行政院及所屬各機關出國報告

（出國類別：實習）

高壓低頻及低壓數位配電線載波自動讀表系統研製技術

服務機關：台灣電力公司
出國人職稱：電機工程師
姓　　名：黃佳文

出國地區：美國、加拿大

出國日期：90 年 7 月 17 日至 7 月 28 日
報告日期：90 年 9 月 3 日

行政院及所屬各機關出國報告審核表

出國報告名稱：高壓低頻及低壓數位配電線載波自動讀表系統研製技術	
出國計畫主辦機關名稱：台灣電力公司人事處	
出國人姓名/職稱/服務單位：黃佳文/十二等電機工程師/電力綜合研究所	
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）不符原核定出國計劃 ☐（2）以外文撰寫或僅以所蒐集外交資料爲內容 ☐（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	☐同意主辦機關意見 ☐全部　☐部份 ________（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，不須填寫「層轉機關審意見」。

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、審核作業應於出國報告提出後 二個月內完成。

總 經 理：

副總經理

主管處主管：（電力綜合研究所所長 90.9.3 費昌仁）（電力綜合研究所副所長 90.9.3 劉志成）

直屬主管：林哲緯

報告人：（電力綜合研究所（負）90.9.3 黃佳文）

行政院及所屬各機關出國報告提要

出國報告名稱：高壓低頻及低壓數位配電線載波
自動讀表系統研製技術

頁數 48 含附件：☑是☐否

出國計畫主辦機關/聯絡人/電話：

台灣電力公司人事處/陳德隆/0223667685

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黃佳文/台灣電力公司/電力綜合研究所/十二等電機工程師/02-2360-1232

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報告日期：90 年 9 月 3 日

分類/號目：G3/電力工程

關鍵詞：自動讀表、被動式電感性中壓耦合器、配電線通訊技術

內容摘要：（二百至三百字）

赴紐約 Consolidated Edison 電力公司實習中低壓數位配電線載波自動讀表系統研製技術，主要利用被動式電感性中壓(35KV)耦合器取代傳統配電線載波中壓耦合器須將控制信號電壓升壓再注入至 35KV 配電線的訊號注入直接耦合方式，而且被動型電感性中壓耦合器不需與 35KV 配電線直接連接，只須用熱黏膠勾掛在 35KV 線上即可，安裝簡單又安全，體積小成本低.因此這種數位配電線通訊技術(PLT)可以利用住戶內的任何電源插座及配電線提供用戶高速資料傳送服務，將用戶網際網路、網路電話、隨選視訊及自動讀表、智慧型需求面管理資料以 1.5 至 12Mbps 的高速雙向傳送至變電所內的光纖骨幹網路再連結到整體資料與語音網路上提供寬頻服務，對電力公司與用戶提供了重大的利益。

出國報告目錄

壹、出國任務內容與過程

一、出國任務內容

(一)赴加拿大溫哥華參加國際電機電子工程學會 2001 年年會及發表論文

國際電機電子工程學會 IEEE 的電力工程組(PES, Power Engineering Society) 2001 年夏季年會於 7 月 15 日至 19 日在加拿大溫哥華市舉行。發表論文「Temperature Sensitivity Analysis of System Power Profiles」，此篇論文「電力系統負載曲線之溫度敏感度分析」被安排於 7 月 18 日之控制中心議題(Control Center Issues)組報告，這項議題涵蓋八篇論文，以 Panel Session 方式讓與會人員充份討論與深入交換意見，與國內電力工程研討會之論文發表完全不同，其中由美國電力研究院 EPRI 與 IEC TC57 標準化工作小組進行的一系列的多供應商全互通測試作業(Multi-Vendor Interoperability Testing Activities)，這種全互通測試是電業自由化後獨立系統運轉中心(ISO, Independent System Operators)及區域輸電運轉中心 RTOs (Region Transmission Operators)所急需的電力網路模型資訊交換(Electric network model information exchange)，以提供軟體的運轉來確保輸電系統的安全運轉，本次會議 ABB 公司及 ESCA 公司提出兩篇論文係由 EPRI 委託研究「建立共同資訊模型」(Common Information Model, CIM)的研究成果，此為一系列多供應商全互通測試作業中第一次測試成果報告，ABB 的能源資訊系統(EIS)公司發表論文為「Progress Report on CIM XML for Model Exchange Interoperability Test」，ESCA 公司發表之論文為「Price Responsive Load in the De-Regulated Environment」，這兩篇「共同資訊模型」之研究成果主要探討不同電力公司因應未來區域調度中心(RDC, Regional Dispatching Center)成立後(美國電力系統將區分為四大區域調度中心)，彼此電力網路架構及電力系統資料之共享，使電力公司在執行調度分析時能將鄰近電力公司的即時資料納入分析。

另外加拿大 BC Hydro 電力公司發表論文「Current State of BC Hydro EMS」及「a Future Application Environment for BC Hydro EMS」，針對 BC Hydro 控制中心的系統配置及應用程式的現況作說明，並且報告其如何將舊有的能源管理系統(EMS)轉移至新設 EMS 系統。

另外由挪威電力公司發表之論文「Market Based AGC with online

Bidding of Regulation Reserves」，研究如何藉由發電機之自動發電控制系統(AGC)在一定備轉容量之限制條件下，調整其發電量，以達到即時發電量競標(real-time generation bidding)之目的。

1、台電發表之論文針對本公司執行負載特性調查分析研究之結果，根據實際裝設電子式調查電表量測之區處及全系統之負載組成推估及不同類型用戶耗電量之溫度敏感度分析，探討溫度變化時對區處及全系統負載之變化量，可作為系統經濟調度與空調類負載管理潛力之評估。根據89年台電系統尖峰負載日(89年7月26日下午3時尖峰負載25,854 MW)的各類用戶分時負載組成推估結果及系統溫度敏感度分析結果，夏季尖峰負載日溫升1℃可增加593.6MW系統負載，與系統實際負載變化量（調度發電資料）621MW比較，推估誤差27.4MW，也就是推估誤差為4.4%，其中住宅用戶負載每升1℃時負載變化量293MW（為住宅用戶尖峰負載7608MW的3.85%），商業用戶負載溫升1℃時負載變化量271MW（為商業用戶尖峰負載4990MW的5.4%），而工業用戶負載則溫升1℃負載變化量僅達36MW（為工業用戶尖峰負載12,760MW的0.28%）。

由於商業用戶白天使用空調比重較其他用戶高，溫度上升1℃其負載增加5.4%住宅用戶次之為3.8%，而工業用戶除了電子業與冷凍業有較明顯的溫度敏感度外，一般工業用戶之溫度敏感度在白天尖峰負載時段只有0.05~0.1，以致工業用戶在尖峰時段溫升1℃其負載僅增加0.28%。
推估結果全系統的溫度敏感度最大值發生在上午12時的0.78及下午3時的0.79，而溫升1℃對全系統的負載變化量增加2.5%

(二)、赴加拿大魁北克電力公司(Hydro Quebec)實習自動讀表與負載特性調查技術

1.Hydro-Quebec電力公司的研究發展

加拿大魁北克電力公司(Hydro-Quebec)屬於加拿大魁北克省政府所擁有的省營電力公司，93%的發電量來自於水力發電，發電裝置容量為3151萬KW，其東北方的邱吉爾大瀑有(Churchill Falls)的水力電廠發電高達542萬KW，發電廠中有51座水力電廠，28座火力電廠(1座60萬KW大型火力電廠，3座複循環，24座小型柴油發電機)，及１座核能電廠。

Hydro-Quebec電力公司有350萬個用戶，其中住宅及農場用戶佔91.5%(320萬戶)，商業綜合用戶佔8%(28萬戶)，工業用戶佔0.4%(14000戶)，

其他用戶佔 0.1%(3500 戶)。尖峰負載發生在 2000 年 1 月 14 日的 3299 萬 KW(夏季尖峰負載只有 1600 萬 KW),用戶滿意度達 92%。魁北克省有 70% 的用戶擁有電熱空調系統，有些用戶擁有雙重燃料(duel Fuel)暖氣空調系統（電熱空調與瓦斯熱空調)。

Hydro-Quebec 電業法賦予其兩項任務(Mission):除了滿足用戶的供電需求外，尚需致力下述兩項工作：

(1)能源有關的研究與推廣

(2)能源轉換(Energy Conversion)與能源節約。

因此 Hydro-Quebec 的研究發展處有高達 620 名員工，其中有 450 位研究師，測試工程師及技術人員，致力於發電輸電配電及用戶服務的四類研究發展。

Hydro-Quebec 設有一位研究與策略規劃副總負責研究工作。

Hydro-Quebec 有 20,676 位員工,2000 年之售電量 1900 億度(台電為 1424 億度)，另外 Hydro-Quebec 也兼營天然瓦斯，天然瓦斯銷售量作其 2000 年收入 114 億加幣的 8.1%，Hydro-Quebec 有 17.3%的電力輸出到美國。

Hydro-Quebec 的輸電系統從 1997 年 5 月 1 日開始對躉售市場(Wholesale Market)開放，開始進入電業自由化競爭市場。

Hydro-Quebec 有 19 家子公司及 65 家高風險聯合投資(joint venture)公司其中 Hydro-Quebec 國際公司(HQI)已有 20 年的全球投資經驗，包括澳洲的兩條輸電連線工程(Directlink, 180MW Interconnection 及 Murraylink 225MW interconnection)，中國大陸的民間電廠 Meiya Power IPP 的 7 座變電站及昆山水力發電廠(20 MW)興建工程，南美洲的智利興建一條長達 7300 公里的高壓輸電線網路 Transelec，中美洲的巴拿馬興建一座 300MW 水力電廠(Fortuna)及貝魯的 230 KV 高壓輸電線工程 TransMantaro，及美國橫跨紐約長島與康乃迪克(Connetic)的 Cross Sound 海峽直流高壓連線 (325MW)。

其中投資在高風險資本市場的 HQ Capitech 投資公司則專門投資於能源科技公司或與私人公司合夥製造燃料電池、微型燃氣渦輪機(Microturbine)等高科技綠色能源產品，例如去年 HQ Capitech 研發一種新型的易於安裝的軟式電池，推出後受消費大眾高度喜愛，2000 年其在 Nasdaq 上市公司

New-Energy 公司的股票就淨賺了 30%。

2. 自動讀表技術：

Hydro-Quebec 針對商業、工業及政府機構用戶提供能源分析(Energy Analysis) 及事件管理(Event Management)的資訊服務，以因應能源工業的競爭性及結構性變革，對用戶提供用戶所需要及期望的加值性服務，因此 Hydro-Quebec 於 2000 年開始利用新的電表計量技術，2000 年底已在 5000 個工商用戶(5 MW 以上)端安裝 GE 的 KV 型電子式電表，利用電話專線自動讀表，目前使用 MV90 的自動讀表分析軟體可自動讀取 26,000 個 KV 電子式電表，預計在 2004 年底可安裝完成 50,000 個工商用戶的自動讀表系統(每年安裝 1 萬台 AMR 電表)，這項工商用戶 AMR 計畫包括可下載到用戶網路的資訊服務及計費服務。資訊服務有兩項：

A. 能源分析：

(1)15 分鐘間隔的負載曲線(15-minutes interval load profile)

(2)用電量總和(Consumption Summation)

(3)績效追蹤

B. 事件管理：

(1)即時警告管理　(2)程序追蹤(Process Tracking)。

資訊服務的計畫流程為：從 2001～2002 年間進行資訊服務的先導計畫(Pilot Project)，主要針對 300 個大工業用戶提供即時電價(real-time pricing)，2001 年到 2003 年間進行資料倉儲系統(Data Warehouse)與用戶網路系統(Web Server)的安裝測試。

2003 年開始正式提供用戶網路下載資訊倉儲資料的資訊服務。

計費服務有兩項：

(1) 用戶計費時間的選舉(Billing Date Choice)，從 2001 年開始推動進行。

(2) 電費天然瓦斯費及水費的整合計費(Billing Consolidation)，從 2002 年開始推動進行。

AMR 的讀表電話專線每月費用為加幣 50 元。

3. 負載特性調查技術：由 Rate Department（電費處）負責。

Hydro-Quebec 每年必須將各類用戶負載特性調查資料提報給魁北克省的

費率管制局(Rate Regulation Board)，用戶負載調查資料包括

(1)負載因數(Load Factor)

(2)各類用戶電價結構(Rate Structure for every Category Customers)

(3)輸配電線路損失估計值。

Hydro-Quebec 的負載特性調查共計在 700 個住宅用戶及 800 個工商用戶端安裝了 1500 台電子式調查電表，記錄每 15 分鐘的用電間隔資料(Interval Data)，其中有 1000 戶使用電話專線自動讀取用戶電表資料，另外，500 戶與用戶共用其電話線自動讀取用戶電表資料。

