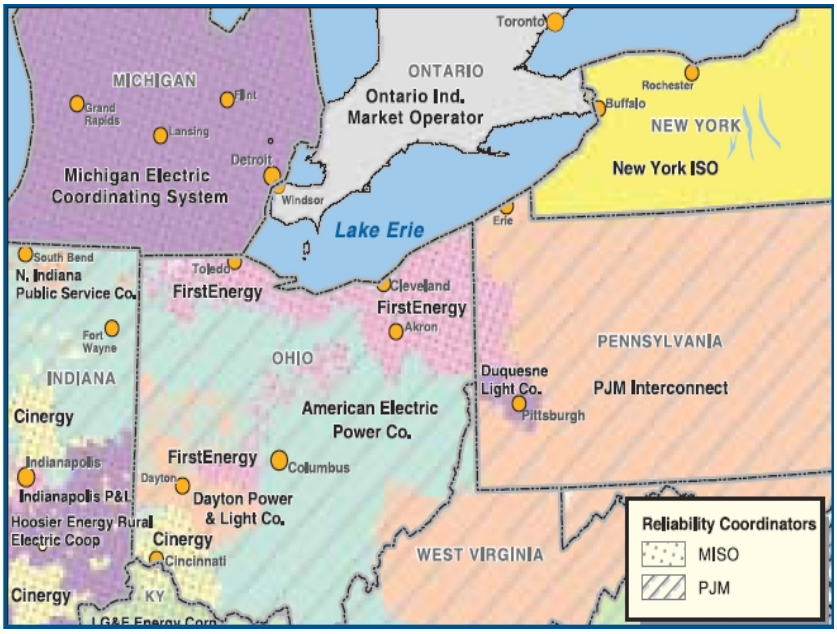


圖 3.3 肇事地區。幾間電力公司的地理相關位置及轄區範圍圖

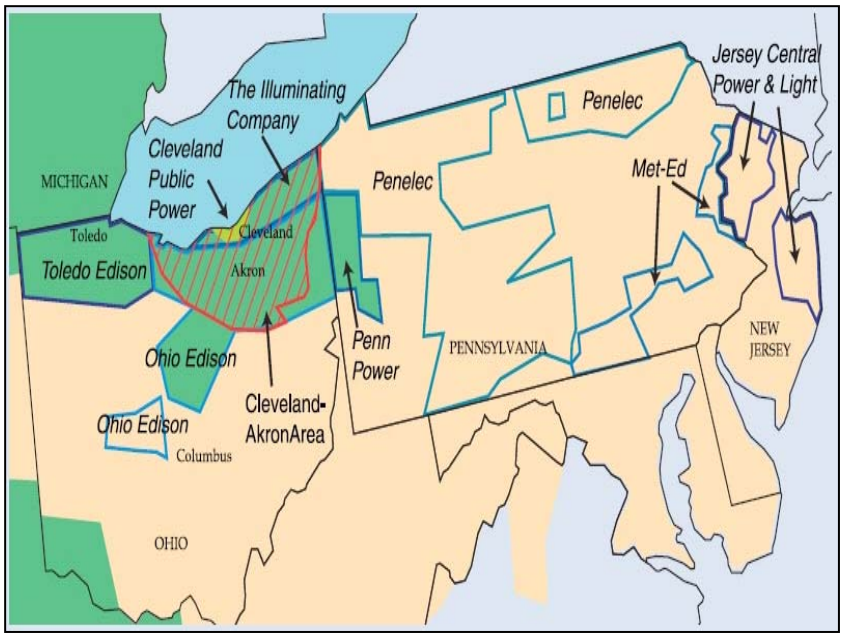


圖 3.4 第一能源公司 (First Energy)的轄區分布圖

圖 3.4 中，描述了第一能源公司旗下的七家子電力公司分佈，分別為

在 OHIO 的 Toledo Edison、Ohio Edison、The Illuminating Company in OHIO;(屬於 MISO 管轄)。

在 Pennsylvania 和 New Jersey 的 Jersey Central Power & Light、Penelec、Met－Ed、Pen Power;(屬 PJM 管轄)。

同一家公司分屬不同的電力可靠協調中心(Reliability Coordinator)(MISO、PJM)其複雜度可見一般。

第一能源公司為全美排名第四大的電力公司，但其控制室沒有設置模擬板(Map Board)，此是令人難以理解的事情;調度員因此非常依賴警報訊息(Alarm Message);這也成了間接導致此次大停電的原因之一。

再從各區域電力可靠協調中心(Regional Reliability Coordinator)的轄區來看整個北美系統的複雜程度：

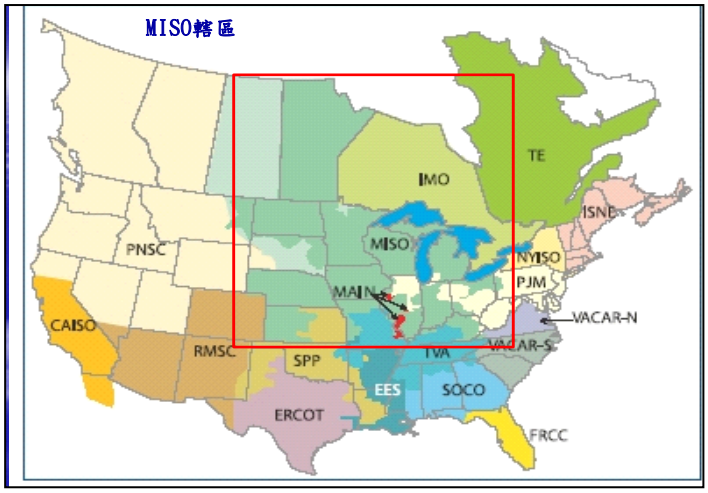


圖 3.5 北美地區十八個區域可靠度委員會的分布圖

圖 3.5 為北美地區十八個區域可靠度委員會的分布圖，其中標示墨綠色的區域係 MISO 的管轄範圍，此次大停電肇始區即屬 MISO 所管轄，請注意其管理區域，大、雜、不規則、且分布零散。

就是因為如此，MISO 的 SCADA 系統跟本不可能對所轄的區域有完整的佈置，所監視的區域內資訊根本就不完整，更別提能有能力去執行 NERC 所要求的工作。

以下開始介紹事故當日下午開始所發生的一連串累積事故：

事件一於 12:15，MISO 的狀態估測程式(State Estimator)出現問題

8 月 14 日 12:15 到 16:04，MISO 的狀態估測程式(State Estimator)出現問題，也無法執行最大偶發事故可靠度評估(Single Contingency reliability assessment)，而狀態估測及單一偶發事故的可靠度評估都是電能管理系統(Energy Management System)所該有的功能。

事件二於 13:31，東湖五號機跳脫

提供克里夫蘭(Cleveland)地區的重要發電機東湖電廠五號機因過度激磁而跳脫，機組跳脫當時出力狀況為 612MW 及 400MVAR，在此機跳脫後，當地立即損失了一個很重要的電源來源。

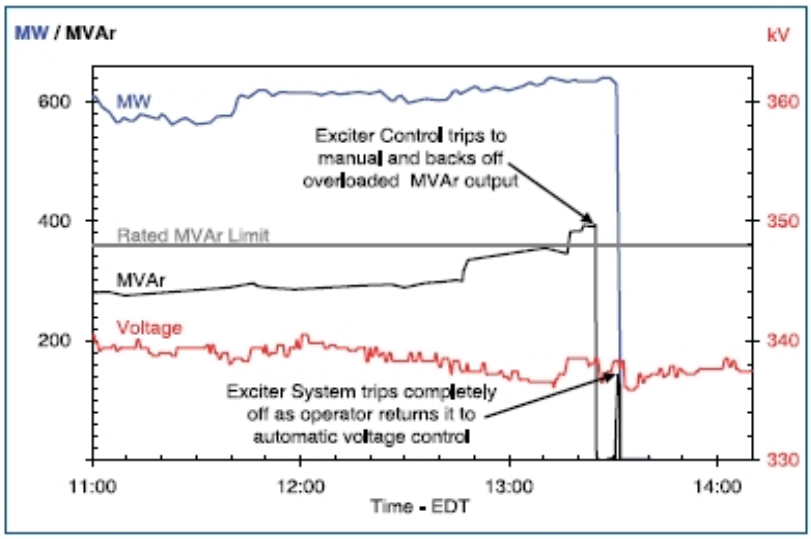


圖 3.6 東湖電廠 5 號機跳脫曲線圖

事故後發現，東湖五號機激磁系統先跳至手動模式，當調度人員再切換至自動電壓調整時，因超出容量曲線太多，發電機過激磁跳脫。

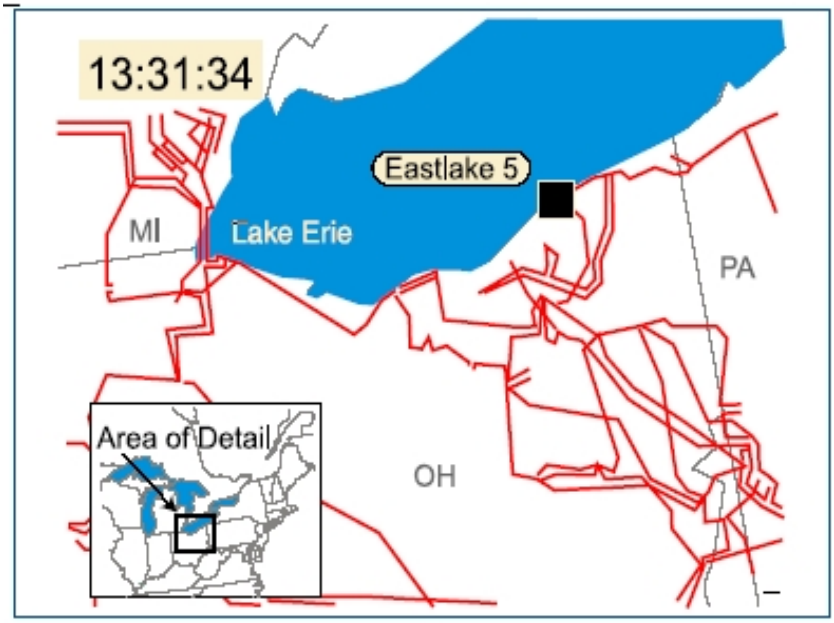


圖 3.7 東湖電廠 5 號機位置圖

事件三於 14:02 Stuart-Atlanta 345 KV 線路跳脫

Dayton Power & Light 公司所屬的 Stuart-Atlanta 345 KV 線路因為碰觸樹木而於 14:02 跳脫，並在 16:10 大停電發生前一直未恢復正常供電。

這一條 345KV 線路的跳脫並沒有影響第一能源公司(First Energy)的供電

能力(由南往北送潮流給第一能源公司)，但卻影響到 MISO 的狀態估測程式(State Estimator)(MISO 不知此線路已跳脫)，使得 SE 功能不正常，而無法進行下一步偶發事故(Contingency Analysis)的評估，也使得 MISO 無法得知所轄區域內電力系統正面臨大面題。

如果 MISO 的偶發事故(Contingency Analysis)功能正常，也許就能在 15:05 Harding-Chamberlin 跳脫時，警告 FE 系統有危險。(在失去這條線後，此地的系統已無法承受任何的單一嚴重事故(N-1 事故)。

事件四於 14:14 First Energy(第一能源公司)電腦故障

從 14:14 開始，第一能源公司(FE)EMS 的警報系統開始發生問題，一直到 15:59 為止，FE 的調度員都不曾再接到任何警報訊號(Alarm Message);雖然在線路發生跳脫時，鄰近的電力公司都曾通知 FE 的調度員有輸電線路跳脫，但 FE 的調度員似乎警覺性不足，以致於未聽信，也未再查証，而為接下來的停電事故再度埋下了因子。

事件五於 15:05 到 15 點 57，三條南北向 345KV 的輸電線路均因樹木碰觸而跳脫

15:05:41 ，Harding-Chamberlin 345 KV 線路於線路負載 44%跳脫。

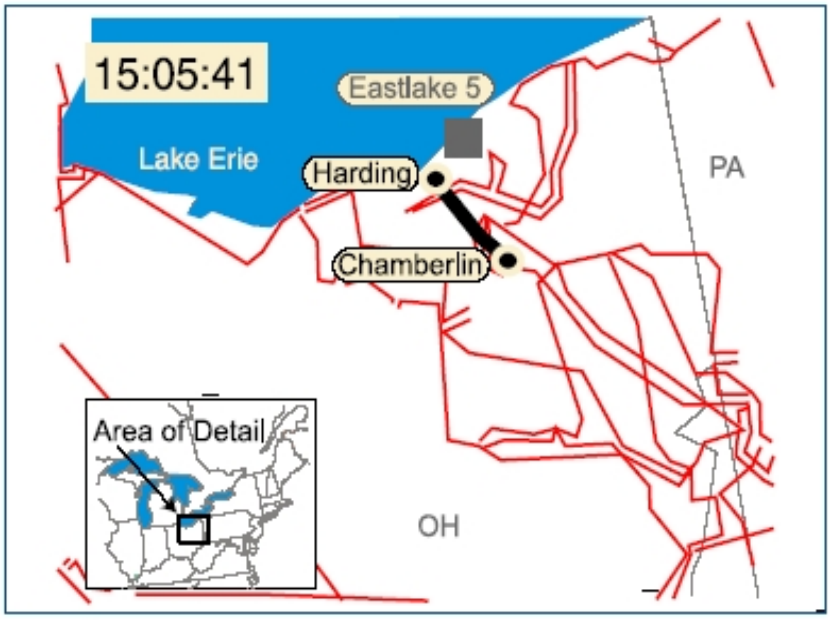


圖 3.8 Harding-Chambling 位置圖

15:32:03 ，Hanna－Juniper 345 KV 線路於線路負載 88%跳脫。

這條線路一失去，345KV 線路 Star－South Canton 立即發生超載情

形;AEP、PJM 在發現這情形後，即在討論如何卸載，以符合 NERC 必須在 10 分鐘內回到事故前狀態的標準。

15:41:33 Star-South Canton 345 KV 線路於線路負載 120%跳脫，(93%的 10 分鐘緊急運轉值)，復閉後，又於 15:41:35 跳脫，至大停電發生前，都未再投入過。

