出國報告(出國類別：實習)

再生能源發電儲能系統
規劃管理技術

服務機關：台灣電力公司再生能源處

姓名職稱：莊鎮源，規劃專員

派赴國家：日本

出國期間：104.12.14~104.12.23

報告日期：105.3.1

內容

照片目錄

圖片目錄

表格目錄

一、 目的

由於化石能源不斷地隨開採日益耗竭，再生能源發電已是世界能源潮流所趨，但再生能源屬間歇性出力，其發電占比逐漸增加後，將造成電力系統不穩定，尤其應用在金門、馬祖等離島區域較為明顯，故補救之道可應用儲能設備。本公司對儲能系統規劃較無此經驗，故有必要赴先進國家了解目前再生能源儲能設備配合運轉情形，以做為離島小電力系統規劃和改善參考，並為大系統整合調度預做準備。

實施要領及要求成果：選派相關研究域同仁赴國外參加國際型會議與展覽，並前往具有專業技術、前瞻性產品之公司機構研習。研習之內容以符合本公司未來規畫項目為原則，以達成技術引進、學習新知及擴展研發智能之目標。本年度研究計畫目標，本次派員出國之成果至少包括：

(1) 赴住友電氣工業株式會社之橫濱製作所及全釩液流電池(Vanadium Redox Flow Battery, VRFB)實驗室，研習觀摩電網級全釩液流電池於再生能源貯電應用之設計、操作、維護及測試技術，並對與併網管理之演算、控制及相關之電能轉換技術進行資料收集，以作為後續規劃改善離島電力系統整體架構之參考基礎。

(2) 赴日本礙子(NGK)株式會社沖繩縣宮古島参訪當地智慧電網社區，及東京柏葉智能城市，研習鈉硫電池(NAS (Sodium Sulfur) Battery System)在微電網之應用技術，並針對鈉硫電池之系統設計、電能管理、示範運行成果進行資料蒐集，以期在未來有機會引進時，預先瞭解其運行基礎、系統架構之優劣及評估標準。

(3) 赴日本電氣(NEC)株式會社總公司參訪，及赴橫濱智能城市(Yokohama Smart City Project, YSCP)研習智慧儲能系統結合城市建設之系統管理，針對市電與太陽光電之發電系統、分散式電能系統管理技術進行資料蒐集，並探究在需量反應措施下，大型商場社區如何進行負載調節之電能管理技術。

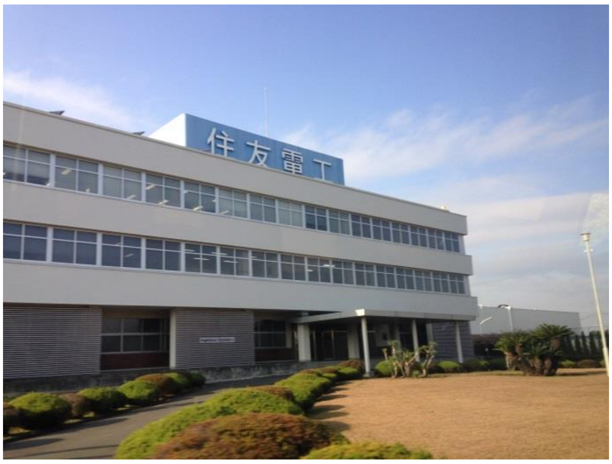
二、 行程與工作概要

日期	研習機構	研習內容
104.12.14	-	往程
104.12.15	住友電氣工業株式会社横濱製作所	前往住友電氣工業株式会社横濱製作所研習VRFB(全釩氧化還原液流電池)儲能與電能管理技術
104.12.16	日本礙子(NGK)株式會社沖繩縣宮古島智慧電網社區	赴NGK沖繩縣宮古島參訪智慧電網社區研習鈉硫電池及進行經驗交流討論
104.12.21	日本礙子(NGK)株式會社東京柏葉智能城市	赴NGK東京柏葉智能城市研習鈉硫電池暨經驗資訊交流
104.12.22	日本電氣(NEC)株式會社總公司及橫濱 Yokohama Smart City Project	赴NEC總公司參訪及赴橫濱 Yokohama Smart City Project 研習智能城市管理技術
104.12.23	-	返程(12/23 ~ 12/24 公畢後自費參觀)