因此 Hydro-Quebec 的負載特性調查完全使用自動讀表調查，節省人工讀表的費時與費力，值得台電進行負載特性調查工作的參考。

其負載特性調查資料除了提供住宅、工業、商業的各類用戶負載組成(Load Composition)及線路損失資料外，亦提供一年 8760 小時的負載持續期間曲線(8760 Hours Load Duration Curve) 。 另外 Hydro-Quebec 在冬季尖峰負載時段提供兩種電價選擇，在下午三點到下午十點時段，電價每度高達加幣 14 分，而在早上 6 點早上 11 點為離峰時段電價只有每度加幣 3 分，因此在尖峰時段尤其是氣溫在零下 20℃時，鼓勵用戶儘量使用天然瓦斯暖氣，不要使用電熱暖氣。

(三)赴紐約 Consolidated Edison 電力公司實習中低壓數位配電線載波自動讀表系統開發技術

1.數位配電線載波通訊（PLT）用戶服務

(1)寬頻資料(broadband Data)服務：PLT（Powerline Telecommunication Technology）提供用戶高速資料管線，PLT 提供 1.5 Mbps ～ 12 Mbps 資料速度；相較於數位用戶迴路(DSL)的問題，PLT 提供的寬頻服務(broadband service)在電力公司與用戶間建立了一個較簡單的組件結構與安裝過程。

(2)網路電話服務(Telephony Voice Ip Services)：

PLT 利用住戶內到處可見的電源插座提供網路電話(Voice over IP, VOIP)的電話通話服務，網路電話為未來成長迅速的電話服務。PLT

的網路電話服務提供用戶重大利益。

(3)隨選視訊服務(Video-on Demand)：為 PLT 用戶的一項未來服務項目之一。隨選視訊服務(Video on demand)代表寬頻服務供應商(broad-band service provider)的較大成長機會。但這項產品大規模商業化之前必須解決帶寬(bandwidth)及技術的問題。

(4)其他服務：警告、監視，守門人（管理員）服務、智慧型電器。

2. PLT 電業產品及服務

(1).AMR：由於電業早已瞭解 AMR 可以降低營運成本與改善可靠度，因此在美國已安裝了 1300 萬台自動讀表電表，PLC 可以使 AMR 安裝更加容易，PLC 也提供了自動讀表降低成本與改善服務的能力.

(2).IDSM：智慧型需求面管理

(3).電業效率服務(utility efficiency service)：

PLT 配合 IDSM 可讓電業改善需求面管理的問題解決程序(ALGORITHM)，因 PLT 可提供較多資料及改善配電系統電力控制的水準。

(4).利基電業產品(Niche utility products): load balancing, peak-shaving，利用電力線提供資料將開放一個巨大的機會來創造配電系統的智慧型裝置，使電業有機會改善系統效能(System Performance)。

3.電業 PLT 網路：

PLT 可容許高頻的資料訊號與低頻的電力訊號同時併存在中壓(2.4 kv ～ 35kv) 或低壓(110v ～ 600v)的電力線上，因此對電業與用戶提供重大利益來有效建立一個"Last mile"問題解決方法。

(1).PLT 讓電業可以在現有電力線架構上佈署一個完整的通訊網路。

(2).PLT 可容許高頻的資料訊號與低頻的電力訊號併存在相同的中壓(2.4 kv ～ 35kv)或低壓(600v 以下)電力線上。

(3).PLT 的技術對電業與用戶提供了重大的利益，有效的建立了一個"Last mile"的解決方法。

而通訊系統的"Last-mile"的難題解決後，通訊系統將可從用戶端延伸到與高速通訊骨幹連結的當地通訊交換機房。

(4).低、中、高壓電力網路的定義：

低壓：600v 以下，中壓（medium voltage): 2.4kv ～ 35kv。

高壓：69kv 以上。

而電力線是傳送高頻 PLT 率號至 Last mile 的管線。

(5).在美國配電變壓器一般可供電給 4 到 10 個家庭：而配電網路為了防止遭受過載、雷擊及其他網路停電而裝設許多保護裝置，這些保護裝置對 PLT 通訊信號造成的影響亦必須在安裝 PLT 網路時列入考慮。

(6).在電業配電網路上鋪設 PLT 通訊網路一般需要六項組件：

(A).資料網路(Data Network)

(B).電力線

(C).網路交通指揮節點(network traffic directing nodes)

(D).信號加強器(repeater)

(E).高低壓信號偶合器(coupler)

(F).數據機。

A.資料網路：用來將電力線 last-mile 連結到通訊骨幹上。許多電業早已鋪設的光纖電纜中有多餘的容量足以被利用於通訊系統的出入。利用電業已鋪設的光纖網路或租用通訊服務供應商的高速資料鏈(high-speed data links)可將 PLT 通訊系統連結至整體資料及語音網路。這個資料網路可提供變電所的監視資訊及提供語音通訊給現場人員。

B.變電所是將資料通訊網路耦合到電業配電網路的一個理想地點：透過 Ambient 專利的中壓耦合器將資料訊號調變後傳送到配電線上。這個中壓耦合裝置必須能夠承受高電壓、氣候因素、外在因素、雷擊突波。

耦合器可分為電容性耦合器與電感性耦合器兩種。

耦合器可以讓各種不同的節點(變電所節點 S-node,變壓器節點 X-node，家庭入口節點 GateWay-Node（GW-Node），或強訊器 repeater-ode（R-node）將 PLT 訊號傳送至或接受自中壓及低壓配電系統。

由於以往配電線載波信號耦合器無法做到低成本、安裝容易，維護成本低、被動型耦合器線路，而且安裝時必須切斷電力線電源才能將耦合器接到中壓配電線上，因此阻礙了配電線載波在中壓配電系統的應用。

然而 AMBIENT 公司研發的被動型電感式耦合器(passive inductive coupler)解決了上述所有的問題。(中壓配電線載波耦合器每具只需美金 50 元，而且只需像勾式電流計一般勾掛在中壓配電線上即安裝完畢，不需與中壓線接線在一起，節省作業時間而且施工較安全）

(C)網路交通指揮節點：

為了維持每個用戶的高可用頻寬，須在電業配電網路上安裝一些通訊網路裝置，其功能為資料傳輸的橋接、交換及路由器（router)。

網路交通指揮節點包含交換與路由技術來管理 PLT 通訊網路，這些節點皆為智慧型網路裝置被用來指揮資料訊號可以沿著最佳的可用路徑到達其最終目的地，並且依其建立的動態虛擬路線傳送資料。

(D)信號加強器(repeater)：

當 PLT 信號 在長距離配電線上傳送時其信號強度會變弱，信號加強器可加強及再生 PLT 訊號。而且 PLT 訊號也會遭遇到外部電磁波輻射及內部信號反射的干擾；因此會造成 PLT 高頻訊號的重大失真與改變。信號加強器須克服上述干擾而且延伸 PLT 訊號在配電線上傳送的距離。

(E)家庭入口節點(Home Gateway Node)：GW-Node 為 PLT 技術提供各項家庭服務(in-home service)的控制中心，in-home service 包括資料網路

(如乙太網路)，網路電話服務 VOIP，自動讀表，需求面管理。

家庭入口節點是一個模組化裝置，可以讓一個家庭能夠利用 PLT 數據機可將數位資料轉換成高頻的類比訊號，同時 PLT 數據機也被用來將無線電干擾放射降至最低而且能對電力線上普遍存在的雜訊干擾提供耐受性。

4. 高階架構：

在設計一套 PLT 資料網路必須涵蓋三個領域：

(1)系統位階架構(System Level Architecture)

(2)實體層元件(Physical layer Components)

(3) 網路層元件(Network layer Components)

(1)系統位階架構：此為一種標準網路設計，涉及如何處理有關應用、通訊條款、管理部份。

網路基本上分成兩部份，第一部份為將 PLT 網路連結至電業資料中心的資料網路。第二部份為舖設在配電網路上的 PLT 網路。

(2)實體層元件：連結至電業配電網路的實體裝置。此實體裝置包括 ISO 開放式系統界面(OSI)中的實體層與資料鏈結層兩個階層(physical layer, Data link layer)所需元件，這部份包括 PLT 數據機的功能說明。

(3)網路層元件：屬於 ISO 開放式系統界面 OSI 第三層 Network layer 的元件，包括佈署於現場的裝置可支援通訊條款的路由(routing)及交換，以及網路電話(VOIP)、隨選視訊(VOD)及企業內部網路的虛擬專用網路 VPN (Virtual privating network)。

此網路架構屬於企業版模式，此企業版模式(enterprise model)包括利用高速骨幹連結在一起的中央化的資料儲存、通訊條款及管理。連結至此網路的尚包括連結到用戶端的許多樹枝及分支(tree and branch)網路分段。連結至變電所的光纖網路類似於骨幹網路，而樹枝及分支網路則類似於配電網路。

當大都會的網路密度增加時，則此大都會網路的元件將變成可資利用的

元件而且將骨幹網路推近到住家。

5.系統位階架構

系統位階架構需考慮電業想要提供的服務與應用範圍，以及網路管理，通訊條款，各項服務的計費。

(1)網路設計：

網路的第二部份為鋪設在電業配電網路的 PLT 網路。PLT 網路包含許多中間網路裝置，在此稱之為節點(Node)。這些節點包括安裝在變電所的 S-Node，長距傳輸使用的訊號加強器的 R-Node，安裝在配電以及裝設在住戶內的入口節點(Gateway Node, GW-Node)。

(2)系統位階功能：

A. PLT 與其他高速通訊技術一樣，PLT 也需要使用路由器、交換器、及信號加強器(repeater)，依據頻寬(bandwidth)、用戶數及所提供服務項目數來決定網路的分段。

B.在 PLT 系統推動的整個過程中維持一定的規模度(Scalability)是一項重要的考量。當網路是第一次佈署而且用戶密度較低時，在電業配電網路的某些特定點採用橋狀網路分段也許是較合乎成本效益的。網路裝置可以策略性的安裝在參與 PLT 系統的用戶端。

由於維持用戶的頻寬需求，網路的分段是必要的，因此在某些節點將改變成交換或路由功能。有時為了維持用戶密度較高時的頻寬，額外增加注入點（Injection Point)可以採用。

有一些案例包括有聯合辦公大樓的橫向環境則需提供分段及隔離。

C. 網路監視：大部份的網路元件都是智慧型的。意即其可以支援網路的管理及其他的服務。這種支援能力能夠做到搜集資料速率與用戶數等統計資料的網路監視，以及特定的電業監視也可以被併入網路監視中。

D. 安全機制：由於網路是非常公開的，因此為了確保網路不被干擾或竊取(snooping),必須提供安全措施致使用戶能安心的進行每筆私人間交易，安全的考量在系統的每個階層都必須考慮到。

E. 計費架構：每一個用戶都能預訂一套所需的不同應用與服務項目，而服務項目的計費架構必須建立。計費架構可能參考使用量、頻寬、服務品質，以及預約的特別服務等因素來釐定。

F. 用戶端裝置識別：在用戶端的 CPE 偶合器裝置必須有其獨特的識別碼。這種獨特的識別碼是為了讓不同的服務供應商可以出入這個終端單元，無論網際網路通訊條款或電業服務皆可。

在多重端點的情況下，用戶及裝置皆需一套精巧的定址系統。在這個領域中應用的標準技術的加強正被評估中。

6.實體層元件：

實體層元件包括：(1)PLT 數據機 (2)耦合裝置或(3)線路調整器(line-conditioner)。

PLT 數據機負責調變機制用來將資料調變後傳送至電力線上，而且也提供實體層的錯誤校正與安全。

PLT 耦合器可將類比信號連接到配電線，而且保證不會危害到用戶的安全、電業員工及配電系統的運轉。

綫路調整器可加強或減弱信號的傳播來達到配電線的分段功能。在下圖中可以明確的瞭解此實體層元件與國際標準化組織 ISO (International Organization for Standardization) 開放式系統界面 OSI 相對應的第一層(Physical layer)與第二層(Data link layer)之間如合調合。

以上三個實體元件必須能在所有可預期到的大氣條件與極端氣候下運轉。

(1) PLT 數據機

PLT 數據機提供耦合器與第一層(實體層)及第二層(資料連結層)的界面，而且將資料連接到耦合器。

數據機執行在通訊媒體（此為電力線）上的資料通訊工作。現今的數據機有多種調變機制設計，而調變機制的評估是根據它們在雜訊環境下運轉的能

力、能否提供較高資料速率、及裝設的成本效益而定。

針對電力線廣泛量測後，Ambient 公司發現電力線對通訊信號展示出一種傳輸線的性質，因此容許通訊信號的傳播。由於電力線對來自於住戶及營業設備如微波烤箱、馬達及機器的雜訊是易於感受到，調變技術的選擇是重要的，如此才能使通訊信號在電力線傳播時能克服雜訊環境。