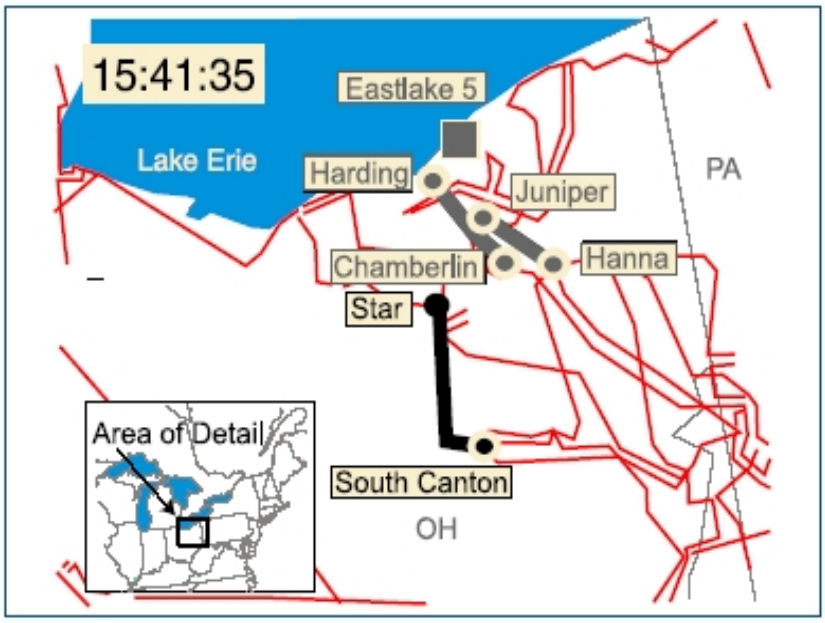


圖 3.9 Hanna－Juniper 線路位置圖

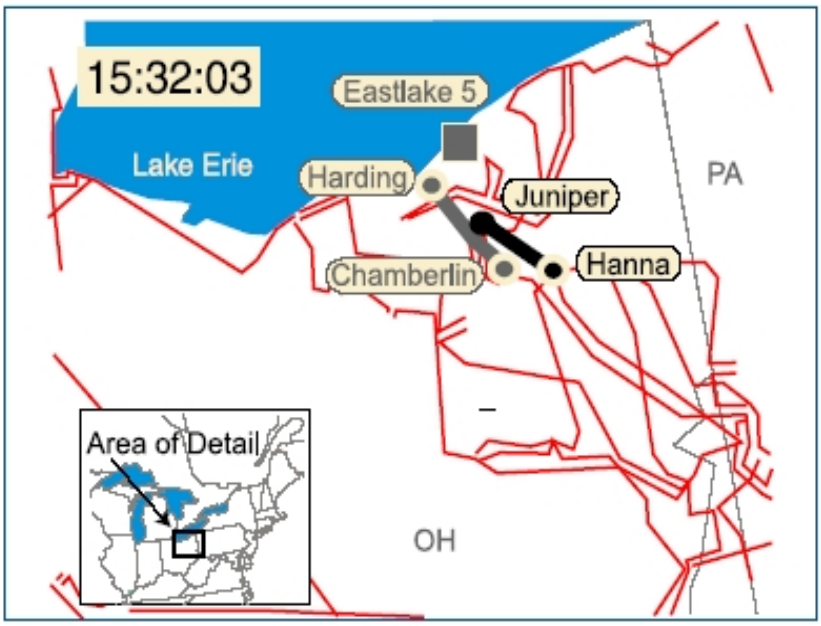


圖 3.10 Star－South Canton 線路位置圖

事件六在 15:39 到 16:08 OHIO 北部的 138KV 輸電系統崩潰

15:39－15:58:47 ，8 條 138KV Chamberlin－West Akron 138KV 輸電線跳脫。

15:59 供應 West Akron 的 6 條 138KV 輸電線，因一顆變壓器跳脫，全部停電。

Dale－West Canton 剩餘的 138KV 輸電線變成全 FE 系統負載最重的線路(120% ~ 180%)，區域內電壓嚴重下降。

16:05:57 開始，整個系統開始進入迅速崩潰的時間起始點，由潮流圖來分析整個大停電散播的狀況：

圖 3.11 顯示在真正大停電開始初期，由於經歷前述的一系列事件後，已在 Cleveland 有小規模停電的情形產生。

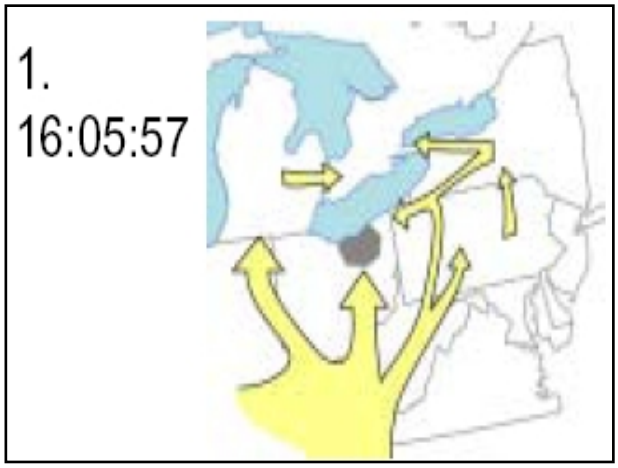


圖 3.11 16:05:57 Clevenland 地區潮流圖

16:05:57，為連鎖事件的開端，Sammis-Star 345 KV 線路跳脫，圖 3.12 顯示 Sami-Star 線路的位置。

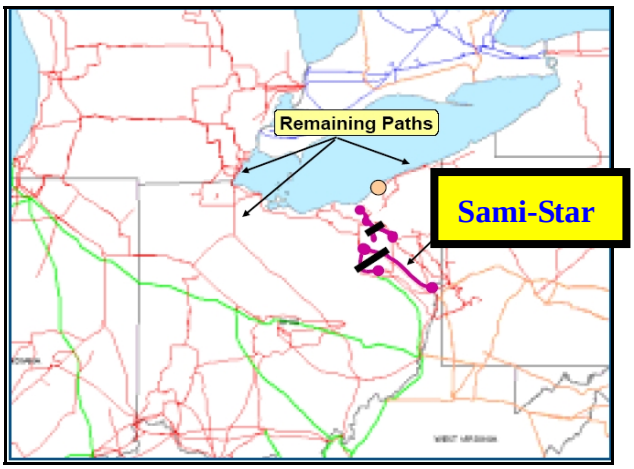


圖 3.12 Sammis-Star 345KV 線路位置圖

在 Sami-Star 345KV 線路跳脫後，當地電力潮流的狀況成為圖 3.13 所示：

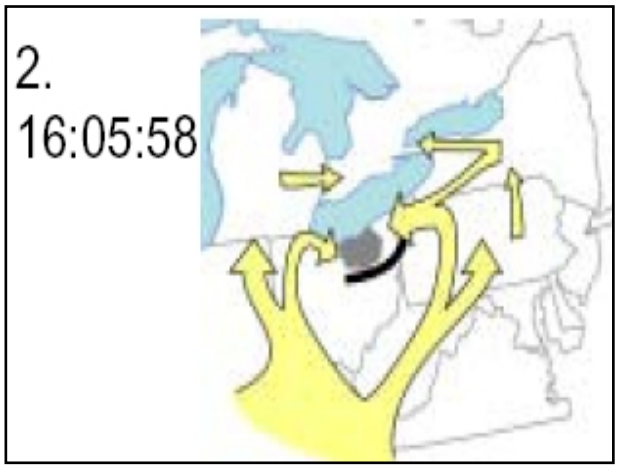


圖 3.13 16:05:58 線路潮流圖

緊接著，

16:08:59 Galion Ohio – Central Muskingum 345KV 線路跳脫，

16:09:06 East Lima -- Fostoria 345KV 線路跳脫

此兩條線路位置如圖 3.14 所示：

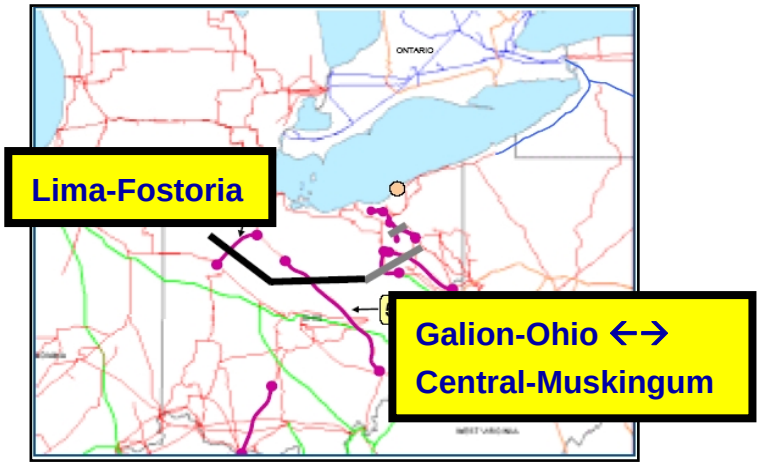


圖 3.14 Galion Ohio－Central Muskingum 及 East Lima－Fostoria 線路位置圖

接下來，

16:09:08 Michigan Cogeneration Venture 電廠減少 300MW 發電量。

16:09:17 Avon Lake 7 號機跳機共 82MW。

16:09:17 Burger 電廠 3、4 、5 號機跳脫共 355MW。

16:09:30 Kinder Morgan 機組 3、6 和 7 號機跳脫共 209MW。

以上 22 秒的時間，總共短少 946MW，其各電廠相關位置如圖 3.15 所示。

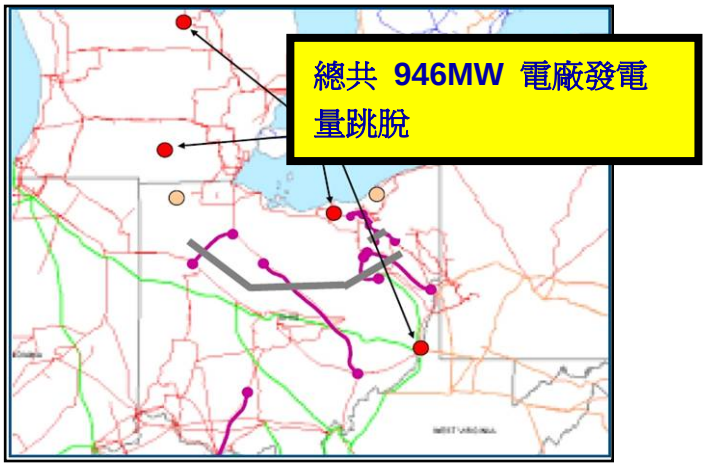


圖 3.15 946MW 發電量短少示意位置圖

在短少上述的發電量後，Cleveland 當地的潮流轉變如圖 3.16：

圖 3.16 16:09:25 潮流圖

在接下來不到兩秒的時間中(16:10:36.2~16:10:37.5)，於密西根州境內有數條 345KV 輸電線路跳脫及 MCV 電廠發電量由 963MW 降到 109MW，導致

16:10:36.2 Argenta-Battle Greek 345 KV 線路跳脫

16:10:36.3 Argenta－Tompkins 345 KV 線路跳脫

16:10:36.8 Battle Greek － Oneida 345 KV 線路跳脫

16:10:37 Sumpter 電廠 1、2、3、4 號機因電壓過低而跳脫，共損失 300MW。

16:10:37.5 MCV 電廠因過電流保護，發電量由 963 MW 掉到 109 MW。

上述的線路及發電機分佈的位置如圖 3.17 所示，

圖 3.17 所述相關線路及發電機位置圖

轉變的電力潮流如圖 3.18 所示，圖中可以看見，由於少了密西根州內部

的上述輸電線路，潮流的流向已經有”繞送”的情形，即潮流由俄亥俄州往北進入密西根州後，再由密西根州往南送回俄亥俄州。

圖 3.18 16:10:37 潮流圖

從 16:10:37.2 到 16:10:38.4 間，Michigan 東西向 345KV 輸電線路跳脫，16:10:38.2 Hampton－Pontiac 345 KV 線路跳脫。

16:10:38.4 Thetford-Jewell 345 KV 線路跳脫，Michigan 分裂成東、西部;

16:10:38.6 Erie West Ashtabula － Perry 345 KV 線在 Perry 端跳脫

此時 Cleveland 從 Pennsylvania 分裂開來，大量的潮流沿著 Lake Erie 逆流一圈，送入分裂的東密西根州及俄亥俄州北部未停電的電力系統中。