1.調變技術：目前常使用的調變技術有兩種：展頻技術(Spread Spectrum)與直交分頻多工技術 OFDM (Orthogonal Frequency Division Multiplexing)。這兩調變技術可防止干擾及提高通訊機密與可靠性，而且已被廣泛的使用在無線電網路上，無線電網路與在電力線上發現的問題類似，也就是寬帶訊(Wideband Noise)，干擾、多路徑(multi-path)反射、及大量用戶數等問題。

A.展頻調變技術：展頻是一種拓展頻帶的技術可將資料拓展在可用的頻帶區間。一種編碼序列被用來將資料展開在此頻帶區間，而接受器也被同步編碼用以在解除展頻過程中將調變資料復原。常用展頻技術有兩種：(I)直接訊號序列(Direct Sequence)、(II)頻率跳躍(Frequency Hopping)技術。

(I).直接訊號序列：將發射器傳送的窄頻帶之資訊載波利用一種擬隨機數(PRN, Pseudorandom number)脈衝序列加以調變。

PRN 的脈衝頻率(稱之為缺口速率 chip rate)遠高於資訊速率，這樣可將資訊信號拓展在一個較寬的頻帶區間。在接收器端，會產生一個複製的 PRN 用來將調變資料復原。

(II)頻率跳躍技術：窄頻帶系統的資訊載波會根據 PRN 序列產生器的輸出位元來跳躍。而跳躍的速率遠高於資料速率。這樣可致使載波信號看來像是一個較原有信號較寬頻帶的信號。接收器端再同步產生跳躍模型的相反模型來復原資料。

C.展頻技術的優點：

・不會有串音干擾(Cross-talk interference)：

由於調變系統是數位的，致使來自於靜態的擾亂與其他雜訊源產生的干擾較少，其他的訊號在此頻帶內被大幅衰減。

・對於多路徑反射的感受度較低。

・較安全：PRN 序列可以提供許多明顯的價值。

・可與其他訊號妥善共存。

・由於它在頻帶上的拓展可容許發射功率較高，致使載波信號的傳播較佳；減少信號加強器的需求。

D.直交分頻多工技術：OFDM

直交分頻多工技術 OFDM(Orthogonal Frequency Division Multiplexing)將訊息(message)拓展後可在一個大量的間隔緊密的載波上傳送。

載波之間距選擇為須使得相鄰的兩個載波成直交，由於只要載波之間成直交方向則兩個載波可以重疊，因此在解調變過程中載波之間不會看到對方而且也不會發生載波之間的串音(cross-talk)問題。至於多程路徑延遲干擾的問題可以增加一個中間符號(Inter-symbol)間隙來解決。任何載波調變技術皆可以使用，諸如直交調幅 OAM，移頻鍵控式 FSK，直交移相鍵控 QPSK 等調變技術。

(I)這種大量載波的調變與解調變過程是等同於不連續傅立葉轉換(Discrete Fourier Transform)的運算，因此己是很熟悉的技術。

每一個載波皆承載相同的資料量，資料是依序列的拓展在載波上。由於所使用的每一個頻率是窄頻帶，因此所有的資料訊號不需要像寬頻帶信號所需之一套複雜的等化(equalization)。調變技術可獲取高資料速率，而且可以針對不連續點阻抗不匹配造成的多重反射提供復原力。

(II)資料是以隨機方式傳送；隨機傳送可以產生寬頻帶的白色雜訊頻譜，它也展開在時間與不同的頻率而產生了各式各樣的訊號。

使用一種被稱為頻道估算(channel estimation)的調變過程可以提供解碼器(Decoder)有關信號頻道的資訊，諸如衰減與信號雜訊比(signal-to-noise ratio)。因此接收器可以提供信號補償來克服頻道的降級(degradation)。

(E)OFDM 的優點有四項：

(I).免除多重路徑延遲的干擾。

(II).窄頻干擾只會影響到少數的載波。

(III).對於隨機性雜訊與爆發性雜訊的良好排斥。

(IV).發射器與接收器的非對稱載波使用。

F.類比界面：

PLT 數據機與電力線之間的類比界面為耦合器。

數據機內的耦合器側界面則包括一個類比級的接收器放大器與驅動級。

接收器界面提供四個功能：線路界面，第一級放大等化，自動增益控制 AGC， 及限流。

驅動級界面提供信號的驅動及提供信號在配電線上傳輸的阻抗於穩定範定範圍內，信號阻抗範圍從 400ohm 到 25 ohm。

從類比輸入級輸入的類比信號經由 PLT 數據機內的 A/D 轉換器轉換成數位訊號。而 A/D 轉換器需要低雜訊放大與低雜訊電源如線性電源。D/A 轉換器則將數位資料信號轉換成類比信號再經輸出放大器傳送至耦合器。而數據機內的資料側則以數位信號處理器(DSP)執行資料緩衝來提供取樣信號之間的一個信號處理視窗。

G.數據機與資料鏈結層的界面:MAC 層界面。

MAC 層對於要傳送到實體層的資料提供分封緩衝器(packet buffer)。MAC 層界面提供頻道分配與媒體狀態的資訊。MAC 層也負責建立從實體層到大量遠端裝置的通訊，提供點對點(point-to-point)的隱秘、安全與頻寬。MAC 層提供界面有關頻道容量、終端用戶站數、線路信號雜訊比(Line SNR)、及其他通訊參數的統計。MAC 數據機層界面可做為監視網路運作的網路管理者。

(2)耦合器：

耦合器可將通訊信號注入至及接受自電業配電網路。耦合器必須能在一次配電線(中壓)及二次配電線(低壓)包括架空線及亭置式和地下電纜(非橡皮被覆電纜)上運轉。一個單一的 耦合器不能適用於所有選擇範圍，因此不同配電筏級會使用不同耦合裝置。

A.中壓耦合器—架空一次配電線

中壓耦合器用來提供 4 kv 到 35kv 級配電線的信號注入與接收，在設計時首先必須防止一次配電線對信號側的電壓閃絡。

中壓耦合器包含一個長漏電路徑的絕緣礙子(long leakage-path insulator)；直接安裝在中壓配電線上,與配電線的木契型礙子鄰近,在電線桿上則安裝有一台或好幾台配電變壓器。中壓耦合器可以直接勾掛在活線上，因此必須加裝保護及隔離裝置(如隔離變壓器 Insulation Transformer)。

中壓耦合器能夠連續承受線電壓及穩態電流和突波電流，而且在極端氣候及大氣環境下也必須能容忍高於線電壓的閃絡電壓。須用熔絲保護來防止過

高電壓及閃絡電壓。MV 耦合器採用被動型電感式耦合器(passive inductive coupler)的中壓耦合。

B.低壓耦合器：

低壓耦合器的設計為可安裝在配電變壓器二次側的低壓配電線或中性線上，適用於架空、亭置式或地下的配電變壓器。低壓耦合器適用電壓可至 600V 及電流 200A。

低壓耦合器由鐵磁心(Ferrite core)構成，有一個鉸鏈，可以用熱黏膠將它勾掛在變壓器的二次配電線上，低壓耦合器主要用在配電變壓器的低壓側，但也可以用在室內。

Ambient 公司使用的 CPE 低壓耦合器為數據機與實體界面的不可缺少的一部份，它提供電容性耦合(capacitive coupling)及變壓器的隔離，CPE 低壓耦合器也包含一個保護熔絲。

CPE 低壓耦合器可以併入界面配電盤(PCB)內，但基於安全考量它也單獨安裝在外面電源入口處。

(3) 線路調整裝置

A.線路調整裝置被安裝在中壓及低壓配電上作為電線業配電網路的分段，只針對通訊頻率的頻帶動作而不是針對電力頻率的頻帶動作。

線路調整裝置的功能是容許或排斥一個信號從這一端通過另一端，它

通常與配電裝置如電容器組接在一起，在某些情況下線路調本裝置與並聯電容器組必須接在一起以獲得想要的結果。

B.中壓並聯電容器(shunt capacitor)安裝在中壓

配電線與中性線之間，用來隔離中壓段，每一個中壓並聯電容器的設計由於電容器的成本考量而不可能函蓋所有電壓等級，所以針對某種電壓等級的配電線有許多不同的併聯電容器設計。

有些裝置如斷流開關(cut-out switch)，電壓調整器，復閉器，分段開關(sectionalizer)及熔絲對於中壓配電線上傳輸的通訊信號會造成相當的衰減。

因此加裝並聯電容器會提供一個射頻信號(RF)的路徑。作為通訊網路拓樸的部份,在通訊頻率的頻帶將兩個配電網路分段連結在一起是必須而且有利的，而利用一個串聯電容器與高阻抗裝置串接將提供這種路徑。

勾式(clamp-on)鐵磁心被放置在電業配電網路的中壓配電線上及低阻抗裝置上，鐵磁心會增加射頻(RF)頻率的阻抗，因此可以減少裝置對通訊信號的衰減。勾式鐵磁心被設計用來與配電變壓器及電容器組連結，這種結構致使這個裝置可用〞熱黏著〞(hot stick)工具勾在。

並聯電容器被設計成安裝在變壓器二次側低壓裝置，而對高頻提供一個短路路徑。如果信號被耦合到變壓器二次側（低壓）的中性線上則在每一相低壓線到中性線之間可以放置兩個並聯電容器。這種方式可以免除變壓器或串音(cross-talk)電客性的影響而提供較高程度的耦合。

7.網路層元件：資料網路交通指揮節點

在電業配電網路上舖設資料網路時，對於網路設備的配置,許多策略性的位置選擇是必須的。

每一個位置被命名為一個節點(Node)而且有其獨特的識別名稱：

(1).S-Node：設置在變電所端

(2).X-Node：設置在配電變壓器端。

(3).R-Node：設置在信號加強器(repeater)端。

(4).GW-Node：設置家庭入口(home-gateway)端。

這套網路系統設計支援家庭用戶一個入口終端服務(gateway terminating service)，這種方式可容許採用多種戶內網路(in-home network)的選擇，戶內網路包括無線電區域網絡、戶內插座 Homeplug(戶內配電線通訊 in-home PLT)，家庭電話線網路 Home PNA(Home Phoneline Networking Alliance)等戶內網路。

假設：所有網路節點的運作是假設服務條款、服務項目的計費、服務品質QO,S、及其他網路功能皆由資料中心提供。網路節點純粹用來支援第二層(資料鏈結層)與第三層(網路層)的運作與管理。

(1).變電所節點：S-Node

變電所節點需要連接到電業資料中心，可透過電業私有網路，服務供應商的競爭區域交換載波 CLEC (Competive Local Exchange Carrier)或電子郵件伺服器 POP，為了確保彈性，必須提供各種不同的廣域網路(WAN)界面，能夠依照用戶密度與所提供的服務項目決定其網路規模。

由於變電所內所有的多條配電饋線可以在變電所內一個地點就能安裝耦合裝置，因此變電所將是廣域網路連接的最佳地點，但是其他建築物也可能做為連接點，例如大公司的地下室、倉庫、私人建築物也可以做為ＷＡＮ的連接點。

在設計時應考慮到與廣域網路管線(WAN pipes)的多重連接、保護開關及熱機備份節點(redundancy node)，這樣才可以減輕單點故障造成系統停擺的危險，另外亦須提供自備電源(standby power)。

變電所節點必須也能夠提供多重的電力線界面（例如 PLT 數據機)給予變電所內的不同饋電線。若變電所內各台變壓器是分散各處，則需要一個分配系統。所有的設備皆是針對嚴酷的環境，包括惡劣的溫度、濕度、大氣、地震環境條件。以及在市電斷電時能提供蓄電池供電運轉。圖３為變電所節點

的連接圖，包括電業光纖骨幹，網際網路，公用電話網路及資料中心。

(2).變壓器節點： X-Node

變壓器節點可提供兩項功能：(1)中壓配電線到低壓配電線的橋接。(2)中壓配電線信號傳輸的加強器(repeater)。當用戶增加時，某些節點被設計為擴充至包含橋接、交換、及或路由功能以獲得較佳的分段交通效果。交通量大幅增加時需要路由器(router)及利用光纖網路佈署變電所節點更深入配電架構。如果需要額外的頻寬，在設計時亦可考慮使用光纖。在邏輯及經濟上的做法提供節點的升級是重要的。

變壓器節點是一個模組化構造的低成本裝置，它必須裝在一個適當的容器內，這個容器可以放在外面的環境而且可以看得到變壓器節點元件。變壓器節點的順應性測試(Conformance Testing)包括不同範圍的溫度、濕度、太陽照射影響，及大氣條件如標高及腐蝕成份。

圖 4 顯示變壓器節點(X-Node)，信號加強器節點(R-Node)及變電所節點(S-Node) 。

(3).信號加強器節點：Repeater Node (R-Node)

信號加強器節點是針對較長距離配電線或對信號有較大衰減的配電線而增設的節點，通常它與信號調整裝置接在一起。

(4).家庭入口節點： Gateway Node (GW-Node)