線路相關位置圖 3.19，及隨後的潮流圖 3.20 所示：

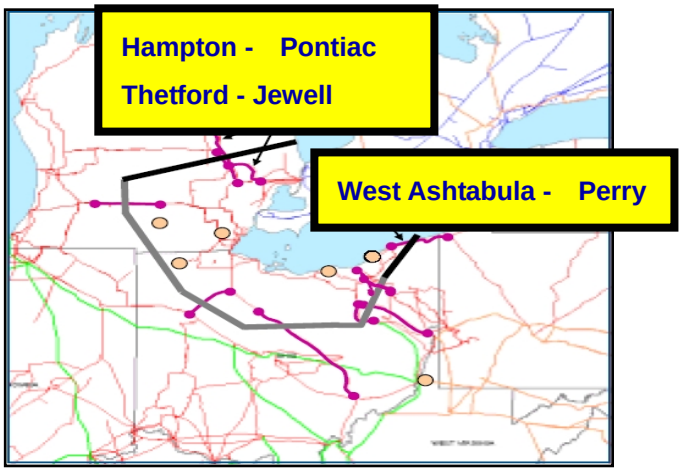


圖 3.19

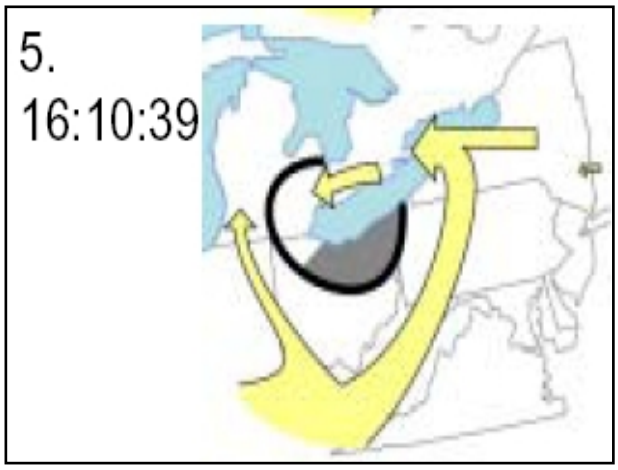


圖 3.20 16:10:39 潮流圖

隨後 2.5 秒鐘的時間(16:10:39.5~16:10:42)，線路及發電機組密集的跳脫於俄亥俄州及東密西根州間的線路

16:10:39.5 Bay Shore – Monroe 345 KV 線路跳脫

16:10:39.6 Allen Junction – Majestic Monroe 345 KV 線路跳脫

16:10:40.0 Majestic – Lemoyne 345 KV 線路跳脫

Majestic 345 KV 變電所:全部的 345KV 線路相繼的單端跳脫

16:10:41.8 Fostoria Central－Galion 345 KV 線路跳脫
16:10:41.911 Beaver－Davis Besse 345 KV 線路跳脫

俄亥俄州內部的低頻卸載:
FirstEnergy 卸載 1754 MVA 。
AEP 卸載 133 MVA 。

俄亥俄州境內七個電廠共 3294 MW 的發電量跳脫
16:10:40 Bay shore 電廠，機組 1-4(靠近 Toledo 的 551MW)因過激磁跳脫。
16:10:42 Lakeshore 電廠，機組 18(靠近 Cleveland156MW)因低頻跳脫。
16:10:41.7 Eastlake 電廠 1,2 和 3 號機組(靠近 Cleveland 的 304 MW)因低頻跳脫。
16:10:41.7 Avon Lake 電廠，機組 9(靠近 Cleveland 的 580 MW)因低頻跳脫。

16:10:41.7 Perry 1 核能電廠機組(靠近 Cleveland 的 1223MW)因低頻跳脫。

16:10:42 Ashtabula 電廠，機組 5(靠近 Cleveland 的 184 MW) 因低頻跳脫。

16:10:43 West Lorain 電廠機組(296MW),因低電壓跳脫。

靠近 Detroit 的四家電廠共 1759MW 跳脫。

16:10:42 Greenwood 電廠，1 號機組(253MW),因低電壓高電流而跳脫。

16:10:41 Belle River 電廠 1 號紙組因失步跳脫 637 MW。

16:10:41 St. Clair 電廠 7 號機因高電壓跳脫 221MW。

16:10:42 Trenton Channel 電廠 7A、8 及 9 號機組跳脫 648MW。

上述的電廠及機組位置，如圖 3.21 所示：

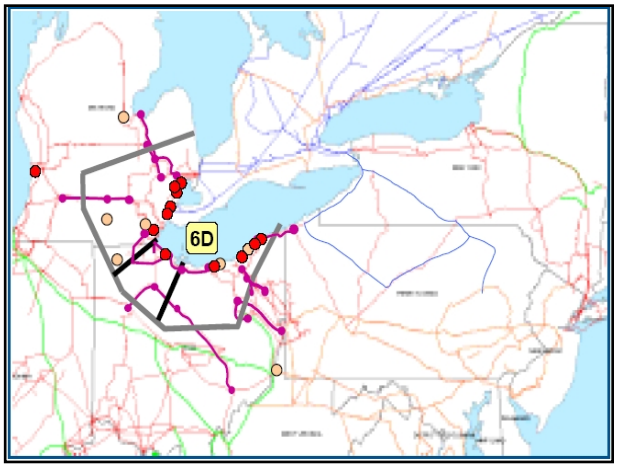


圖 3.21

在(16:10:39~16:10:44)的時段中，有下列的輸電線路因電力搖擺跳脫(只有 Zone1 瞬跳，而沒有 Zone3 延時跳脫)，導致 Western Pennsylvania 電力系統與紐約系統分裂，其線路跳脫時間如下：

16:10:39 Homer City－Watercure Road 345 KV 線路跳脫

16:10:39 Homer City－Stolle Road 345 KV 線路跳脫

16:10:44 South Ripley－Erie East 230 KV 線路及 South Ripley－Dunkirk 230 KV 線路跳脫

16:10:44 East Towanda－hillside 230 KV 線路跳脫

以上的線路的相對位置如圖 3.22 所示：

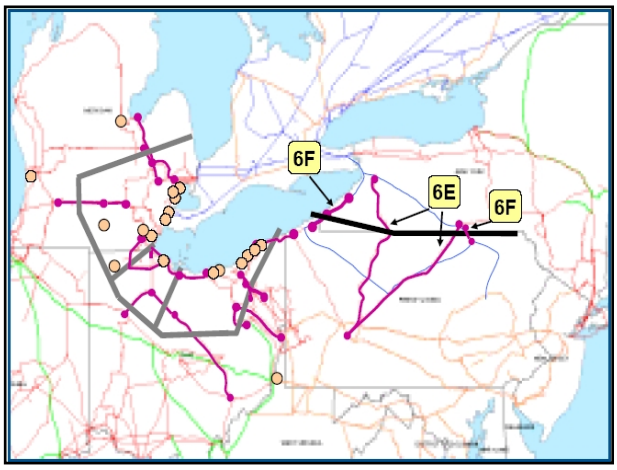


圖 3.22

隨後的潮流狀況如圖 3.23、圖 3.24、及圖 3.25 所示

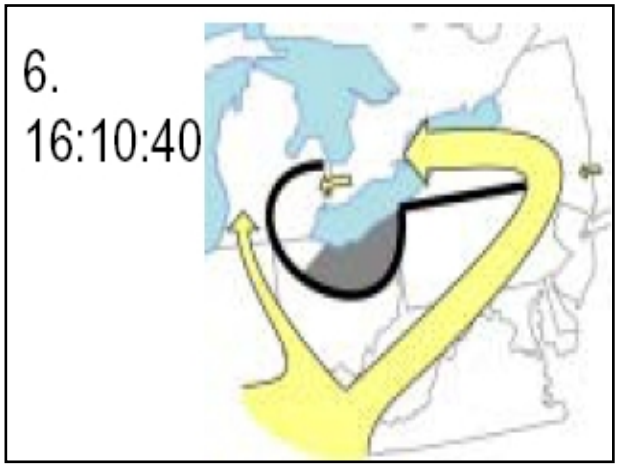


圖 3.23 16:10:40 潮流圖

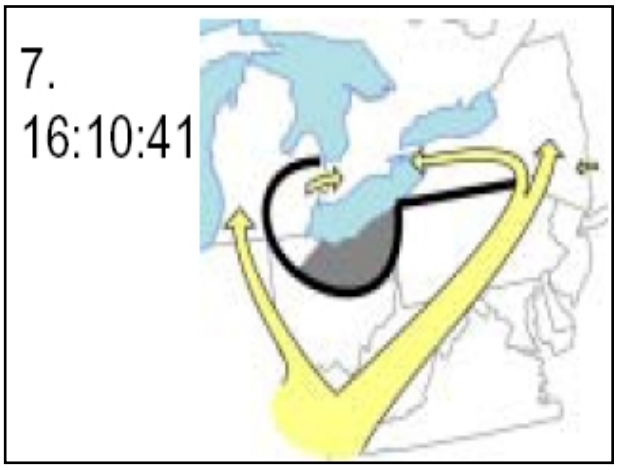


圖 3.24 16:10:41 潮流圖

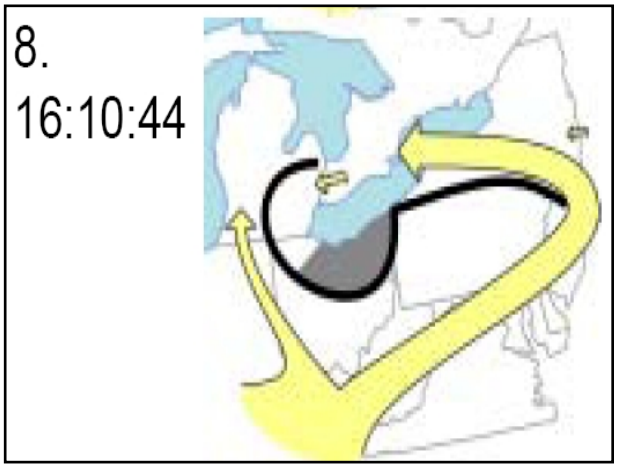


圖 3.25 16:10:44 潮流圖

導致 New Jersey 和 northern Ontario 間的輸電路徑被切斷，並且在東部互連系統產生了獨立區的跳脫線路時程：

16:10:43 Keith－Waterman 230 KV 線路跳脫
16:10:45 Wawa－Marathon 230 KV 線路跳脫
16:10:45 Branchburg－Rampapo 500 KV 線路跳脫

此線路的位置圖 3.26 及跳線後的潮流情形圖 3.27：

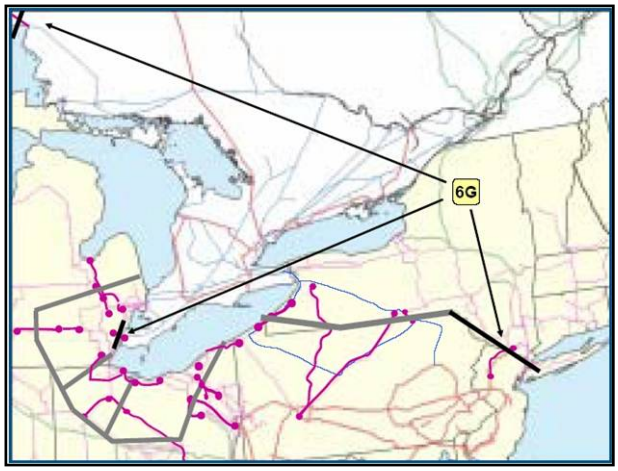


圖 3.26

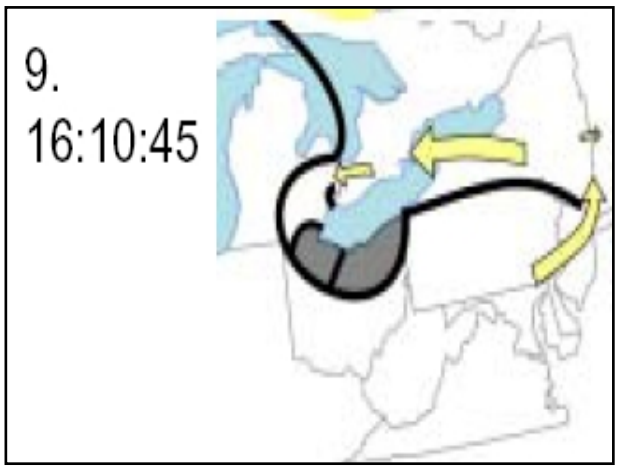


圖 3.27 16:10:45 潮流圖

圖 3.28 顯示各區分裂的主要事件，其詳述如下：

7A 16:10:46-16:10:47 New York－New England 間的輸電線中斷

7B 16:10:49 New York 的輸電系統完全和東部海岸的系統分裂

7C 16:10:50 Niagara Fall 及 St. Lawrence 西邊的 Ontario 系統，完全和紐約西邊的獨立系統分離

7D 16:11:22 紐約市和西南部系統分離

7E 16:11:57 僅存的 Ontario 及東 Michigan 系統分裂

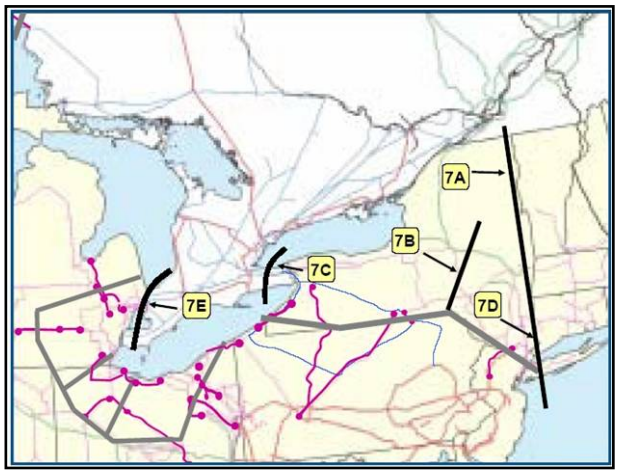


圖 3.28

前後不到六分鐘，大停電完成…，總共損失發電量 61800MW，為全台尖峰供電能力的兩倍，影響五千多萬人;接近下班時間，此時的美東一切陷入大混亂…，停電區域圖如圖 3.29 所示。