PLT 配電線載波通訊網路的終點站為用戶端的入口節點(Gateway Node)，它將提供 PLT 與低壓配電線的界面。入口節點是模組化構造,因而容許不同戶內服務項目的各種界面。

戶內服務項目包括一個資料網路如乙太網路(Ethernet)或通用串列匯流排 USB (Universal Serial Bus)及可支援網絡電話 VOIP 或筆記型影像電話 POTS 的語音網路。

電業提供的額外加值服務包括自動讀表(AMR)及需求面管理(DSM)也可以適用在此 PLT 系統。

入口節點的模組化特性將容許戶內網路(in-home networks)如無線電，室內

配電線載波通訊 in-home PLT (Homeplug)，或家庭電話網路 Home PNA (The Home Phoneline Networking Alliance 的簡稱)的合併使用。

圖五顯示變壓器節點與家庭入口節點(GW-Node)的配置。

二、出國公務過程

1、 90 年 7 月 17 日：行程（台北~溫哥華）

2、 90 年 7 月 18 日~19 日：參加國際電機電子工程學會 2001 年年會及發表論文。

3、 90 年 7 月 20 日~21 日：實習加拿大魁北克電力公司自動讀表與負載調查技術。

4、 90 年 7 月 22 日~26 日：實習紐約 Consolidated Edison 電力公司中低壓數位配電載波自動讀表系統開發技術。

5、 90 年 7 月 27 日~28 日：返程（紐約~台北）

貳、出國公務的心得與感想

一、台電發表之論文獲得此次 IEEE 夏季年會與會多家電力公司之迴響與重視:

1. 台電發表之論文針對本公司執行負載特性調查分析研究之結果，根據實際裝設電子式調查電表量測之區處及全系統之負載組成推估及不同類型用戶耗電量之溫度敏感度分析，探討溫度變化時對區處及全系統負載之變化量，可作為系統經濟調度與空調類負載管理潛力之評估。根據 89 年台電系統尖峰負載日(89 年 7 月 26 日下午 3 時尖峰負載 25,854 MW)的各類用戶分時負載組成推估結果及系統溫度敏感度分析結果，夏季尖峰負載日溫升 1℃可增加 593.6MW 系統負載，與系統實際負載變化量(調度發電資料)621MW 比較，推估誤差 27.4MW，也就是推估誤差為 4.4%，其中住宅用戶負載每升 1℃時負載變化量 293MW(為住宅用戶尖峰負載 7608MW 的 3.85%)，商業用戶負載溫升 1℃時負載變化量 271MW(為商業用戶尖峰負載 4990MW 的 5.4%)，而工業用戶負載則溫升 1℃負載變化量僅達 36MW(為工業用戶尖峰負載 12,760MW 的 0.28%)。

由於商業用戶白天使用空調比重較其他用戶高，溫度上升 1℃其負載增加 5.4%住宅用戶次之為 3.8%，而工業用戶除了電子業與冷凍業有較

明顯的溫度敏感度外，一般工業用戶之溫度敏感度在白天尖峰負載時段只有 0.05~0.1，以致工業用戶在尖峰時段溫升 1℃其負載僅增加 0.28%。推估結果全系統的溫度敏感度最大值發生在上午 12 時的 0·78 及下午 3 時的 0·79，而溫升 1℃對全系統的負載變化量增加 2·5%。

2· 論文發表完畢後，計有 BC Hydro 電力公司之 Y·Chang 先生就變電所負載受溫對如何提升負載特性之準確性提出建議，另外來自於南加州愛迪生(SCE)電力公司的工程師就如何藉由用戶之負載溫度敏感度評估溫度變化對系統尖峰負載之影響，深感興趣，此乃因為今年夏季加州因電源不足導致加州大規模輪流限模輪流限電之緣故，而其中空調等溫度敏感度較高之負載如何評估其對電力系統尖峰負載之影響，更受到加州電力公司的重視。

3. 此次就台電執行負載特性調查分析研究計畫所提出之系統負載溫度敏感度分析之論文已獲得參加此次 IEEE 夏季年會與會多家電力公司之迴響與重視

二、加拿大魁北克電力公司利用自動讀表系統提供用戶資訊服務及計費服務作法值得臺電借鏡:

Hydro-Quebec 電力公司從 2000 開始安裝 5000 戶自動讀表系統提供工商業用資訊服務與計費服務資料，包括用戶利用網際網路下載得到用戶本身的每日負載曲線資料，用戶也可自由選擇電表計費時間。

方便用戶依現金週轉流程選擇繳納電費日期。

而且利用自動讀表系統自動取得負載特性調查所需用戶用電資料，節省調查電表的用戶端安裝及人工讀表的費時費力，值得台電推動負載特性調查的參考。

三、紐約 Consolidated Edison 電力公司推動中低壓數位配電線自動讀表系統技術，提高電業多角化經營的競爭力。

1·PLT 與其他高速資料傳輸競爭技術的比較:

(1).數位用戶服務迴路 DSL：

數位用戶服務迴路(DSL, Digital Subscriber Line)目前的資料傳輸速度為用戶端下載速度可高達 8 Mbps 而指令上傳至前端系統的速度為 1 Mbps。

但是由於通訊線工廠及通訊裝置諸如分接頭(tap)致使大部份的用戶只能到達下載 1 Mbps 而上傳 128 kbps 的速度。而且很不幸的，DSL 有許多失策而提供了 PLT 推動的地圖來改善服務與安裝。除了用戶服務與安裝上的問題外,DSL 也有其他擔憂的事情，用戶必需在電話公司主機房 5.5 公里以內的距離，而且用戶與主機房間是點對點的連接，所以一次安裝成本是較高的，安裝時間較長，而且可利用率較稀少。電話公司需要投資增加以加強其網路，因為電話網路原本不是為高速資料而設計的。

相對的，電力線載波通訊技術(PLT)網路可以在大約一兩天內佈署整個住家地區,而且 PLT 可以直接連接到通訊骨幹不會造成瓶頸或大量投資需求。而且在屋內電話線插座通常只有一到三個,但是電源插座則每個房間都有。

(2).T1 幹線(T1 Trunks)

T1(1.544 Mbps)是一條數位電話幹線，通常是由電話公司提供給大公司機構電話服務使用。它提供了高速的雙向通訊。然而每月高達數百美元的高通信費率價格，一般家庭及小公司機構是不可能用 T1 幹線的。此外,T1 不是一個全系統的解決,而是孤立的安裝。

(3).衛星：

有些衛星可做為資料中繼站，有些被連接到網際網路骨幹來提供資料給用戶。而用戶需要去購置一個很大的碟形天線及微波收發器及特製的數據機。由於地面基地台的天線不能發射強訊號傳回到衛星上，因此從用戶端傳送資料到網站(Web)的速度只能 56 kbps 的低速，與一般電話撥話式數據機同樣低速。

(4).有線電視電纜數據機：Cable Modem

有線電視網路提供高帶寬單向的大量頻道給大量用戶。由於有線電視用戶與這麼大量的用戶共享有線電視電纜，因此即使有高達 36 Mbps 的資料傳輸速率，也不能保證很好的服務使用品質，由於從所有連線的用戶產生的雜訊累積在有線電視電纜線的累積總和雜訊，導致要利用有線電視纜線將用戶端資料回傳至網路是有困難。

有線電視公司必須大筆投資於提升其設備才能將用戶資料上傳，以及投資於都會以外地區的大量舖設電纜，達成資料雙向通訊。因此有線電視系統的資料服務僅適用於少部份的網路用戶。

相對地，PLT 利用住戶配電網的自然分段,將分享資料流道的用戶數保持在合理的限制內，一般在美國地區每條饋線供電給 50 戶到 200 個用戶，而且需要同時間下載大量檔案資料的用戶數可能非常少。Ambient 預期一般用戶可享用 1 到 10 Mbps 的資料速率。已足夠來通過用戶存取網站的最大可用資料速率。

此外，有線電視的屋內插座不像電源插座這麼多這麼方便，當資料用戶使用個人電腦、網際、網路電話(Internet telephone)及許多智慧型電器設備時，PLT 可以節省許多支出及避免有破壞性的重新配線。

(5).無線電區域迴路(Wireless Local loop)：

類似於行動電話的佈署，微波中繼站可以佈署在住家附近來提拱住家及商業用戶的網際網路資料的"Last-mile"出入。

行動電話被阻檔的通訊可靠度問題一樣可能影響此無線電區域迴路系統。這些問題包括在用戶與網路集線器(hub)之間需要很近的視線，在住宅密集區的多重信號反射，金屬建築材料對無線電阻檔的影響，樹葉的季節變化及暴雨對無線電傳輸品質的影響等問題。

其他先天的限制為共用無線電頻率範圍使可用的頻率帶寬降低，以及未取得管制許可及大幅更新設備前提供資料速度明顯升級的困難。所有其他的系統目前的受限因素為基礎構造、成本、普及率、速率及其他限制因素，但 PLT 卻沒有上述的限制因素等問題。

(6).光纖(Fiber optics)：

光纖網路提供不受雜訊干擾的高速資料連接。目前在大都會地區已有許多發展提供光纖連接或針對高密度的高速資料用戶提供光纖網路連接。光纖明顯的優點是寬頻網路，缺點是成本較高，許多人認為電業擁有更多的光纖及路權(Right of Way)後光纖可能是最終的網路需求，但是電業舖設 PLT 的密度增加後則邏輯的動向應是開始將光纖趕出去，因為電業本身擁有的配電網路是提供高速資料連結的最佳自有資源。

2・PLT 的優點：

(A).函蓋性(Coverage)：

電力網是世界各國最廣泛的全面性配線網路，連電話線的函蓋性也遠不如電力網。低壓配電線延伸到每一個房屋，因此 PLT 省去了昂貴的再配線成本。

(B)現代性：電力網在目前世界各地都是較其它有線通訊網路具有更大的現代性與較佳的維持率。

(C)簡單性：

電力線通訊 PLT 不會有電話傳統科技的困擾，諸如過時的路由器，橋接器，入口(Gateway)，交換器(Switch)及軟體造成傳統通訊的速度減低之困擾。

(D)電力線：

電力線最明顯的優點是所有配電線皆可當作 PLT 通訊線而不需像光纖網路的大規模基礎建設。

(E)另外，一些大氣條件變化及物理的障礙對無線電的防礙，電力線就沒有這些問題。

(F)另外電業提供的附加實用功能可以強化 PLT 的商業化。

參、對本公司之具體建議：

一、 PLT 在美國、日本及香港地區的推展情形：

(1).與美國紐約市 Consolidated Edison 電力公司（ConEd）的先導型計畫

(Pilot Project)：

Ambient 公司與紐約市 ConEd 電力公司於 2000 年 8 月 16 日簽訂一筆美金 200 萬美元的電力線通訊科技(PLT)先導型計畫：

初期在紐約皇后區的學習中心(ConEd Learning Center)的 50 呎長禮堂利用配電線路與 PLT 通訊技術進行點對點的高速網際網路與視訊會議資料傳輸測試。第一期計畫(Alpha-Testing)在 2000 年 11 月 20 日完成測試

第二期計畫：小規模的多點(Multi-point)測試計畫，針對 10 到 25 個住宅用戶，於 2001 年 5 月完成測試

第三期計畫(Beta-Testing)：大規模測試，從 100 個住宅用戶擴大到 1000 個用戶，於 2001 年 12 月完成。

第四期計畫：預計 2002 年夏季完成 PLT 的商業化，除了提供用戶端的網際網路、網路電話(VOIP)、隨選視訊(VOD)、智慧型電器及警告、監視、守門人(管理員)等用戶加值服務外，也將提供電業自動讀表、智慧型需求面管理(IDSM)，負載平衡，抑低尖載，警告監視，停電偵測回報等電業效率服務與利基產品。

(2).ConEd 電力公司成為 Ambient PLT 公司諮詢委員會(Advisory Board)的一席委員：

除了 ConEd 電力公司代表為諮詢委員外，另外前美國參議院能源委員會主席 J. Bennett Jonston 及前參議院 Rudy Boschewitz 國會議員也加入 Ambient 的諮詢委員會，另外美國其他電力公司也派代表加入。

(3).Ambient PLT 與日本最大的電線電纜製造廠 Sumitomo Electric Industies 公司於 2000 年 7 月 11 日簽訂意向書(Letter of Intent)在日本大阪進行 PLT 先導計畫；以及共同致力於研究 PLT 在日本高速資料市場的應用可行性。

SEI 電線電纜公司 2000 年的年收入為美金 123 億美元，SEI 在 2000 年 12 月 5 日至 12 月 6 日完成第一階段的聯合測試(Alpha Phase Joint

Testing)，在大阪電力公司進180個電表與PLT裝置連接的連線測試及120個電表的網際網路，視訊會議、隨選視訊等高速資料服務。

在日本大阪的PLT測試其連線距離為500呎較在紐約ConEd電力公司測試的50呎多了10倍距離，網路服務的測試距離為350呎也較ConEd的50呎測試多了7倍距離。

(4).2001年1月25日在香港進行八層樓公寓的PLT裝置與配電室及與第一層到第八層的每層連線測試。這項第一階段的點對點測試(沒有加入網路測試)將持續進行2至4個月。在2001年夏季將進行網路化多點測試(Networked Beta Testing)。

(5).2000年12月在底特律電力公司(Detroit Edison)完成第一階段點對點測試(Alpha Test)

(6).PLT在Alpha Test第一階段測試結果，PLT的產出資料速率(Throughput data rate) 達8 Mbps，而粗資料速率(raw data rate)超過25 Mbps。

二、建議：

1. 綜觀上述美國紐約Consolidated Edison電力公司及底特律Edison電力公司以及日本、香港地區發展配電線通訊技術利用電業擁有的全体用戶配電線路執行網際網路、網路電話、視訊服務及自動讀表等電力供應以外的用戶加值服務、對電力公司面對電業自由化的競爭環境提供了一項重大的利基、值得台電借鏡。

2. 建議台電加速研究中低壓配電線通訊技術的研究與應用，利用台電擁有全部用戶配電線的優勢開發未來網際網路與網路電話、視訊服務、自動讀表與智慧型需求面管理的寬頻服務市場、提升台電面臨自由化的競爭力。

ambient Corporation

Figure 1

Ambient PLT System Architecture

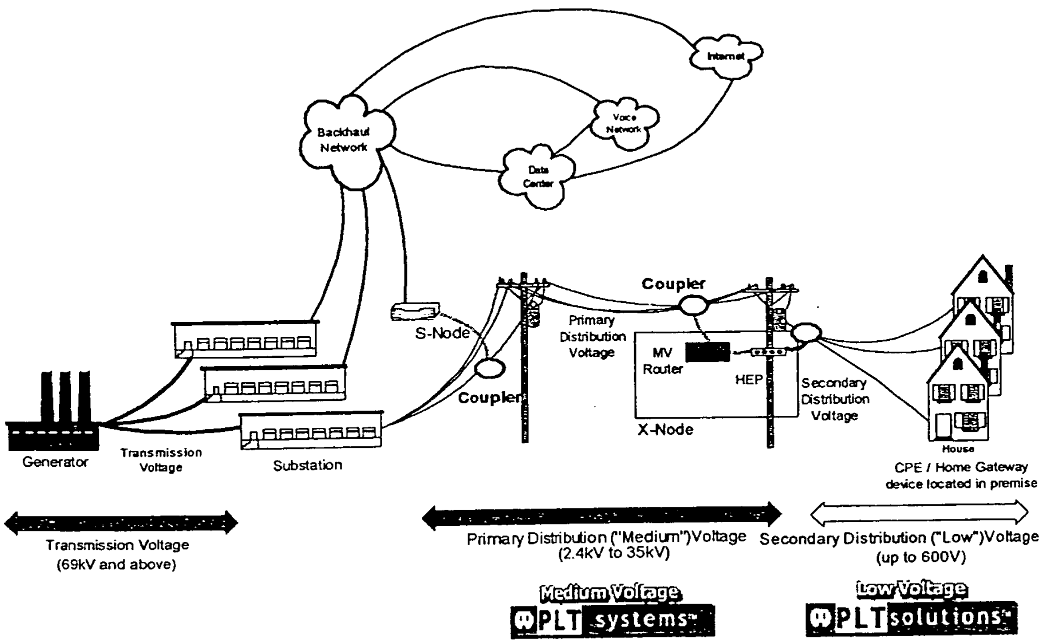


Figure 2

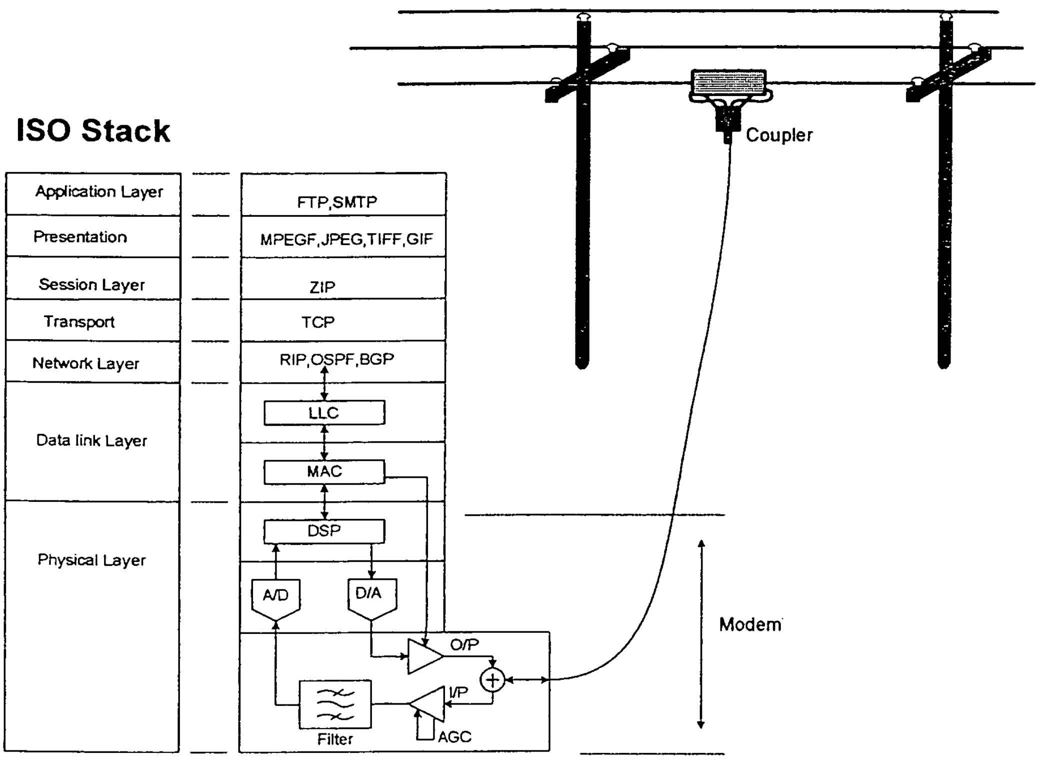
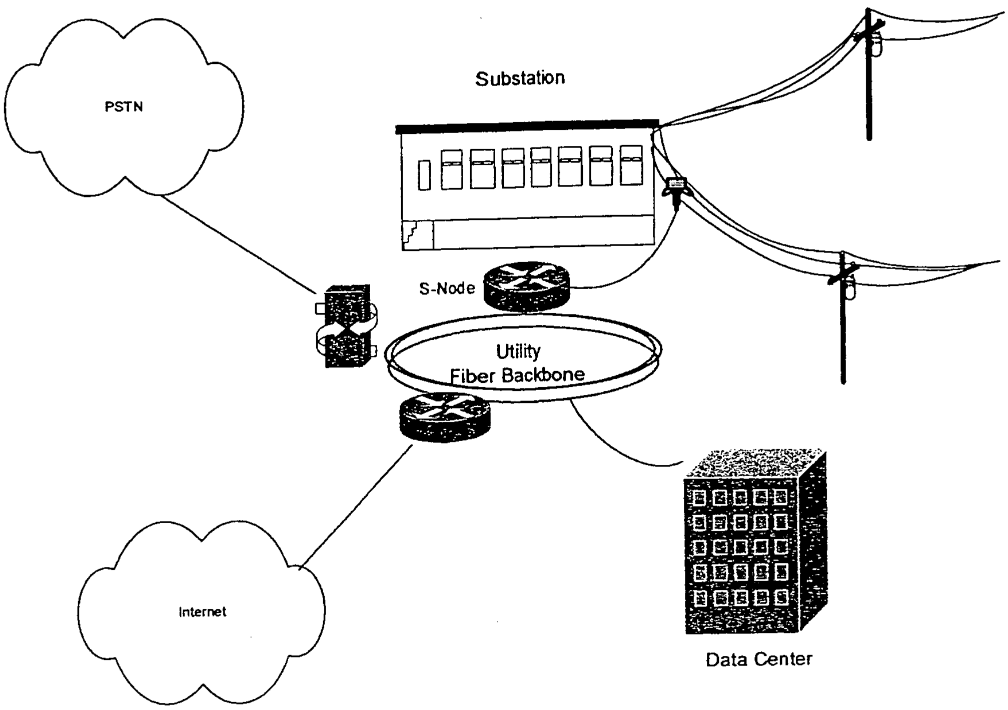

ISO Stack
Application Layer
Presentation
Session Layer
Transport
Network Layer
Data link Layer
Physical Layer
FTP,SMTP
MPEGF,JPEG,TIFF,GIF
ZIP
TCP
RIP,OSPF,BGP
LLC
MAC
DSP
A/D
D/A
O/P
I/P
Filter
AGC
Coupler
Modem

Figure 3



PSTN
Substation
S-Node
Utility
Fiber Backbone
Internet
Data Center

Figure 4 shows the S-Node, R-Node and X-Node.

Figure 4

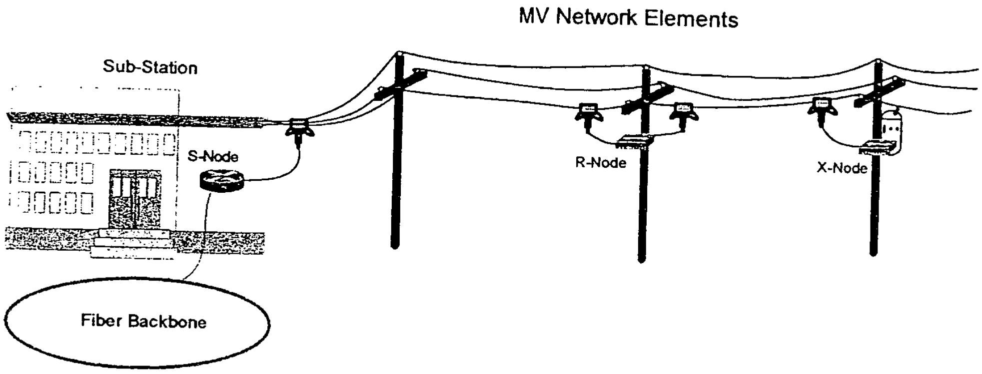
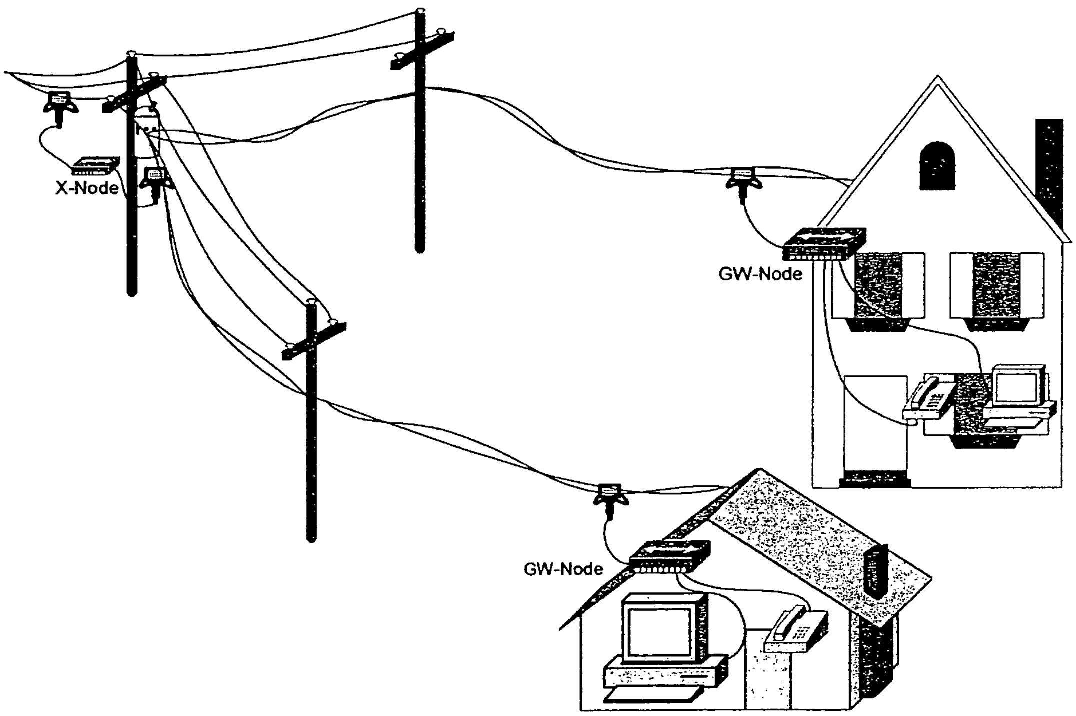


Figure 5 shows the X-Node and GW-Node

Figure 5

LV Network Elements



Temperature Sensitivity Analysis of System Power Profiles

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Abstract- This paper proposes a novel methodology to estimate the impact of temperature rise to the system power consumption. The load survey study is performed to derive the typical load patterns of the residential, commercial, and industrial customer respectively. By analyzing the relationship of customer power consumption and temperature, the temperature sensitivity of power consumption for each customer class is determined. By integrating the typical load patterns and total energy consumption, the daily power profiles and load composition of Taipower system has been obtained. With the load compositions and temperature sensitivities of all customer classes, the hourly increase of system power loading due to temperature rise is solved. According to the study, the peak loading of Taipower system will be increased by 585 MW or 2.4% of the system power demand for each 1℃ temperature rise. The actual Taipower system loading is used to verify the accuracy of the temperature sensitivity solved by the proposed method. It is concluded that the power increase due to temperature rise has been mainly contributed by the usage of air conditioners in the commercial and residential customers.