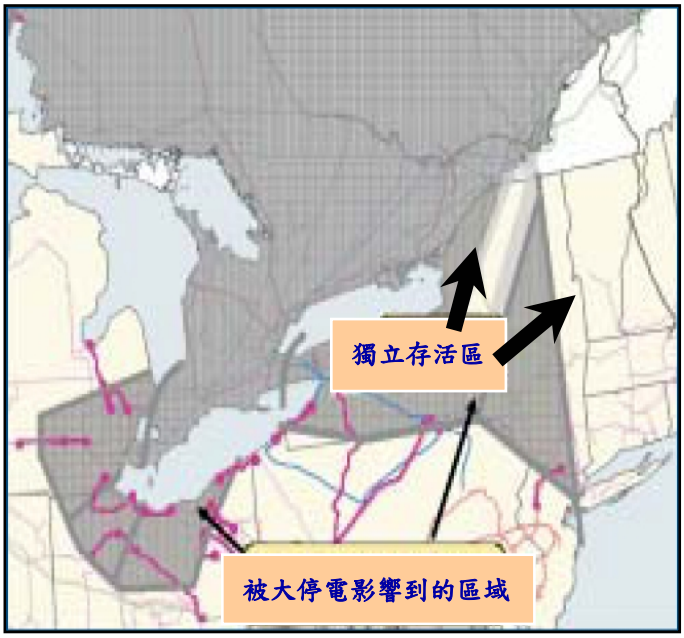


圖 3.29 大停電區域分佈圖

北美東北部大部分區域均全停電，波及範圍包括加拿大兩個省及美國八個州;但並非沒有獨立的供需平衡的區域維持下來，此區域可概括的分出兩塊區域;由於負載和發電達到平衡，而自成兩塊獨立的電立系統：

1.第一塊區域為：
大部分 NEW ENGLAND STATE 的靠海區域及部分加拿大的靠海的省的部分區域，因供需自成平衡而存活下來

2.第二塊區域為：
負載組成：紐約州西部的負載加上部分安大略省的負載
發電組成：紐約州部分的發電機，加上安大略省 BECK 及 SAUNDERS 兩大發電廠，加上由 QUEBEC 互聯過來的 765KV 輸電線路。

圖 3.29 顯示大停電前後的衛星空照圖，圖左方為大停電前 20 小時，約為 8 月 13 日晚上 8 點時的照片;右方為大停電後 7 小時，約為 8 月 14 日晚上 11 點的照片;圖中可見到停電前後供電的差異情況，可注意幾個北美的大都市，New York City、Boston、Montreal、Toronto，都處在停電狀況下。

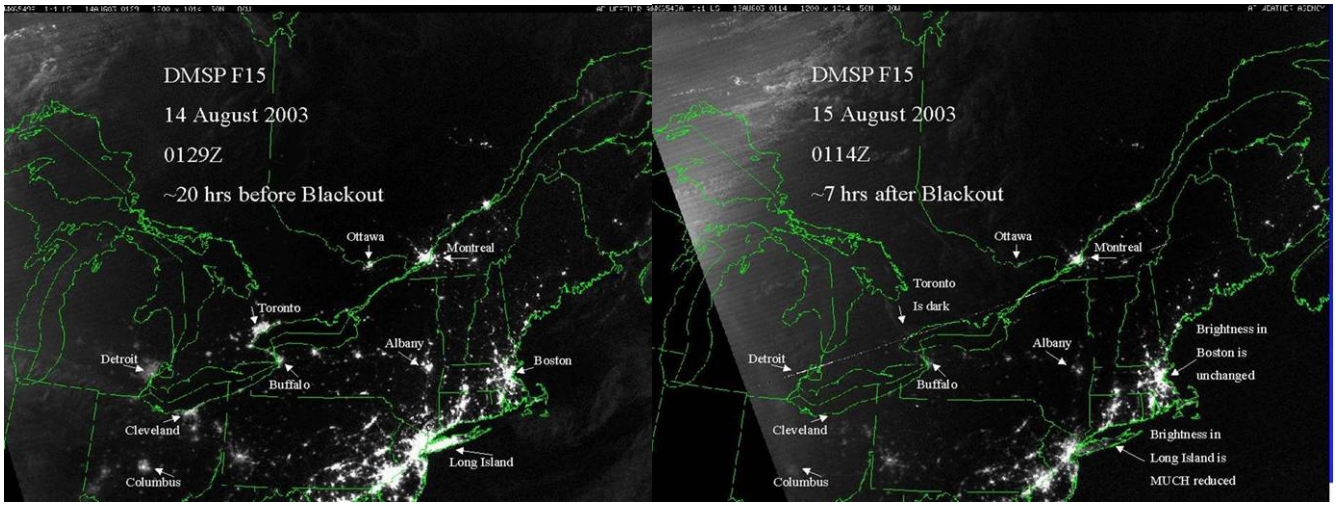


圖 3.30 大停電前後衛星空照圖

大停電事故最後終於在 2003,8,14 下午 16 時 10 分左右發生，由圖 3.31 的上半圖可以看見各控制中心轄區的連絡線潮流大幅搖擺及各區域分裂的時間點;而下半圖可以看見紐約州東半部及西半部的系統頻率先由激烈擺動到相互分裂開來。

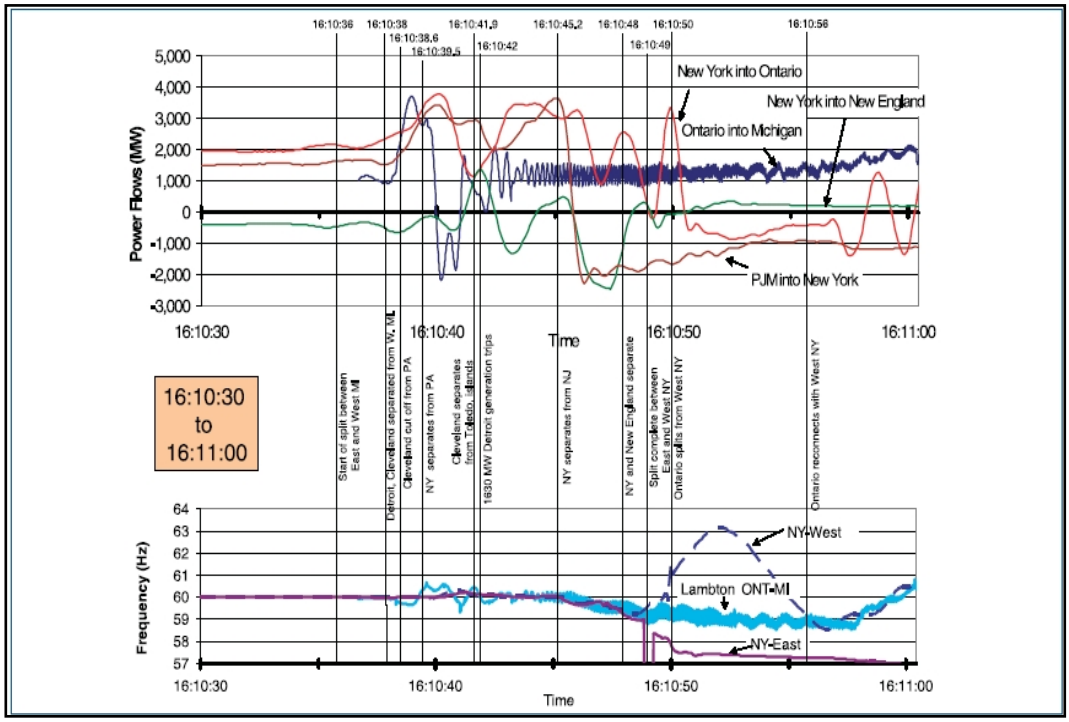


圖 3.31

圖 3.32 為各觀測點所記錄下來的頻率紀錄，可以清楚的看到系統彼此的分裂及有獨立的系統產生。

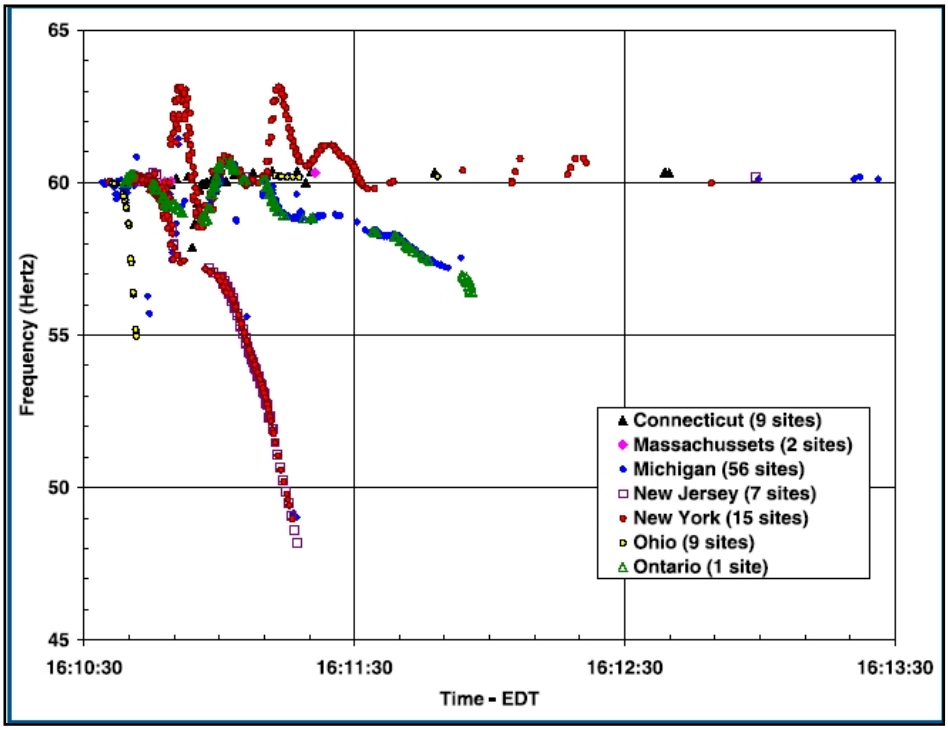

65
60
55
50
45
Frequency (Hertz)
16:10:30
16:11:30
16:12:30
16:13:30
Time - EDT
Connecticut (9 sites)
Massachussets (2 sites)
Michigan (56 sites)
New Jersey (7 sites)
New York (15 sites)
Ohio (9 sites)
Ontario (1 site)

圖 3.32 頻率紀錄圖

由發電機停機的狀況來看 16:05:57~16:13 間的大停電的傳播情形，如圖 3.33。

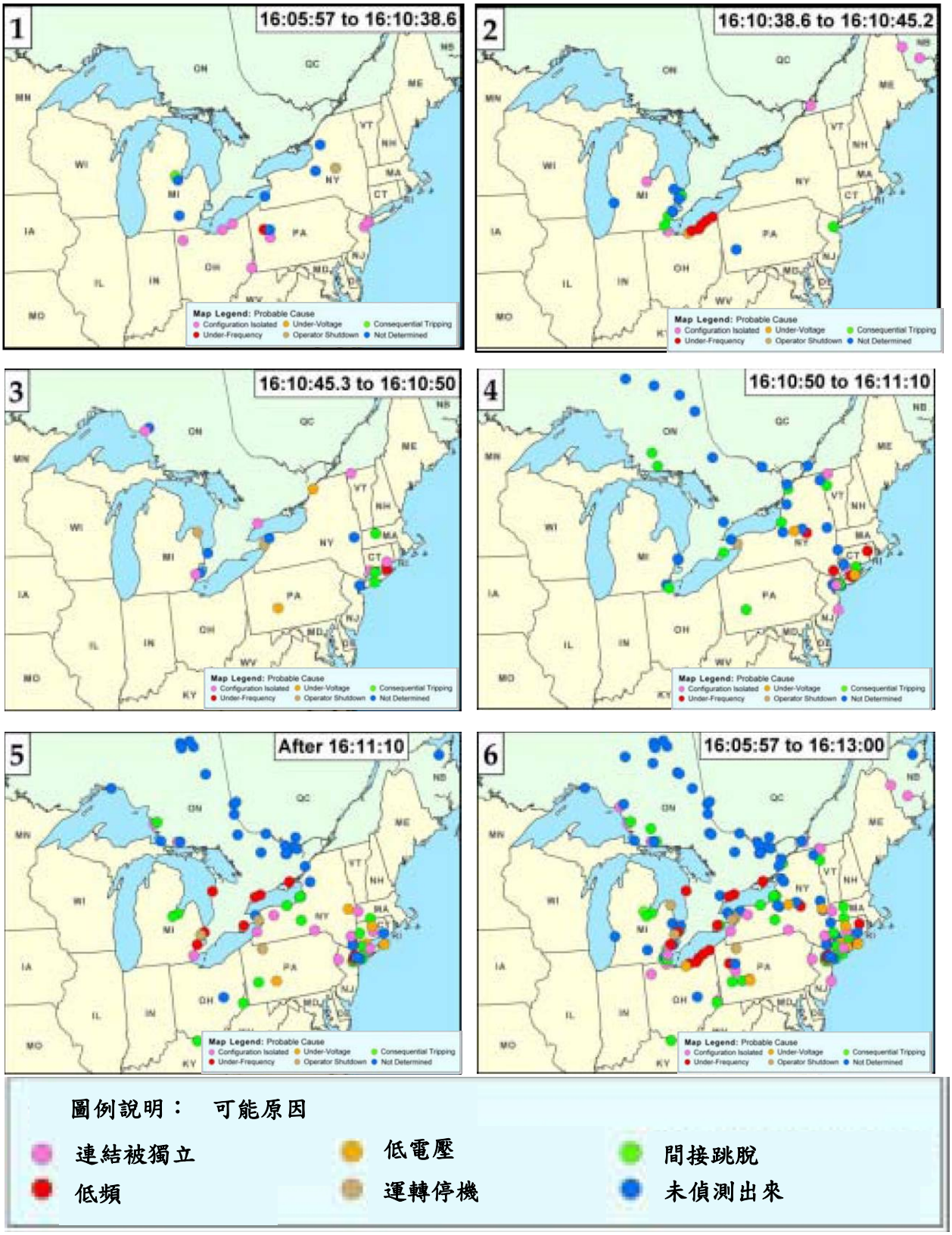


圖 3.33 發電機停機情形分佈圖

再將輸電線跳脫量、發電機跳機數量及總發電損失配合時間軸製成累計曲線圖如圖 3.34 所示：

由此圖可以發現，電力系統一旦發生崩潰(16:10~16:11 間)，其停電成長速度之快，絕非人力所能控制，唯一能停止的方式，只有其因巧合的供需平衡而自然停止;所以，事故前的預防非常重要，每一個變化的徵兆，例如跳線、跳發電機、或跳變壓器，調度人員一定都要有足夠的工具去監視電力系統的情形，常保高度的警戒心，不要單純的只視為一簡單的跳脫事故，並具備充足的知識及能力去做適當的處置，以防患未然，杜絕大部分的停電事故。