Keywords: load survey, power profile synthesis, typical load patterns, temperature sensitivity

I. INTRODUCTION

With the economic development and the increase of national GNP, more and more air conditioners are used in the commercial and residential sections. The air conditioning load has contributed more than 35% of the system peak loading in Taiwan Power Company (Taipower) to result in the deterioration of system loading factor during recent years. Many main transformers in the substations, which serve the urban areas, have become over loaded in summer. A single fault contingency in distribution system often causes serious outage problem for the service customers.

To enhance the operation of Taipower system with such a high percentage of air conditioners more effectively, a load survey study has been performed in Taipower since 1993. The power consumption of more than 968 customers over different service classes has been collected. By analyzing the power consumption of all test customers in the same class, the typical load patterns of each type of customers can be derived. The system load profiles and load composition are therefore derived according to the hourly load contribution of each customer class. To assess the impact of temperature change to the system power loading, the temperature sensitivity analysis of the power consumption is performed for each customer class by investigating the relationship of customer power consumption and temperature. Although the power consumption of air conditioners under different temperature conditions has been estimated by field test [1-4], it is still a tedious work to include the load models of end use components in the study for the system wise load study. By the field measurement of power consumption for the sample customers, the temperature sensitivity of each customer class can be evaluated more effectively by statistics methodology.

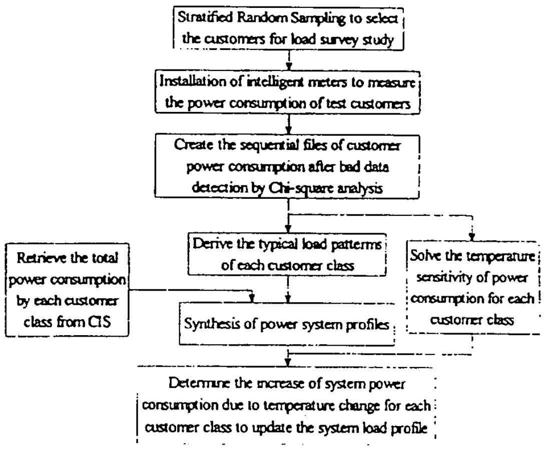

Fig. 1 Temperature sensitivity analysis of system power consumption

II. STRATIFIED RANDOM SAMPLING OF LOAD SURVEY STUDY [5-7]

For load survey, it is important to select the proper customer size for load study so that the typical load patterns derived can effectively represent the load behavior of the class. Since the customers within the same service class often illustrate more similar load characteristics, the stratified random sampling strategy is used in this paper to select the test customers for meter installation to record the power consumption. The total sampling size of the test customers is determined according to the pre-defined confidential level and the budget available for the load study. The total population size and variances of customer power consumption within each class are considered in (1) to determine the total sampling size of test customers. The total sampling size is then allocated to each class as defined by n_h in (2) according to the weighting factors, which are determined by the variance of power consumption and total customer number in the class.

$$n = \frac{\left(\sum_{h=1}^{H} N_h S_h\right)^2}{\left(B^2/4\right) + \sum_{h=1}^{H} N_h S_h^2} \tag{1}$$

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$$n_h = n\left(\frac{N_h S_h}{\sum_{i=1}^{H} N_i S_i}\right) \quad (2)$$

$$B = 2\sqrt{\frac{N-n}{N}}\left(\frac{S}{\sqrt{n}}\right) \quad (3)$$

where n: total sampling size of test customers
H: total customer classes
S_h, S_i: class variance of customer power consumption
N_h, N_i: total customer number of class h
B:sampling error bound with $(1-\alpha)$ confidential level

According to (2), more customers have to be selected for the class with larger variances of power consumption. On the other hand, only few customers are selected for the class with smaller variance of power consumption because of the consistency of power profiles among the customers. By this manner, the typical load patterns of all customer classes can be solved with the same level of accuracy. Table 1 shows the total customer number to be selected for load study in each customer class.

Table 1 Sample and population size of customer layers in Taipower district

layer	Customer class description	population size	sample size
1	residential(1-ϕ · 110V)	3,127,665	103
2	commercial(1-ϕ · 110V)	372,672	86
3	low voltage composite commercial (3-ϕ · 220V)	986	35
4	low voltage composite non commercial (3-ϕ · 220V)	441	16
5	low voltage industrial(3-ϕ · 220V)	72,018	109
6	high voltage composite commercial (3-ϕ · 11KV)	1,466	125
7	high voltage composite non commercial (3-ϕ · 11KV)	1,254	114
8	high voltage industrial(3-ϕ · 11KV)	4,779	306
9	extra high voltage industrial (3-ϕ · 69KV or 161KV)	147	74
sum		3,581,428	968

III. PROCESS OF CUSTOMER POWER CONSUMPTION DATA

In this study, 968 customers are selected by the above sampling method and the intelligent meters have been installed to measure the customer power consumption within every 15 minutes. The notebook PC is used to retrieve the customer power consumption once every 3 months. To prevent the analysis bias due to abnormal power consumption, the Chi-square test is performed on the customer power consumption to identify the existence of bad data in (4). Fig. 2a shows the original power consumption of a test customer and three data of abnormal power consumption are detected.

$$\text{Prob}(\chi^2_n \geq \chi^2_{n-1,\alpha}) = \alpha \quad (4)$$

where: $\chi^2_{n-1,\alpha}$ Threshold value of Chi-square distribution with α significance level

By substituting the bad data with the mean power consumption for the corresponding hours, the daily load profiles are modified as Fig. 2b. After performing the bad data detection, the sequential file of power consumption is then created for each test customer, which will be used for statistics analysis to derive the typical load patterns for the customer class.

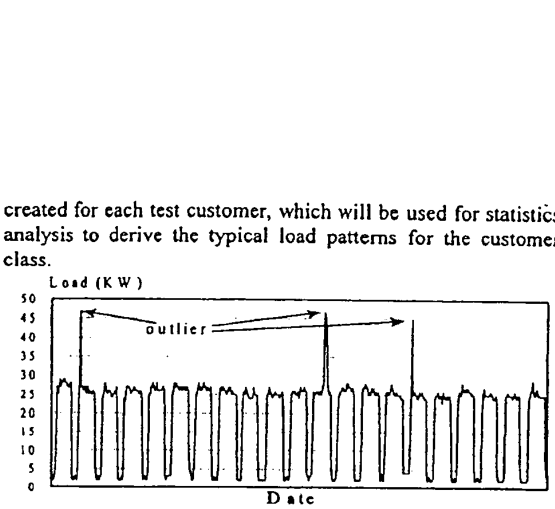

Fig. 2a The original daily power consumption of a test customer

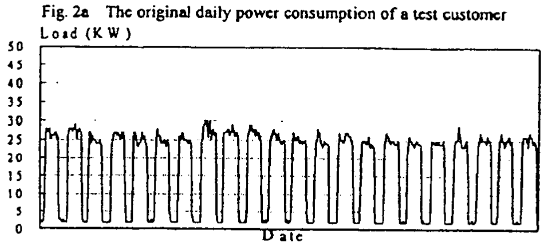

Fig. 2b The revised daily power consumption of a test customer

IV. TYPICAL LOAD PATTERNS OF CUSTOMER CLASSES

To develop the typical load patterns for different customer classes, the hourly power consumption of all customers within the same class are integrated to solve the mean value and standard deviation of customer power consumption by statistic analysis. The daily peak value is used as the base to normalize the hourly mean power consumption to derive the typical daily load patterns of the customer class during each study season.

Fig. 3 shows the typical load patterns of three customer classes during the summer season. It is found that the peak loading of residential customers occurs at 9 PM when people stay at home and use a lot of electric appliances such as air conditioners (A/C), lamps and TV sets, etc. For the commercial customers, the peak loading occurs during the business hours from 8 AM to 10 PM with high percentage of lighting loads and most of the A/C units are operated. For the industrial customers, the loading variation is relatively smaller as compared to the residential and commercial customers, because of the implementation of load management and time of use (TOU) rate.

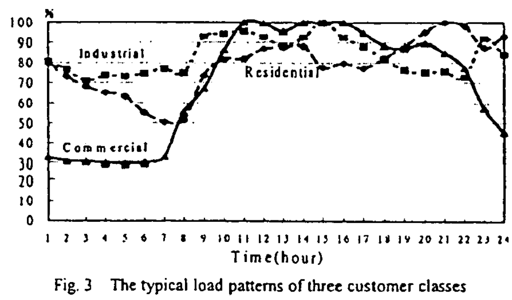

Fig. 3 The typical load patterns of three customer classes

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V. LOAD COMPOSITION

The load composition of a power system can be estimated by the typical load patterns derived and total energy consumption of all customers in the system. The monthly energy consumption of each customer can be obtained by retrieving the billing data from the customer information system (CIS) in Taipower. The total energy consumption of the residential, commercial, and industrial customers is calculated by summing up the energy consumption of all customers within the same class. According to the ratio of power consumption and number of the weekdays and weekends in a month, the total energy consumption by customer class i for all weekdays $E_{i,w}$ is determined. After allocating the total energy consumption to each hour according to the typical load pattern i in Fig. 3, the mean value of power consumption for customer class i at hour j is then derived as (5).

$$P_{i,j} = E_{i,w} + D_w * \frac{\tilde{P}_{i,j}}{\sum_{k=1}^{24} \tilde{P}_{i,k}} \quad (5)$$

Where D_w :total weekdays

$\tilde{P}_{i,j}$:typical load patterns of customer class i at hour j

By integrating the power consumption profiles of all customer classes, the system daily power profile and load composition can be obtained. Fig. 4 shows the synthesized daily power profile and load composition of Taipei district in Taipower for the summer season. It is found that both the residential and commercial customers contribute most of the power consumption while the industrial customers consume the least power in the service area. The district peak load demand is 2019 MW at 2 PM and the power demands of the commercial and residential customers are 1038 MW and 928 MW respectively. The daily power consumption is varied with the load behaviors of the service customers. Fig. 5 shows the synthesized daily power profiles and load composition of Kaohsiung district. With the development of the heavy industry in the service area, the industrial customers have consumed 50% of the total district power demand. The residential and commercial customers contribute 31% and 19% of the district power demand respectively. The peak load demand of the whole district is 1758 MW, which occurs at 3 PM. By comparing Fig. 4 and Fig. 5, it is found that the significant different daily power profiles have been illustrated because of the difference of load composition between Taipei and Kaohsiung districts. Besides, the power consumption by industrial customers remains very stable over the daily period, while the commercial class consumes most of the power during daytime period.

To verify the accuracy of the synthesized daily power profiles and load composition in this study, the actual power consumption of the Kaohsiung district has been recorded as shown by the solid line in Fig. 6. It is found that the average mismatch between the actual and synthesized load profile is 1.7%, which implies that the typical load patterns derived for customer classes can represent the system load behavior very accurately.