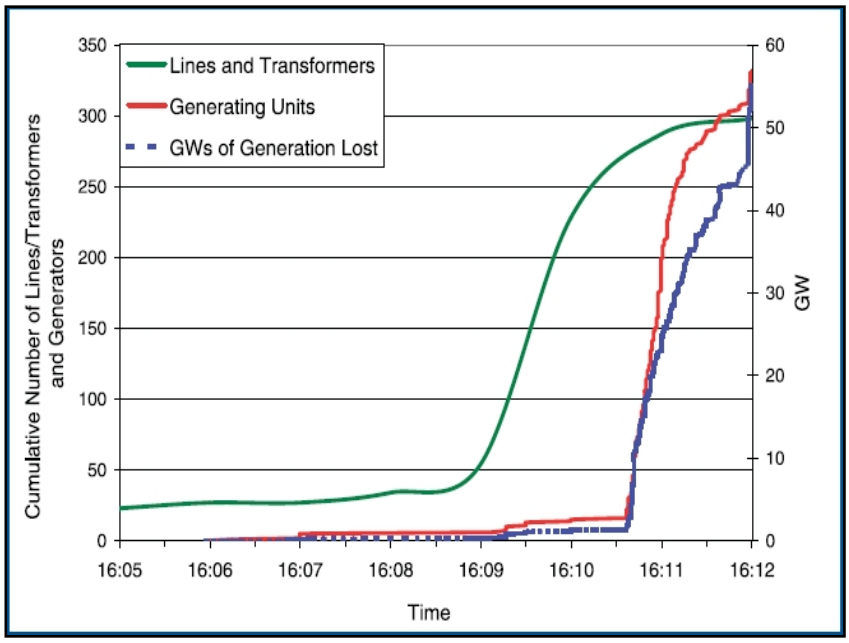


圖 3.34 線路、發電機跳脫及停電量的累計圖

肆、美國紐約電力調度中心(NYISO)

此次出國研究，透過美國 GE 公司的安排，於 93 年 10 月 8 日上午 9:00，參訪位於 3890, Carman Rd. , Schenectady , NY 12303-5608 U.S. 的紐約電力調度中心。當時由公共事務部的 Kenneth M. Klapp 接待並簡報，時間共兩個小時，除了瞭解 NYISO 的大致狀況外，也交流了許多關於美加地區 2003,8,14 大停電的看法與心得。

NYISO 的尖峰負載

30983MW

NYISO 的外觀：

外觀非常平常，就設立在路邊的一塊空地上，一般人很難去想像這是一個很重要的設施建物。

NYISO 內部控制室：

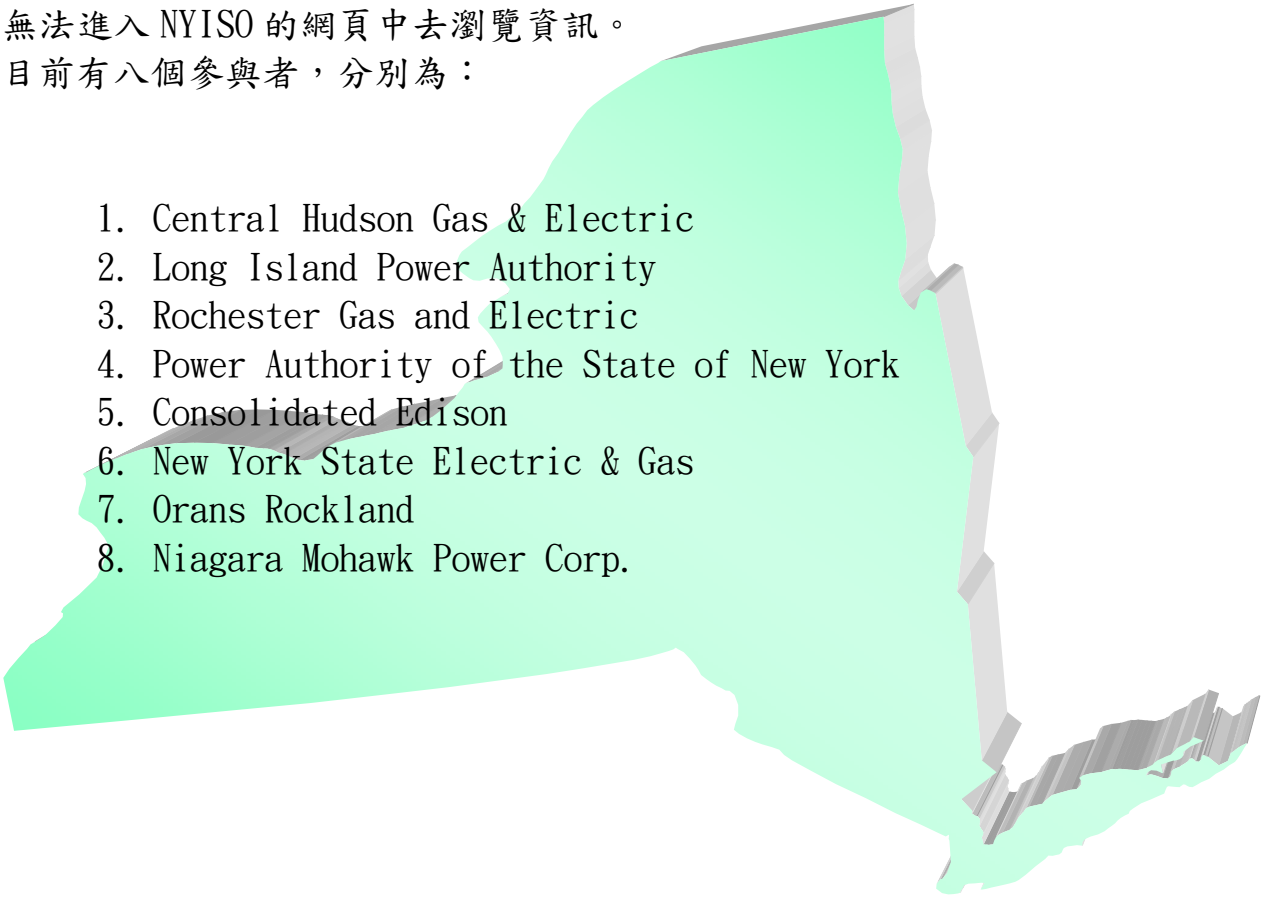
一個高度管制的地方，未經由授權無法入內。

NYISO 內部控制室

採取的仍是傳統的馬賽克調度面盤，系統調度人員與市場運轉人員同處於同一間調度室，一班的值班人員約有七至八人。

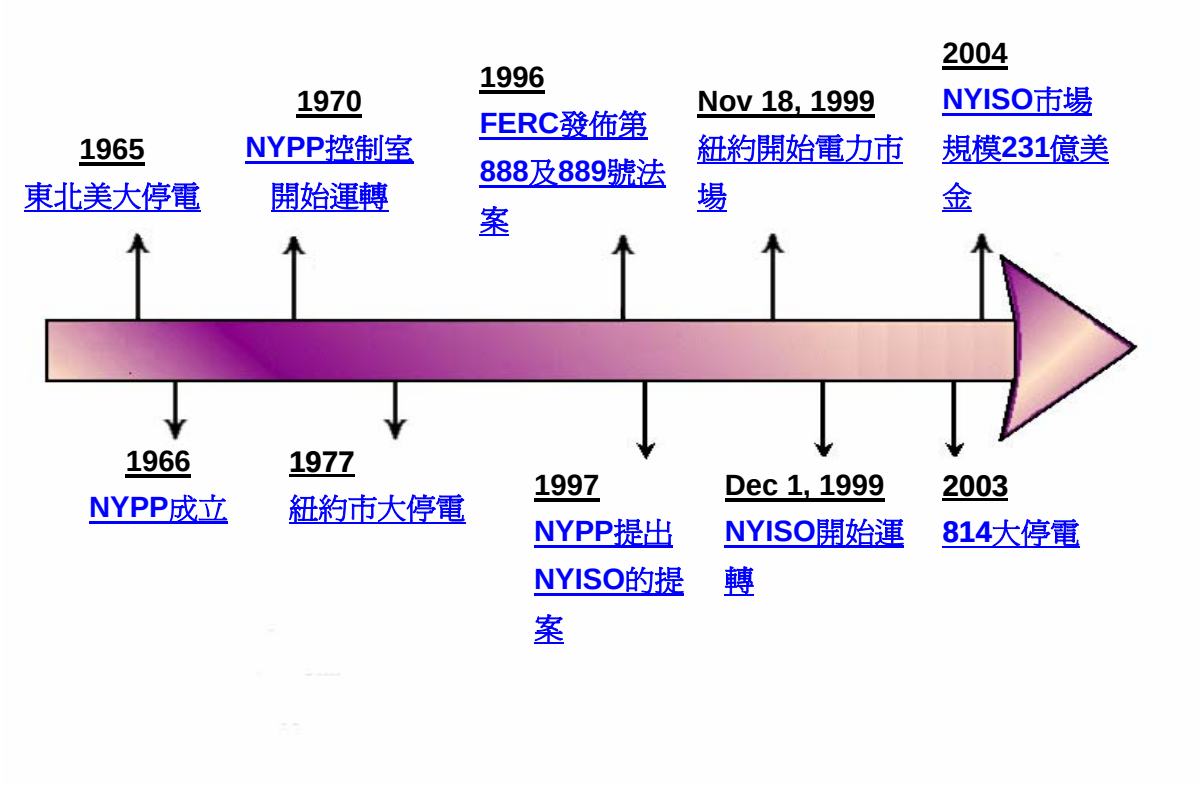
NYISO 於 2002 年 911 事件之後，嚴格管制所有的參訪人員及公開的資訊，若非必要的參訪，均拒絕參訪;另外，如登錄的網域不是在美國本土境內，也無法進入 NYISO 的網頁中去瀏覽資訊。

目前有八個參與者，分別為：



1. Central Hudson Gas & Electric
2. Long Island Power Authority
3. Rochester Gas and Electric
4. Power Authority of the State of New York
5. Consolidated Edison
6. New York State Electric & Gas
7. Orans Rockland
8. Niagara Mohawk Power Corp.

NYISO 的演進過程



NYISO 的背景資訊：

NYISO 服務紐約州人口約 19,157,532 人，包括整個紐約市，2003 共供電 158,013GWH;歷史尖峰負載為 2001 年 8 月 9 日的 30,983MW，總裝置容量為 37,524MW，超高壓輸電線長度為 10,775 英哩;主要的負載區為著名的紐約市(New York City)。紐約市生活水平高，居民環保意識高漲，區內興建發電廠不容易，但用電量卻甚大，故主要的用電在尖峰時，都向北方加拿大的魁北克省 (Quebec)及安大略省 (Ontario)購電，並經由很長的輸電線路向南傳送到紐約市及其他負載區。

參訪完 NYISO 後，與接待人 Klapp 合影於 NYISO 外，此時的 NYISO 正值大興土木之際，建物外空地上處處圍籬及工地，此時前去參訪，看到不一樣的 NYISO，也是一種很不一樣的經驗。

另外，紐約的負載尖峰也是在夏季，主要的用電為空調機，此情況恰好與位於北方的加拿大 Quebec 及 Ontario 二省相反，所以在夏季來臨時，紐約會向 Quebec 及 Ontario 二省購進電力，以應付用電尖峰;

但在冬季時，此北方二省因天冷，暖器用電增加而產生用電尖峰，此時則換為紐約向北賣電給此二省;紐約內部並非冬天不冷而不用開暖器，而是電價太高，每一度電光發電的成本就高達 USD 20 cents，用來應用於電暖器並不經濟，因此紐約大部分的暖器，都以天然氣當能源的來源。

伍、加拿大安大略省電力調度中心(IMO)

此次研究，於 2004 年 10 月 14 日 Am10:00~Pm 4:00 參訪位於
2635 Lakeshore Rd. W, Toronto, Ontario L5J4R9
的 IMO 控制中心，由
Bruce Mackay-Manager-Contracts & Agreements Market Operations & Forecasts

Geoff Elmer- Senior Engineer-Training Market Operations & Forecasts

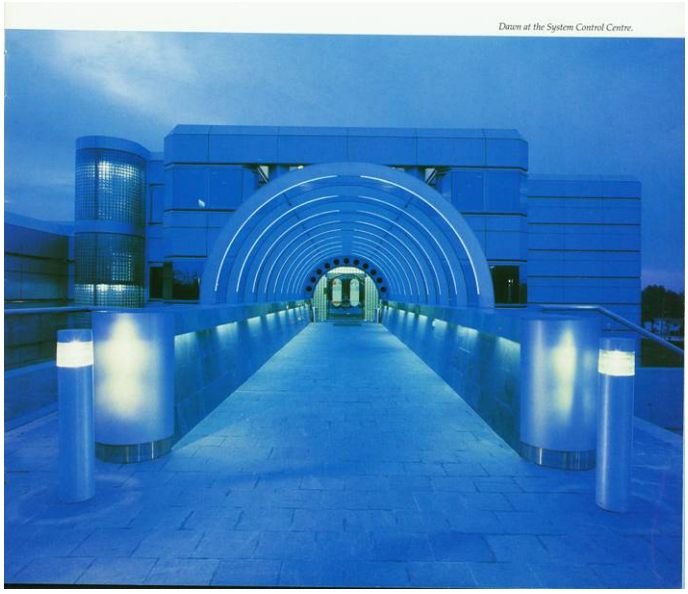
David Tsai- Senior Surveillance Specialist Market Assessment Unit

Al Miller- Senior Technical Officer-Customer Support Market Operations & Forecasts

共同接待並介紹。在交談過程中，除了瞭解到 IMO 有完善的教育訓練制度，亦對 IMO 在整個運轉的機制更加一層的認識。IMO 也是一個剛自由化的電力市場的控制中心，整個轄區中有超過 240 個市場參與者，為整個北美控制中心的模範生之一，NERC 及其他控制中心的調度人員訓練都會委託 IMO 代為訓練並核發執照。

IMO 控制室的外觀，與 NYISO 相似的地方為，控制室並不位於熱鬧的地區，而是位於郊區路旁的一塊寬闊空地上，門禁管制一樣的嚴格。不同的地方為其建築物外觀較為現代化，並可看到大型的微波鐵塔及立在大門外的旗幟，雖沒有路標標明此處為何地，但很容易就讓人聯想到這是一個重要的地方。

此圖為要走進 IMO 整棟建物前的走廊，位置在上圖建築物的後方，有一種科技的美感與神秘。由於 IMO 目前亦於 911 恐怖攻擊事件後嚴格管制參訪，並全程不准攝影，此圖為資料照片。

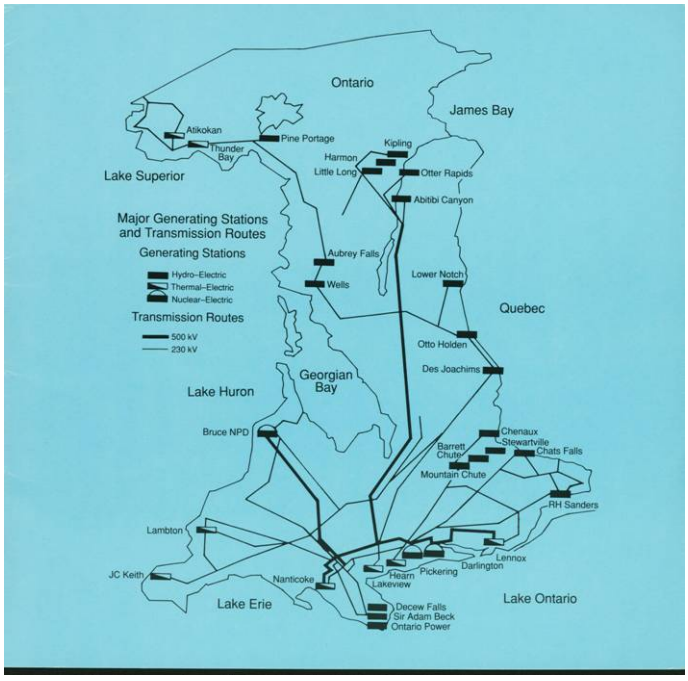


IMO 的控制室一角景像，IMO 採用的是 ABB 的 EMS 系統，調度盤採用的是較新的動態背投影式電視牆，感覺相當的先進與有質感，每班值班同仁與 NYISO 大概相當，約有七至八人(包含市場運作人員三人)。

IMO 的控制室一角景像，IMO 的電視牆中，分佈的格式是固定的，並不隨時變動，其中一格固定會播放新聞節目，讓調度人員能隨時掌握外界事件的動態。

此次參訪完 IMO 後，本人陳政宏(右一)與 David(左二)、Al(右二)兩人及同行的祁培倫工程師(左一)，一同攝於 IMO 的接待室。相片中的 David 亦為台灣人，在 IMO 已服務二十多年，此次參訪能如此順利，真的很感謝 David(蔡東榮博士)的幫助。

IMO 的轄區圖及內部電力設施的分布概況，從此圖可以瞭解，整個 Ontario 的重要負載都在南部地區，尤其是多倫多市(Toronto City)。



IMO 在 2003 年 814 大停電中是個受害者，因故障點位在美國 MISO 的控制轄區下的 FE，並不在 IMO 的控制區內;根據 IMO 事後的模擬指出，如果 IMO 對外的連絡線路全部都有加裝 Phase Shifter 的話，在當天大量潮流搖擺的時候，IMO 的系統就不會受到波汲而停電。

另外在大停電之後，IMO 內部亦在檢討不能有自有能源不夠的問題，政策因而做了大轉變，原本被存封的十座核能發電廠，都即將再開封服役。在整個北美地區，一開始自由化時，有些地方採取的是向外購電的措施而自己不興建或只興建極少數的發電廠，結果這樣的想法後來都受到考驗，例如加州 ISO(CAISO)、及此次提及的 IMO;大致上來說，自身的控制區內如有充足的能

源，控制區內的穩定運轉彈性就會較高，而不至於處處有限制;但如何在充足的電源及經濟效益上取得平衡，就很值得深入探討。

陸、比較及建議

◆比較-

尖峰負載規模

控制中心	TPC	NYISO	IMO
尖峰負載(MW)	29034	30983	25937
尖峰時間	夏季	夏季	冬季

台灣電力規模已和世上其他電力系統單一控制區的規模差不多大小，以單一控制區來說，已屬偏大的規模;台電又屬獨立島型電力系統，不像其他控制區一般有其他相鄰控制區幫忙調整，因此以調度員的責任量來說，非常吃重;增加每一班的值班人力及再分割責任區，是一個刻不容緩的重要議題。

自由化

控制中心	TPC	NYISO	IMO
尖峰負載(MW)	尚未	已自由化	已自由化

目前電業開放自由化，已成世界性的勢趨走向，雖說開放自由化後，可以促進電業相關產業的競爭發展，但開放後所面臨的衝擊我們也不可不重視，例如：1. 供電一定要有利可圖廠商才願供電，已不是責任與義務。

2. 電網的興建議題牽涉到許多的公司機關及政府法令，已非單純的電力系統問題，導致輸電線路興建將更困難。
3. 單一收據內收費項目繁雜，每一項服務都將正名收費或反應成本，故電價有可能上漲或劇烈變化。

EMS 系統

控制中心	TPC	NYISO	IMO
EMS 系統	SIEMENS	ABB	ABB

NYISO 及 IMO 都是採用 ABB 的電能管理系統，在使用上尚未遇到像導致此次美加 814 大停電的嚴重問題(GE 的 XA21 電能管理系統);而台電目前正在採購新的電能管理系統，得標廠商為 SIEMENS。SIEMENS 在國際上亦享有不錯的聲譽，期待此次更新的 EMS 系統能為台電帶來更穩定的運轉。

ABB公司的客戶：

Colorado Springs(USA)
PEPCO (USA)
IBERDROLA (Spain)
NYSEG(USA)
INDE (Guatemala)
LADWP (USA)
KNR (Korea)
ICE (Costa Rica)
DEWA (Dubai)
TRANSNER (Argentina)
SRP (USA)
SMHEA (Australia)
CAMMESA (Argentina)
COLBUN (Chile)
LYSE KRAFT (Norway)
HEDMARK (Norway)
JPS (Jamaica)
Transba (Argentina)
NEPCO (Jordan)
ADCO (Abu Dhabi)
Great Lakes (Canada)
PPOA (Canada)
Oakville Hydro (Canada)
EKPC (USA)
LEPA (USA)
OPSIS (Venezuela)
EDELCA (Venezuela)
PDVSA (Venezuela)
CESP (Brazil)
EVN (Vietnam)
LAGEN (USA)
Electroandes (Peru)
DTE Energy (USA)
NYSEG Upgrade (USA)
CFE (Mexico) Level 1, 2
CFE (Mexico) Level 3
CFE (Mexico) Phase 4
PEPCO Upgrades (USA)
ITAIPU (Brazil)
Tacoma(USA)
ETESA (Panama)
El Paso (USA)
TENASKA (USA)
UTE (Uruguay)
CAISO
Austin Energy
Com Ed
Pacific Corp
IP & L
LCRA
NYISO
TRACTEBEL
VECTREN
IMO

SIEMENS的客戶：

Baltimore Gas ans Electric Company
Houston Lighting and Power
Florida Power and Light
Delmarva Power and Light
Rheinisch-Westfaelisches Elektrizitatswerk AG- Germany
Technische Werke der Stadt Stuttgart - Germany
Long Island Lighting Company
Southern California Edison
Hydro-Quebec
Egyptian Electric Authority
Union Electric
Romenergo Bukarest - Romania
REMVEC (Rhode Island, Eastern Massachusetts, Vermont Energy Control)
Gas-Elekrizitaets-und Wasserwerke Koeln AG - Germany
Agua y Electrica - Argentina
Northern States Power Company
Puerto Rico Electric Power Authority
Salt River Project
Wisconsin Electric Power
Southern California Edison
Azienda Communale Electtricita ed Acque - Italy
Saudi Consolidated Electricity Company - Saudi Arabia
Sacramento Municipal Utility District (SMUD)
SEP of the Netherlands
Omaha Public Power District
Tampa Electric
Mississippi Power & Light
Pacific Gas and Electric
Brazos Electric Power Cooperative
Bonneville Power Administration (2 Systems)
General Public utilities (4 systems)
Taiwan Power Company (3 systems)
Entergy Services
South Carolina Electric & Gas
CADAFE (Venezuela)(2 systems)
Dairyland Power Corp.
Iowa, Illinois Gas and Electric
National Grid Company (NGC)(UK)(5 systems)
Electric Generating Authority Thailand (3systems)
Zhejiang Province Electric Power Bureau (China)
Jiangsu Electric Power Bureau (China)
Iowa Power

電價

控制中心	TPC	NYISO	IMO
電價/KWH	～NTD 2.2	～USD 0.11	～ CND 0.0543

比較起來 IMO 的電價是最便宜的，但就結構上來說，IMO 境內自然能源充沛，有大量的水力可用作廉價的發電，但在 814 大停電後，仍決定讓十座存封的核能電廠重新服役，值得我們參考比較能源政策。

控制中心

控制中心	TPC	NYISO	IMO
個數	目前 1 未來 2	2	2
位置	距市區 台北市 10 分鐘車程	距市區 Albany 40 分鐘車程 NYC 120 分鐘車程	距市區 Toronto 50 分鐘車程
兩調度中心距離(小時)	目前：無 未來：約 5	0.3	0.3

台電目前僅有一個調度中心，雖有訓練有素的調度人員與嚴謹的工作態度，但實在顯得孤單與較不可靠;新 EMS 系統，將同時建立另一個調度中心，屆時將為台電的系統提供更佳的可靠度。

值班人力

控制中心	TPC	NYISO	IMO
人數/班	3	7	7
班數	5	6~7	6~7
總人數(人)	目前：16 未來：44	42~49	42~49
平均年齡(歲)	目前：49.9	約 40	約 40

相較起來台電的調度中心目前人力顯得不足，每一調度人員負擔的壓力責任

也比較大，再加上平均年齡大很多，是目前值得我們加強的部分，不論是增加調度人力的預備餘裕、降低人員平均年齡、或是加強人員流動將調度經驗由封閉的調度室中流傳出來，都可有效增加台電系統的可靠度。

專業調度員証照制度

控制中心	TPC	NYISO	IMO
有無証照制	目前：無	有	有

專業證照制度，除了可以用做認可一位優質調度人員的憑證外，更可保障一位認真投入調度工作的調度員工作權，更可促進一個教育訓練機制。

電力系統特性

控制中心	TPC	NYISO	IMO
連結性	獨立島型系統	大陸互連系統	大陸互連系統

台電電力系統獨立，未和任何其他系統連結，故有事故發生時，必須靠自求才行，因此無時無刻都必須花很多資源做為準備備轉容量，用以調整頻率及應付突發事故。

目前主要議題

控制中心	TPC	NYISO	IMO
主要議題	1.大事故發生時只能靠自己自救 2.離峰時電壓過高	1.輸電線興建不易 2.非自己控制區的問題監視不到	1.輸電線興建不易 2.非自己控制區的問題監視不到

雖說事故發生時，台電只能靠自己所準備的備轉電源自救，但由於系統沒有和其他電力系統連結在一起，故不至於發生像此次 814 大停電一樣，因其他控制區的疏失而造成自己的電力系統被拖垮;另一方面，正因為組織方面較國外簡單，因此輸電線路的興建也較為容易。再者，由於大都會愈來愈多，地下電纜的佈設也愈來愈多，因此，離峰時間電壓偏高變成台電一個很嚴肅的議題。

台電必需更積極的興建電抗器及增加發電機組進相運轉的能力，以調整系統中目前過多的無效功率。

◆建議-

整體來說，電力系統彼此權責的不清，電能管理系統的部分功能瑕疵、系統運轉人員的素質不齊、系統分析能力的不足、及制度上的溝通協調不夠，都是引發此大停電極主要的因素。針對此次事故的建議大致上可分為兩大部分：

一、軟硬體設備方面：

1. 要為調度人員提供充足的網路監視與運轉即時工具。
2. 電能管理系統要有完整的 RTU 佈置。
3. 要提供調度人員資訊充分的模擬盤(Map Board) 。
4. 要加強特殊保護系統(SPS)的功能及可靠度。
5. 要再評估保護電驛第三區間保護的必要性。
6. 要強化資通安全機制。

二、制度方面：

1. 要加強輸電線下樹木的管理。
2. 要加強調度員訓練及檢定。
3. 各電力公司及區域可靠度協調中心，轄區的責任範圍要明確界定與劃分。
4. 要訂定規定保護依照核准規則執行負載限制的調度員能免於賠償與追究報復之責。
5. 要設立與強化類似電力可靠度理事會的組織。

要再發生類似北美此次 814 大停電，雖不是絕無可能，但台電要發生類似這樣的事件機率不大，因我們的電力市場組織較為單純，係一國營的壟斷事業，不易發生單一區域內責任劃分不清的問題，RTU 的佈置也一定可以很完整;且台灣最長輸電線路僅有 167.8 公里(天輪～龍崎)，而非北美系統中的超過五百公里，在發生事故時的系統穩定度較佳；再者，台灣為獨立系統，頻率響應都比電壓響應快，在有大規模的電壓崩潰的事故發生前，頻率早已先出現問題而讓調度員必須去解決；獨立電力系統雖讓調度員運轉壓力較大，但也的確有其得天獨厚的優點。

電業自由化這條路台電雖然走的沒有人家快，但台電走得小心與謹慎，這是台電的優勢，也是我們要去珍惜的地方。
期待台電的電力系統能更穩定與可靠，邁向一具有聲望的世界級電力公司。

柒、英文名詞縮寫(Acronyms)解釋

CNSC Canada Nuclear Safety Commission

DHS U.S. Department of Homeland Security

DOE U.S. Department of Energy

ECAR East Central Area Reliability Coordination Agreement

EIPP Eastern Interconnection Phasor Project

ERO Electric Reliability Organization

FE FirstEnergy

FERC Federal Energy Regulatory Commission (U.S.)