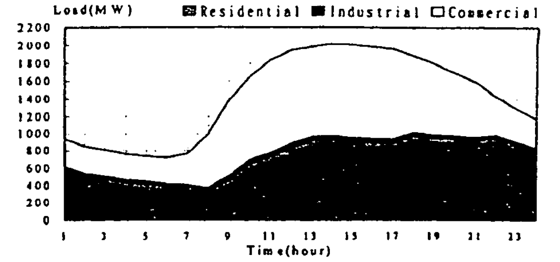

Fig. 4 Synthesized daily power profiles of Taipei district for the summer season

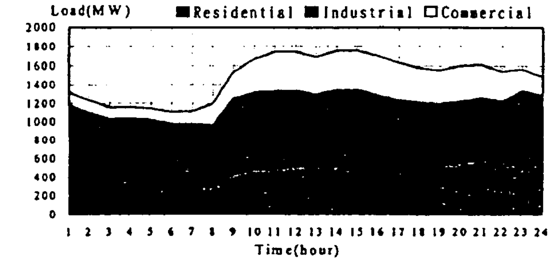

Fig. 5 Synthesized daily power profiles of Kaohsiung district for the summer season

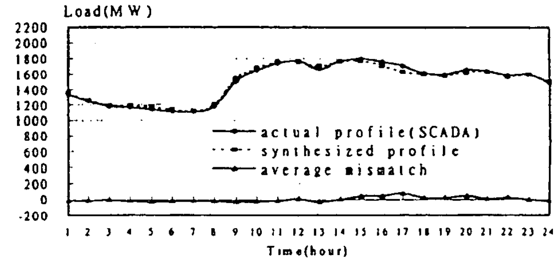

Fig. 6 Comparison of the actual and synthesized load curves (Kaohsiung district)

VI. TEMPERATURE SENSITIVITY OF POWER CONSUMPTION

Due to the usage of air conditioners in the commercial and residential customer classes, the temperature rise always introduces dramatic increase of system power demand in Taipower. The interruptible load control has been implemented to reduce the system peak loading during the summer season to prevent the shortage of system capacity reserve. It is important to investigate the temperature sensitivity of the power consumption for each customer class in Taipower system.

The Pearson product moment analysis [8] is applied in this study to find the relationship among the customer power consumption, temperature and humidity. The two tail t-test in (6) is then used to determine whether the relationship between the above variables has reached the significant level.

$$t = \frac{r\sqrt{k}}{1 - r^2} \quad (6)$$

where K is the degree of freedom and r is the correlation coefficient

Table 2 shows the correlation coefficients and t values of the actual Taipower system demand, temperature and humidity. In this paper, the significant threshold $t_{22,\ 0.025}$ is set as 2.074 with 95% confidential level. The correlation coefficient of power consumption and temperature is solved as 0.87 and the corresponding t value is 8.3, which is much larger than the predefined threshold value. This implies that the temperature change will have significant impact to the system power demand. The correlation coefficient of power consumption and humidity is –0.22 with t value as –1.07, which means that the variation of humidity will not cause too much change of power consumption.

Table 2 Correlation coefficients and t values of power consumption, temperature and humidity.

		Pn	Tn	Hn
Pn	r	1.00	0.87126	-0.22208
	t	∞	8.32598	-1.06833
Tn	r	0.87126	1.00	-0.4420
	t	8.32598	∞	-2.31118
Hn	r	-0.22208	-0.4420	1.00
	t	-1.06833	-2.31118	∞

By performing the statistic regression analysis [9] of the power consumption with respect to the temperature as shown in Fig. 7, the power consumption can therefore be represented by a polynomial function of temperature.

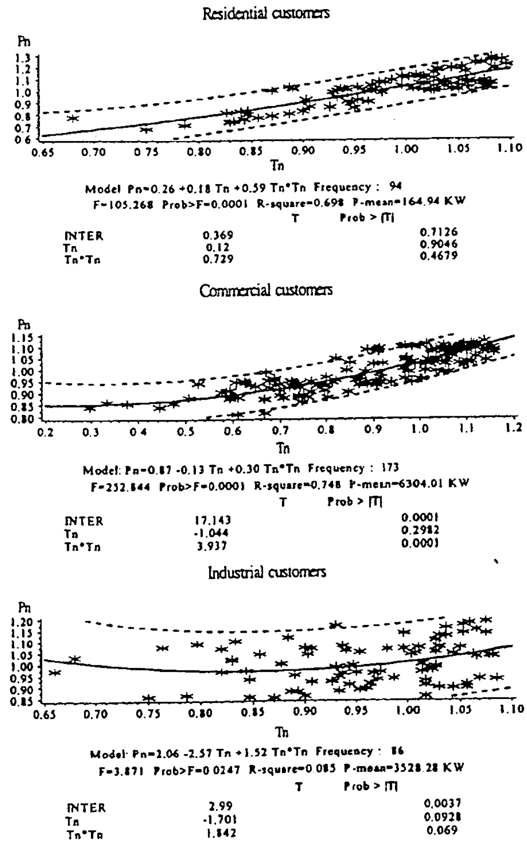

Fig.7 The statistic regression analysis of the power consumption with respect to the temperature

With large R^2 value and small 95% confidential interval, the power consumption of the residential and commercial customers can be expressed as quadratic functions of temperature in (7) and (8) respectively. On the other hand, the power consumption of the industrial customers is randomly distributed with temperature and less effect of temperature change to the power consumption is concluded in (9).

$$P_R = 0.26 + 0.18T_n + 0.59T_n^2 \quad (7)$$

$$P_C = 0.87 - 0.13T_n + 0.30T_n^2 \quad (8)$$

$$P_I = 2.06 - 2.57T_n + 1.52T_n^2 \quad (9)$$

After solving the power consumption as functions of temperature, the temperature sensitivity (TS) of power consumption, which is defined as the percentage change of power consumption for 1% temperature rise, can therefore be derived. By differentiating the power consumption with respect to temperature, the temperature sensitivities of power consumption for the residential, commercial, and industrial customers are obtained as follows.

$$TS_R = 0.18 + 1.18T_n \quad (10)$$

$$TS_C = 0.13 + 0.60T_n \quad (11)$$

$$TS_I = -2.57 + 3.04T_n \quad (12)$$

Fig. 8 shows the hourly temperature sensitivities of the power consumption for three customer classes. It is found that the average power consumption will be increased by 1.6% and 1.1% for the residential and commercial customers when the temperature rises by 1%. It is interesting to note that the largest TS of commercial customers occurs at 8 AM instead of 2 PM when temperature reaches the highest. With high temperature at 2 PM, the duty cycle of most A/C units will approach to 1.0. The temperature rise will not cause so much power consumption increase as compared to the low duty cycle at 8 AM when the commercial customers begin their business.

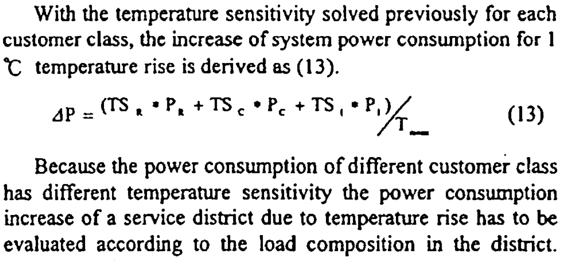

Fig. 8 Temperature sensitivity of power consumption for customer classes

With the temperature sensitivity solved previously for each customer class, the increase of system power consumption for 1 ℃ temperature rise is derived as (13).

$$\Delta P = (TS_R \bullet P_R + TS_C \bullet P_C + TS_I \bullet P_I) / T_{max} \quad (13)$$

Because the power consumption of different customer class has different temperature sensitivity the power consumption increase of a service district due to temperature rise has to be evaluated according to the load composition in the district. Fig. 9 and Fig. 10 show the variation of system power profiles for Taipei district and Kaohsiung district respectively when the temperature changes by ±2℃. With very high percentage of commercial loading, the power consumption of Taipei district will be increased by 175 MW for 2℃ temperature rise at 3 PM. For Kaohsiung district which serves high percentage of industrial customers with low TS, the power consumption increase for the same temperature rise is only 85 MW.

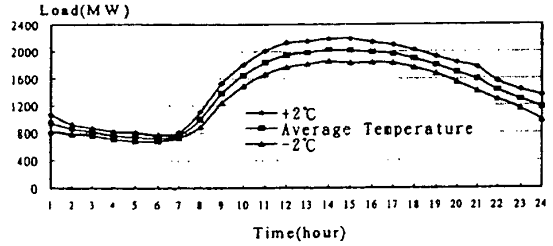

Fig. 9 The variation of power consumption with temperature change by ±2℃ for Taipei district

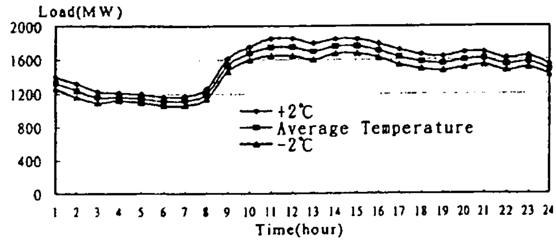

Fig. 10 The variation of power consumption with temperature change by ±2℃ for Kaohsiung district

According to the typical load patterns derived for each customer class and total energy consumption by all customers in the same class, the system load profile can be obtained by integrating the power profiles of all customer classes. Fig. 11 shows the synthesized power profile and load composition of Taipower system for July, 2000. The industrial customers consumed 53% of the total energy consumption while the residential and commercial customers consumed 31% and 16% of the total system load respectively. The peak loading of Taipower system is solved as 24765 MW at 3 PM.

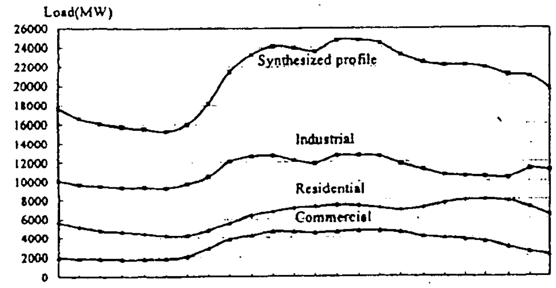

Fig. 11 The typical daily power profile and load composition of Taipower for July, 2000

After solving the typical power profiles and temperature sensitivity for each customer class, the increases of power consumption. For the residential, commercial, and industrial customers when the temperature rises by 2℃ has been solved as Fig. 12 The power consumption of residential customers is increased by 1346 MW at 10 PM when most of the A/C units are committed. During the daytime peak period, the power consumption of both commercial and residential customers is increased by 536 MW respectively. For the industrial customers, the impact of temperature rise to the power consumption is much less significant as compared to the other classes.

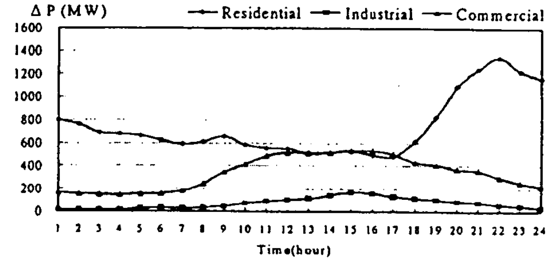

Fig. 12 The increase of power consumption by each customer class for 2℃ temperature rise

Fig. 13 shows the daily power profile and load composition of Taipower system with temperature rise by 2℃. The system peak loading at 3 PM is increased from 24827 MW to 25995 MW due to the temperature rise. The peak loading of residential customers is 9180 MW at 10 PM while the peak loading of commercial and industrial customers occurs at 3 PM with magnitudes of 5239 MW and 12910 MW respectively. By comparing Fig. 11 and Fig 13, it is found that very significant effect of temperature rise to the increase of power consumption for both commercial and residential customers.

In this paper, the actual system power consumption of Taipower is also used to perform the statistic analysis. The temperature sensitivity of system power consumption has been obtained and the increase of system peak loading for 2℃ temperature rise is solved as 1204 MW for July, 2000. By comparing to the power consumption increase of 1168MW solved for the same temperature rise in this study the mismatch is less than 3% and the accuracy of the proposed methodology has therefore been verified.

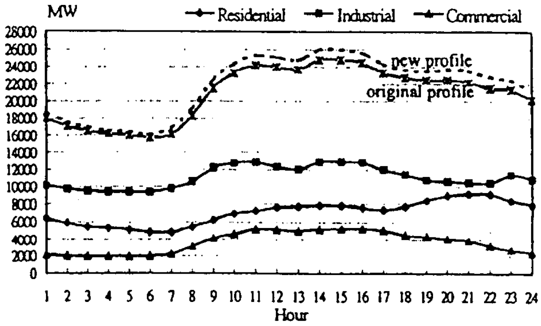

Fig. 13 The daily power profile and load composition of Taipower system with temperature rise 2℃.

VII. CONCLUSION

In this paper, a systematic approach has been proposed to solve the temperature effect to the system power consumption. By performing the load survey study, the typical load patterns of residential, commercial and industrial customers have been derived. According to the energy consumption of all customers, the hourly power demand of each customer class has been solved to determine the load composition and daily power profile of Taipower system. By statistic regression analysis, the temperature sensitivity of power consumption for each customer class is derived. The power consumption increase caused by temperature rise has been evaluated by the load composition and temperature sensitivity. It is found that Taipower system peak loading during summer season will be increased by 1168 MW when temperature rises by 2℃, which has been verified by the actual system power consumption. The system power loading increase is mainly contributed by the commercial and residential customers due to the usage of air conditioners. The system spinning reserve has been significantly deteriorated by the summer peak loading. To solve the problem, the load management of A/C cycling control for the commercial customers has been investigated by Taipower. This paper does provide a good reference for Taipower to determine the system load composition and identify the potential of system peak load reduction by air conditioner load management for each customer class.