FPT group Federal-Provincial-Territorial group (Canada)

ISO Independent System Operator

MISO Midwest Independent System Operator

NEB National Energy Board (Canada)

NERC North American Electric Reliability Council

NPCC Northeast Power Coordinating Council

NRC U.S. Nuclear Regulatory Commission

NRCan Natural Resources Canada

PJM PJM Interconnection

PSEPC Public Safety and Emergency Preparedness Canada

RTO Regional Transmission Organization

AC: Alternating current; current that changes periodically (sinusoidally) with time.

ACE: Area Control Error in MW. A negative value indicates a condition of under-generation relative to system load and imports, and a positive value denotes over-generation.

Active Power: See “Real Power.”

Adequacy: The ability of the electric system to supply the aggregate electrical demand and energy requirements of customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.

AGC: Automatic Generation Control is a computation based on measured frequency and computed economic dispatch. Generation equipment under AGC automatically responds to signals from an EMS computer in real time to adjust power output in response to a change in system frequency, tie-line loading, or to a prescribed relation between these quantities. Generator output is adjusted so as to maintain a target system frequency (usually 60 Hz) and any scheduled MW interchange with other areas.

Apparent Power: The product of voltage and current phasors. It comprises both active and reactive power, usually expressed in kilovoltamperes (kVA) or megavoltamperes (MVA).

Blackstart Capability: The ability of a generating unit or station to go from a shutdown condition to an operating condition and start delivering power without assistance from the bulk electric system.

Bulk Electric System: A term commonly applied to the portion of an electric utility system that encompasses the electrical generation resources and bulk transmission system.

Bulk Transmission: A functional or voltage classification relating to the higher voltage portion of the transmission system, specifically, lines at or above a voltage level of 115 kV.

Bus: Shortened from the word busbar, meaning a node in an electrical network where one or more elements are connected together.

Capacitor Bank: A capacitor is an electrical device that provides reactive power to the system and is often used to compensate for reactive load and help support system voltage. A bank is a collection of one or more capacitors at a single location.

Capacity: The rated continuous load-carrying ability, expressed in megawatts (MW) or megavolt-amperes (MVA) of generation, transmission, or other electrical equipment.

Cascading: The uncontrolled successive loss of system elements triggered by an

incident. Cascading results in widespread service interruption, which cannot be restrained from sequentially spreading beyond an area predetermined by appropriate studies.

Circuit: A conductor or a system of conductors through which electric current flows.

Circuit Breaker: A switching device connected to the end of a transmission line capable of opening or closing the circuit in response to a command, usually from a relay.

Control Area: An electric power system or combination of electric power systems to which a common automatic control scheme is applied in order to: (1) match, at all times, the power output of the generators within the electric power system(s) and capacity and energy purchased from entities outside the electric power system(s), with the load in the electric power system(s); (2) maintain, within the limits of Good Utility Practice, scheduled interchange with other Control Areas; (3) maintain the frequency of the electric power system(s) within reasonable limits in accordance with Good Utility Practice; and (4) provide sufficient generating capacity to maintain operating reserves in accordance with Good Utility Practice.

Contingency: The unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch, or other electrical element. A contingency also may include multiple components, which are related by situations leading to simultaneous component outages.

Control Area Operator: An individual or organization responsible for controlling generation to maintain interchange schedule with other control areas and contributing to the frequency regulation of the interconnection. The control area is an _ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _ 213 electric system that is bounded by interconnection metering and telemetry.

Current (Electric): The rate of flow of electrons in an electrical conductor measured in Amperes.

Curtailability: The right of a transmission provider to interrupt all or part of a transmission service due to constraints that reduce the capability of the transmission network to provide that transmission service. Transmission service is to be curtailed

only in cases where system reliability is threatened or emergency conditions exist.

Demand: The rate at which electric energy is delivered to consumers or by a system or part of a system, generally expressed in kilowatts or megawatts, at a given instant or averaged over any designated interval of time. Also see “Load.”

DC: Direct current; current that is steady and does not change sinusoidally with time (see “AC”).

Dispatch Operator: Control of an integrated electric system involving operations such as assignment of levels of output to specific generating stations and other sources of supply; control of transmission lines, substations, and equipment; operation of principal interties and switching; and scheduling of energy transactions.

Distribution: For electricity, the function of distributing electric power using low voltage lines to retail customers.

Distribution Network: The portion of an electric system that is dedicated to delivering electric energy to an end user, at or below 69 kV. The distribution network consists primarily of lowvoltage lines and transformers that “transport” electricity from the bulk power system to retail customers.

Disturbance: An unplanned event that produces an abnormal system condition.

Electrical Energy: The generation or use of electric power by a device over a period of time, expressed in kilowatthours (kWh), megawatthours (MWh), or gigawatthours (GWh).

Electric Utility: Person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for the generation, transmission, distribution, or sale of electric energy primarily for use by the public, and is defined as a utility under the statutes and rules by which it is regulated. An electric utility can be investorowned, cooperatively owned, or governmentowned (by a federal agency, crown corporation, State, provincial government, municipal government, and public power district).

Element: Any electric device with terminals that may be connected to other electric devices, such as a generator, transformer, circuit, circuit breaker, or bus section.

Energy Emergency: A condition when a system or power pool does not have adequate energy resources (including water for hydro units) to supply its customers’

expected energy requirements.

Emergency: Any abnormal system condition that requires automatic or immediate manual action to prevent or limit loss of transmission facilities or generation supply that could adversely affect the reliability of the electric system.

Emergency Voltage Limits: The operating voltage range on the interconnected systems that is acceptable for the time, sufficient for system adjustments to be made following a facility outage or system disturbance.

EMS: An energy management system is a computer control system used by electric utility dispatchers to monitor the real time performance of various elements of an electric system and to control generation and transmission facilities.

Fault: A fault usually means a short circuit, but more generally it refers to some abnormal system condition. Faults are often random events.

Federal Energy Regulatory Commission (FERC):
Independent Federal agency that, among other responsibilities, regulates the transmission and wholesale sales of electricity in interstate commerce.

Flashover: A plasma arc initiated by some event such as lightning. Its effect is a short circuit on the network.

Flowgate: A single or group of transmission elements intended to model MW flow impact relating to transmission limitations and transmission service usage.

Forced Outage: The removal from service availability of a generating unit, transmission line, or other facility for emergency reasons or a condition in which the equipment is unavailable due to unanticipated failure.

Frequency: The number of complete alternations or cycles per second of an alternating current, measured in Hertz. The standard frequency in the 214 _ **U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations** _ United States is 60 Hz. In some other countries the standard is 50 Hz.

Frequency Deviation or Error: A departure from scheduled frequency; the difference between actual system frequency and the scheduled system frequency.

Frequency Regulation: The ability of a Control Area to assist the interconnected system in maintaining scheduled frequency. This assistance can include both turbine governor response and automatic generation control.

Frequency Swings: Constant changes in frequency from its nominal or steady-state value.

Generation (Electricity): The process of producing electrical energy from other forms of energy; also, the amount of electric energy produced, usually expressed in kilowatt hours (kWh) or megawatt hours (MWh).

Generator: Generally, an electromechanical device used to convert mechanical power to electrical power.

Grid: An electrical transmission and/or distribution network.

Grid Protection Scheme: Protection equipment for an electric power system, consisting of circuit breakers, certain equipment for measuring electrical quantities (e.g., current and voltage sensors) and devices called relays. Each relay is designed to protect the piece of equipment it has been assigned from damage. The basic philosophy in protection system design is that any equipment that is threatened with damage by a sustained fault is to be automatically taken out of service.

Ground: A conducting connection between an electrical circuit or device and the earth. A ground may be intentional, as in the case of a safety ground, or accidental, which may result in high overcurrents.

Imbalance: A condition where the generation and interchange schedules do not match demand.

Impedance: The total effects of a circuit that oppose the flow of an alternating current consisting of inductance, capacitance, and resistance. It can be quantified in the units of ohms.

Independent System Operator (ISO): An organization responsible for the reliable operation of the power grid under its purview and for providing open transmission access to all market participants on a nondiscriminatory basis. An ISO is usually not-for-profit and can advise utilities within its territory on transmission expansion and maintenance but does not have the responsibility to carry out the functions.

Interchange: Electric power or energy that flows across tie-lines from one entity to another, whether scheduled or inadvertent.

Interconnected System: A system consisting of two or more individual electric systems that normally operate in synchronism and have connecting tie lines.

Interconnection: When capitalized, any one of the five major electric system networks in North America: Eastern, Western, ERCOT (Texas), Québec, and Alaska. When not capitalized, the facilities that connect two systems or Control Areas. Additionally, an interconnection refers to the facilities that connect a nonutility generator to a Control Area or system.

Interface: The specific set of transmission elements between two areas or between two areas comprising one or more electrical systems.

ISAC: Information Sharing and Analysis Centers (ISACs) are designed by the private sector and serve as a mechanism for gathering, analyzing, appropriately sanitizing and disseminating private sector information. These centers could also gather, analyze, and disseminate information from Government for further distribution to the private sector. ISACs also are expected to share important information about vulnerabilities, threats, intrusions, and anomalies, but do not interfere with direct information exchanges between companies and the Government.

Island: A portion of a power system or several power systems that is electrically separated from the interconnection due to the disconnection of transmission system elements.

Kilovar (kVAr): Unit of alternating current reactive power equal to 1,000 VArs.

Kilovolt (kV): Unit of electrical potential equal to 1,000 Volts.

Kilovolt-Amperes (kVA): Unit of apparent power equal to 1,000 volt amperes. Here, apparent power is in contrast to real power. On AC systems the voltage and current will not be in phase if reactive power is being transmitted.

Kilowatthour (kWh): Unit of energy equaling one thousand watthours, or one kilowatt used over one hour. This is the normal quantity used for _ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _ 215 metering and billing electricity customers. The retail price for a kWh varies from

approximately 4 cents to 15 cents. At a 100% conversion efficiency, one kWh is equivalent to about 4 fluid ounces of gasoline, 3/16 pound of liquid petroleum, 3 cubic feet of natural gas, or 1/4 pound of coal.

Line Trip: Refers to the automatic opening of the conducting path provided by a transmission line by the circuit breakers. These openings or “trips” are to protect the transmission line during faulted conditions.

Load (Electric): The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers. See “Demand.”

Load Shedding: The process of deliberately removing (either manually or automatically) preselected customer demand from a power system in response to an abnormal condition, to maintain the integrity of the system and minimize overall customer outages.

Lockout: A state of a transmission line following breaker operations where the condition detected by the protective relaying was not eliminated by temporarily opening and reclosing the line, possibly several times. In this state, the circuit breakers cannot generally be reclosed without resetting a lockout device.

Market Participant: An entity participating in the energy marketplace by buying/selling transmission rights, energy, or ancillary services into, out of, or through an ISO-controlled grid.

Megawatthour (MWh): One million watthours.

Metered Value: A measured electrical quantity that may be observed through telemetering, supervisory control and data acquisition (SCADA), or other means.

Metering: The methods of applying devices that measure and register the amount and direction of electrical quantities with respect to time.

NERC Interregional Security Network (ISN): A communications network used to exchange electric system operating parameters in near real time among those responsible for reliable operations of the electric system. The ISN provides timely and accurate data and information exchange among reliability coordinators and other system operators. The ISN, which operates over the frame relay NERCnet system, is a

private Intranet that is capable of handling additional applications between participants.

Normal (Precontingency) Operating Procedures: Operating procedures that are normally invoked by the system operator to alleviate potential facility overloads or other potential system problems in anticipation of a contingency.

Normal Voltage Limits: The operating voltage range on the interconnected systems that is acceptable on a sustained basis.

North American Electric Reliability Council (NERC): A not-for-profit company formed by the electric utility industry in 1968 to promote the reliability of the electricity supply in North America. NERC consists of nine Regional Reliability Councils and one Affiliate, whose members account for virtually all the electricity supplied in the United States, Canada, and a portion of Baja California Norte, Mexico. The members of these Councils are from all segments of the electricity supply industry: investor-owned, federal, rural electric cooperative, state/municipal, and provincial utilities, independent power producers, and power marketers. The NERC Regions are: East Central Area Reliability Coordination Agreement (ECAR); Electric Reliability Council of Texas (ERCOT); Mid-Atlantic Area Council (MAAC); Mid-America Interconnected Network (MAIN); Mid-Continent Area Power Pool (MAPP); Northeast Power Coordinating Council (NPCC); Southeastern Electric Reliability Council (SERC); Southwest Power Pool (SPP); Western Systems Coordinating Council (WSCC); and Alaskan Systems Coordination Council (ASCC, Affiliate).

OASIS: Open Access Same Time Information Service (OASIS), developed by the Electric Power Research Institute, is designed to facilitate open access by providing users with access to information on transmission services and availability, plus facilities for transactions.

Operating Criteria: The fundamental principles of reliable interconnected systems operation, adopted by NERC.

Operating Guides: Operating practices that a Control Area or systems functioning as part of a Control Area may wish to consider. The application of Guides is optional and may vary among Control Areas to accommodate local conditions and individual system requirements.

Operating Policies: The doctrine developed for interconnected systems operation.

This doctrine 216 _ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _ consists of Criteria, Standards, Requirements, Guides, and instructions, which apply to all Control Areas.

Operating Procedures: A set of policies, practices, or system adjustments that may be automatically or manually implemented by the system operator within a specified time frame to maintain the operational integrity of the interconnected electric systems.

Operating Requirements: Obligations of a Control Area and systems functioning as part of a Control Area.

Operating Security Limit: The value of a system operating parameter (e.g. total power transfer across an interface) that satisfies the most limiting of prescribed pre- and post-contingency operating criteria as determined by equipment loading capability and acceptable stability and voltage conditions. It is the operating limit to be observed so that the transmission system will remain reliable even if the worst contingency occurs.

Operating Standards: The obligations of a Control Area and systems functioning as part of a Control Area that are measurable. An Operating Standard may specify monitoring and surveys for compliance.

Outage: The period during which a generating unit, transmission line, or other facility is out of service.

Planning Guides: Good planning practices and considerations that Regions, subregions, power pools, or individual systems should follow. The application of Planning Guides may vary to match local conditions and individual system requirements.

Planning Policies: The framework for the reliability of interconnected bulk electric supply in terms of responsibilities for the development of and conformance to NERC Planning Principles and Guides and Regional planning criteria or guides, and NERC and Regional issues resolution processes. NERC Planning Procedures, Principles, and Guides emanate from the Planning Policies.

Planning Principles: The fundamental characteristics of reliable interconnected bulk electric systems and the tenets for planning them.

Planning Procedures: An explanation of how the Planning Policies are addressed

and implemented by the NERC Engineering Committee, its subgroups, and the Regional Councils to achieve bulk electric system reliability.

Post-contingency Operating Procedures: Operating procedures that may be invoked by the system operator to mitigate or alleviate system problems after a contingency has occurred.

Protective Relay: A device designed to detect abnormal system conditions, such as electrical shorts on the electric system or within generating plants, and initiate the operation of circuit breakers or other control equipment.

Power/Phase Angle: The angular relationship between an AC (sinusoidal) voltage across a circuit element and the AC (sinusoidal) current through it. The real power that can flow is related to this angle.

Power: See “Real Power.”

Power Flow: See “Current.”

Rate: The authorized charges per unite or level of consumption for a specified time period for any of the classes of utility services provided to a customer.

Rating: The operational limits of an electric system, facility, or element under a set of specified conditions.

Reactive Power: The portion of electricity that establishes and sustains the electric and magnetic fields of alternating-current equipment. Reactive power must be supplied to most types of magnetic equipment, such as motors and transformers. It also must supply the reactive losses on transmission facilities. Reactive power is provided by generators, synchronous condensers, or electrostatic equipment such as capacitors and directly influences electric system voltage. It is usually expressed in kilovars (kVAr) or megavars (MVAr), and is the mathematical product of voltage and current consumed by reactive loads. Examples of reactive loads include capacitors and inductors. These types of loads, when connected to an ac voltage source, will draw current, but because the current is 90 degrees out of phase with the applied voltage, they actually consume no real power.

Readiness: The extent to which an organizational entity is prepared to meet the functional requirements set by NERC or its regional council for entities of that type or

class.

Real Power: Also known as “active power.” The rate at which work is performed or that energy is **_ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _** 217 transferred, usually expressed in kilowatts (kW) or megawatts (MW). The terms “active power” or “real power” are often used in place of the term power alone to differentiate it from reactive power.

Real-Time Operations: The instantaneous operations of a power system as opposed to those operations that are simulated.

Regional Reliability Council: One of ten Electric Reliability Councils that form the North American Electric Reliability Council (NERC).

Regional Transmission Operator (RTO): An organization that is independent from all generation and power marketing interests and has exclusive responsibility for electric transmission grid operations, short-term electric reliability, and transmission

services within a multi-State region. To achieve those objectives, the RTO manages transmission facilities owned by different companies and encompassing one, large, contiguous geographic area.

Regulations: Rules issued by regulatory authorities to implement laws passed by legislative bodies.

Relay: A device that controls the opening and subsequent reclosing of circuit breakers. Relays take measurements from local current and voltage transformers, and from communication channels connected to the remote end of the lines. A relay output trip signal is sent to circuit breakers when needed.

Relay Setting: The parameters that determine when a protective relay will initiate operation of circuit breakers or other control equipment.

Reliability: The degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. Reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. Electric system reliability can be addressed by considering two basic and functional aspects of the electric system, Adequacy and Security.

Reliability Coordinator: An individual or organization responsible for the safe and reliable operation of the interconnected transmission system for their defined area, in accordance with NERC reliability standards, regional criteria, and subregional criteria and practices. This entity facilitates the sharing of data and information about the status of the Control Areas for which it is responsible, establishes a security policy for these Control Areas and their interconnections, and coordinates emergency operating procedures that rely on common operating terminology, criteria, and standards.

Resistance: The characteristic of materials to restrict the flow of current in an electric circuit. Resistance is inherent in any electric wire, includingthose used for the transmission of electric power. Resistance in the wire is responsible for heating the wire as current flows through it and the subsequent power loss due to that heating.

Restoration: The process of returning generators and transmission system elements and restoring load following an outage on the electric system.

Right-of-Way (ROW) Maintenance: Activities by utilities to maintain electrical clearances along transmission or distribution lines.

Safe Limits: System limits on quantities such as voltage or power flows such that if the system is operated within these limits it is secure and reliable.

SCADA: Supervisory Control and Data Acquisition system; a system of remote control and telemetry used to monitor and control the electric system.

Schedule: An agreed-upon transaction size (megawatts), start and end time, beginning and ending ramp times and rate, and type required for delivery and receipt of power and energy between the contracting parties and the Control Area(s) involved in the transaction.

Scheduling Coordinator: An entity certified by an ISO or RTO for the purpose of undertaking scheduling functions.

Seams: The boundaries between adjacent electricity- related organizations. Differences in regulatory requirements or operating practices may create

“seams problems.”

Security: The ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.

Security Coordinator: An individual or organization that provides the security assessment and emergency operations coordination for a group of Control Areas.

Short Circuit: A low resistance connection unintentionally made between points of an electrical circuit, which may result in current flow far above normal levels. 218 _ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _

Shunt Capacitor Bank: Shunt capacitors are capacitors connected from the power system to an electrical ground. They are used to supply kilovars (reactive power) to the system at the point where they are connected. A shunt capacitor bank is a group of shunt capacitors.

Single Contingency: The sudden, unexpected failure or outage of a system facility(s) or element(s) (generating unit, transmission line, transformer, etc.). Elements removed from service as part of the operation of a remedial action scheme are considered part of a single contingency.

Special Protection System: An automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components.

Stability: The ability of an electric system to maintain a state of equilibrium during normal and abnormal system conditions or disturbances.

Stability Limit: The maximum power flow possible through a particular point in the system while maintaining stability in the entire system or the part of the system to which the stability limit refers.

State Estimator: Computer software that takes redundant measurements of quantities related to system state as input and provides an estimate of the system state (bus voltage phasors). It is used to confirm that the monitored electric power system is operating in a secure state by simulating the system both at the present time and one step ahead, for a particular network topology and loading condition. With the use of a state estimator and its associated contingency analysis software, system operators can review each critical contingency to determine whether each possible future state is within reliability limits.

Station: A node in an electrical network where one or more elements are connected.

Examples include generating stations and substations.

Storage: Energy transferred form one entity to another entity that has the ability to conserve the energy (i.e., stored as water in a reservoir, coal in a pile, etc.) with the intent that the energy will be returned at a time when such energy is more useable to the original supplying entity.

Substation: Facility equipment that switches, changes, or regulates electric voltage.

Subtransmission: A functional or voltage classification relating to lines at voltage levels between 69kV and 115kV.

Supervisory Control and Data Acquisition (SCADA): See SCADA.

Surge: A transient variation of current, voltage, or power flow in an electric circuit or across an electric system.

Surge Impedance Loading: The maximum amount of real power that can flow down a lossless transmission line such that the line does not require any VArs to support the flow.

Switching Station: Facility equipment used to tie together two or more electric circuits through switches. The switches are selectively arranged to permit a circuit to be disconnected, or to change the electric connection between the circuits.

Synchronize: The process of connecting two previously separated alternating current apparatuses after matching frequency, voltage, phase angles, etc. (e.g., paralleling a generator to the electric system).

System: An interconnected combination of generation, transmission, and distribution components comprising an electric utility and independent power producer(s) (IPP), or group of utilities and IPP(s).

System Operator: An individual at an electric system control center whose responsibility it is to monitor and control that electric system in real time.

System Reliability: A measure of an electric system’s ability to deliver uninterrupted service at the proper voltage and frequency.

Thermal Limit: A power flow limit based on the possibility of damage by heat. Heating is caused by the electrical losses which are proportional to the square of the *real power*

flow. More precisely, a thermal limit restricts the sum of the squares of *real* and *reactive power*.

Tie-line: The physical connection (e.g. transmission lines, transformers, switch gear, etc.) between two electric systems that permits the transfer of electric energy in one or both directions.

Time Error: An accumulated time difference between Control Area system time and the time standard. Time error is caused by a deviation in Interconnection frequency from 60.0 Hertz.

Time Error Correction: An offset to the Interconnection's scheduled frequency to correct for the time error accumulated on electric clocks. **_ U.S.-Canada Power System Outage Task Force _ August 14th Blackout: Causes and Recommendations _** 219

Transactions: Sales of bulk power via the transmission grid.

Transfer Limit: The maximum amount of power that can be transferred in a reliable manner from one area to another over all transmission lines (or paths) between those areas under specified system conditions.

Transformer: A device that operates on magnetic principles to increase (step up) or decrease (step down) voltage.

Transient Stability: The ability of an electric system to maintain synchronism between its parts when subjected to a disturbance and to regain a state of equilibrium following that disturbance.

Transmission: An interconnected group of lines and associated equipment for the movement or transfer of electric energy between points of supply and points at which it is transformed for delivery to customers or is delivered to other electric systems.

Transmission Loading Relief (TLR): A procedure used to manage congestion on the electric transmission system.

Transmission Margin: The difference between the maximum power flow a transmission line can handle and the amount that is currently flowing on the line.

Transmission Operator: NERC-certified party responsible for monitoring and assessing local reliability conditions, who operates the transmission facilities, and who

executes switching orders in support of the Reliability Authority.

Transmission Overload: A state where a transmission line has exceeded either a normal or emergency rating of the electric conductor.

Transmission Owner (TO) or Transmission Provider:

Any utility that owns, operates, or controls facilities used for the transmission of electric energy.

Trip: The opening of a circuit breaker or breakers on an electric system, normally to electrically isolate a particular element of the system to prevent it from being damaged by fault current or other potentially damaging conditions. See “Line Trip” for example.

Voltage: The electrical force, or “pressure,” that causes current to flow in a circuit, measured in Volts.

Voltage Collapse (decay): An event that occurs when an electric system does not have adequate reactive support to maintain voltage stability. Voltage Collapse may result in outage of system elements and may include interruption in service to customers.

Voltage Control: The control of transmission voltage through adjustments in generator reactive output and transformer taps, and by switching capacitors and inductors on the transmission and distribution systems.

Voltage Limits: A hard limit above or below which is an undesirable operating condition. Normal limits are between 95 and 105 percent of the nominal voltage at the bus under discussion.

Voltage Reduction: A procedure designed to deliberately lower the voltage at a bus. It is often used as ameans to reduce demand by lowering the customer’s voltage.

Voltage Stability: The condition of an electric system in which the sustained voltage level is controllable and within predetermined limits.

Watthour (Wh): A unit of measure of electrical energy equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

捌、參考資料

U.S.-Canada Power System Outage Task Force Final Report on the Auguest,14,2003 Blackout in the United States and Canada Caused and Recommendations -- released in April ,2004

2003,8,14 美、加大停電,美國、加拿大聯合專案調查小組最終報告—2004,4 公佈

The Auguest,14,2003 Blackout One Year Later Actions Taken in the United States and Canada to Reduced Blackout Risk - Released by Natural Resources Canada and U.S. Department of Energy on Auguest,13,2003

2003,8,14 大停電一年後，美國及加拿大為減少停電風險已執行的行動—由加拿大自然資源部及美國能源部於 2004,8,13 公佈

NERC 網站：WWW.NERC.COM

FERC 網站：WWW.FERC.GOV

Ontario Ministry of Energy：WWW.ENERGY.GOV.ON.CA

IMO 網站：WWW.THEIMO.COM

NYISO 網站：WWW.NYISO.COM(非在美國本土則無法連上)

玖、誌謝：

非常感謝公司各級長官給予職這次出國研究計劃,以身為本公司第一線調度人員之實務經驗，深深瞭解目前公司因各種內、外在環境的壓力，不論上下都承受著很大的責任;職此次出國，過程中雖有不順，有辛苦，但對於公司內同仁與長官的協助與指導，尤其出國在外，各站行程安排，皆須事先妥善連絡協調，願藉此深致銘謝之意。

期待本件報告，提供公司同仁參考訊息，有助於公作的推動。

陳政宏 2004,12,29