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BIOGRAPHIES

C. S. Chen received the B.S. degree from National Taiwan University in 1976 and the M.S, Ph.D. degree in Electrical Engineering from the University of Texas at Arlington in 1981 and 1984 respectively. From 1984 to 1994 he was a professor of Electrical Engineering department at National Sun Yat-Sen University. Since 1994, he works as the deputy director general of Department of Kaohsiung Mass Rapid Transit. From Feb.1997 to July 1998, he was with the National Taiwan University of Science and Technology as a professor. From August 1998, he is with the National Sun Yat-Sen University as a full professor. His majors are computer control of power systems and distribution automation.

J. C. Wang received the B.S. degree in Electrical Engineering from National Taiwan University of Science in 1991 and 1993 and the M.S. degree in Electrical Engineering from National Cheng Kung University in 1993 and 1995 respectively. He has been a lecturer in Kao Yuan Inst. of Tech. and is working for his Ph.D. degree in National Sun Yat-Sen University. His research interest is in the area of load management and demand subscription service.

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C. W. Huang received the B.S degree in Electronic Engineering from National Taiwan Ocean University in 1972. He is a senior research engineer of Power Research Institute of Taipower and works as the project leader of the Taipower system load survey and the development of master plans for demand-side management and integrated resource planning.

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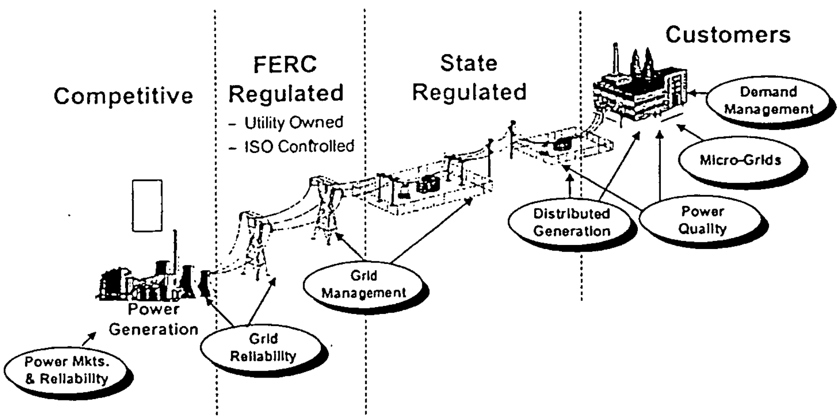

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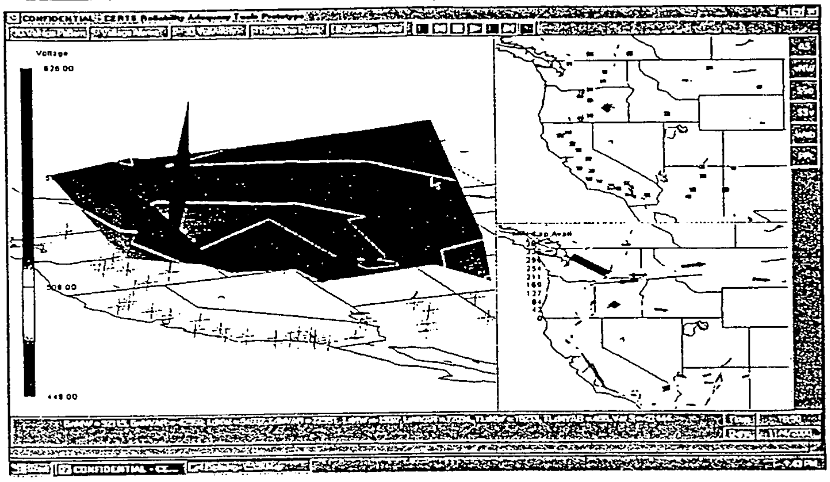

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- Market structure was a product of political consensus.

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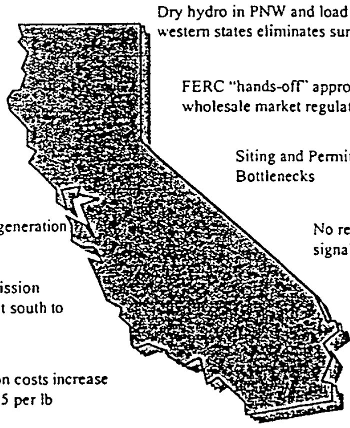

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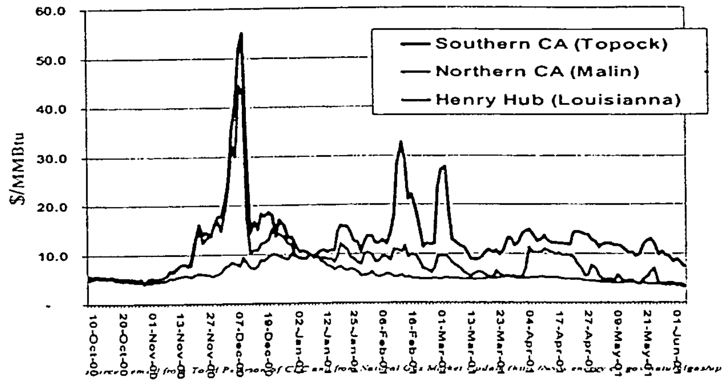
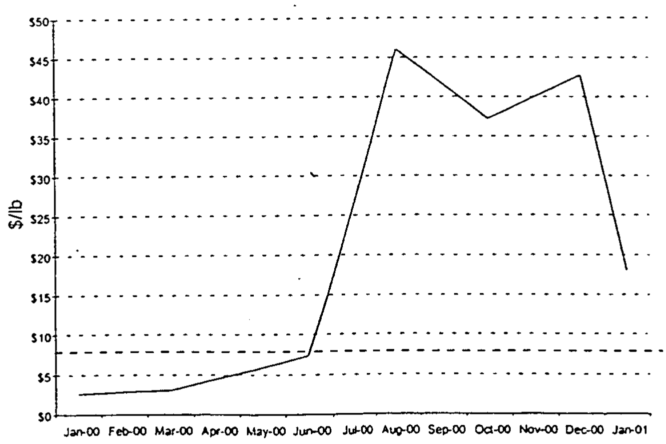


NO_X Emission Costs ($/lb)



June 2001

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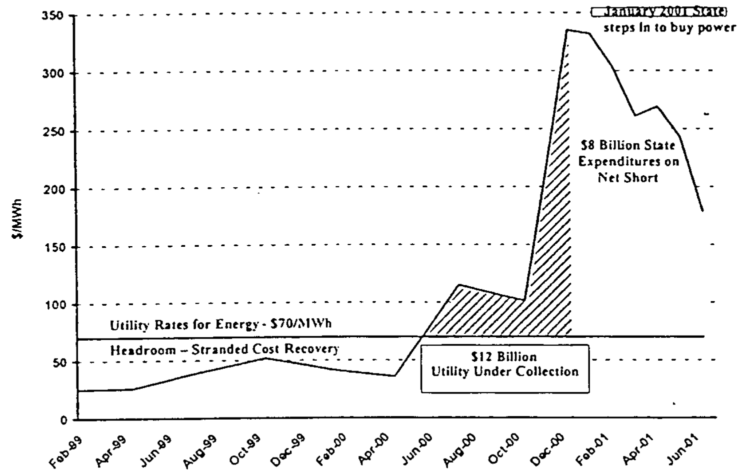
Source: CA-ISO

California's Spot Market Costs



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- Fuel Pipelines

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- Load as Reliability Resource

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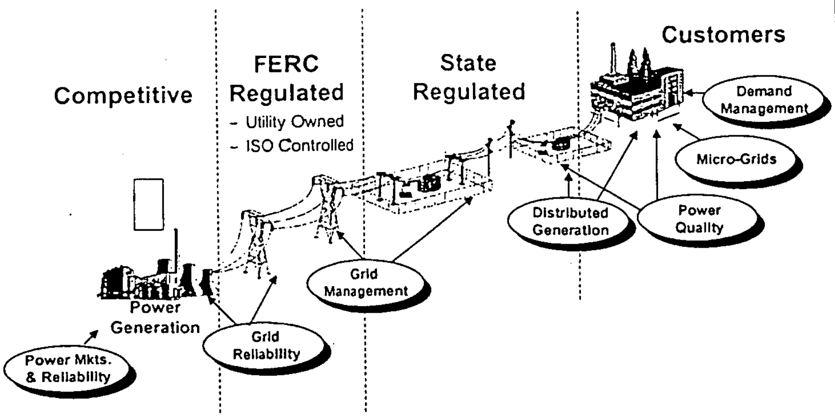

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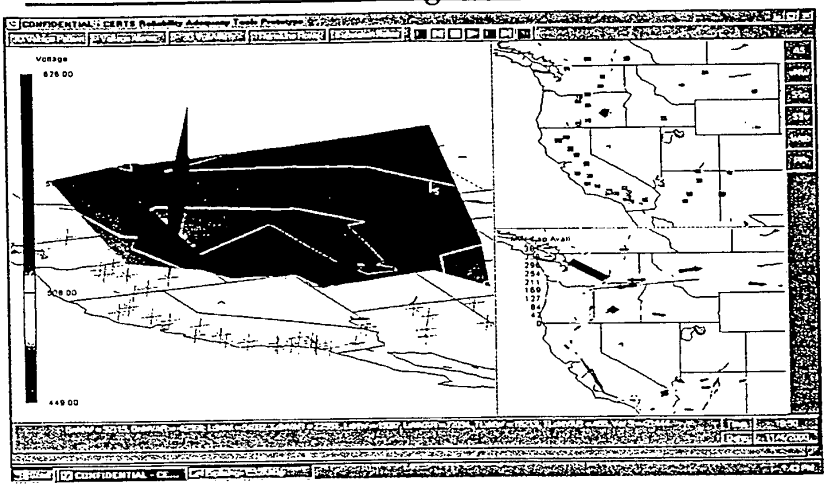

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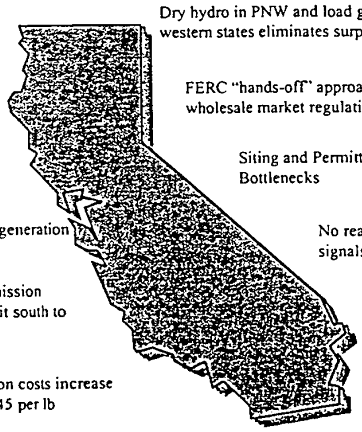

Dry hydro in PNW and load growth in western states eliminates surplus

Dysfunctional Market

FERC "hands-off" approach to wholesale market regulation

California reserve margins decline to single digits
-- no reserve responsibility

Siting and Permitting Bottlenecks

Reliance on Spot Markets
-- utilities required to sell generation
-- no forward contracts

No real-time price signals to customers

Path 15 Transmission bottlenecks limit south to north transfers

Spot market price of gas spikes above $60/MMBtu – 20-30 fold increase

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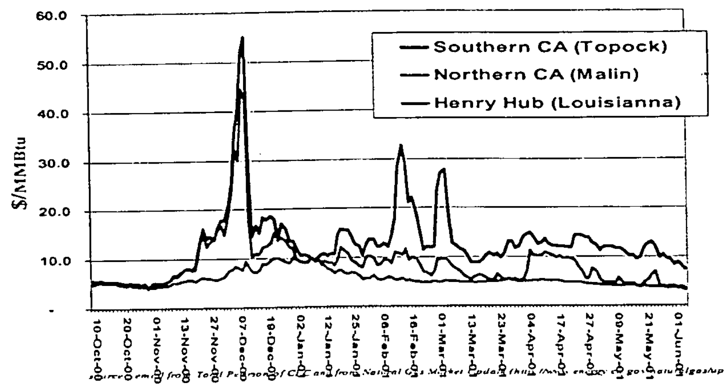

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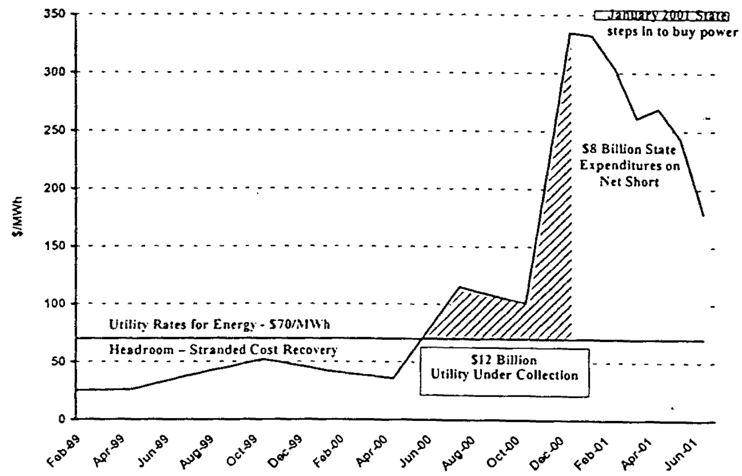

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