三、 研習內容

3.1 住友電氣工業株式會社

當天行程先前往住友電氣工業株式會社位於橫濱的製作所(以下簡稱住友電工)研習，該製作所設立於 2012 年，為 5MWh 儲能系統之示範型運行中心(FEMS center)，並設置 100kWp 地面型之聚光型太陽光電系統及 4MW 的汽電共生系統，如照片 1、住友電工橫濱製作所及其聚光型太陽光電系統，現況正以大型設備工廠的角色參與明電舍株式會社(MEIDENSHA)主導之橫濱智能城市專案計畫，如圖 1、橫濱智能城市架構圖圖 1；該示範運行中心 (Factory Energy Management System center, FEMS center) 除監控調配數種電力來源(含柴油機組、太陽光電系統、儲能系統及市電)，以供應廠內用電外，亦搭配廠內負載調配之需量反應技術，及針對工廠內日常所需的電力供需，以不間斷供電暨維護電力穩定之前提下，達到各種目標最佳化(如成本最佳化、孤島運行模式、符合電力契約容量等目標)的演算技術。



照片 1、住友電工橫濱製作所及其聚光型太陽光電系統

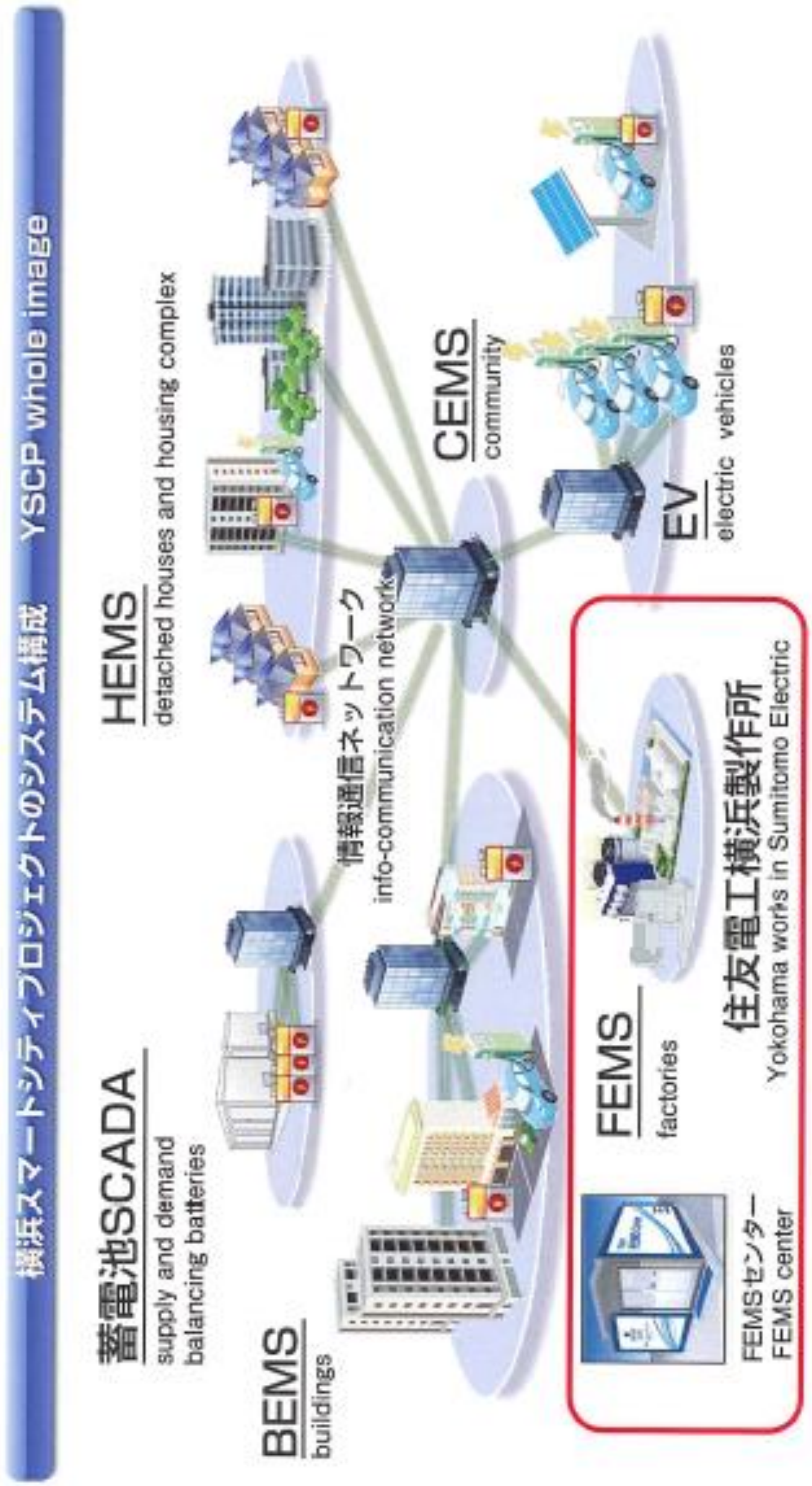


圖 1、橫濱智能城市架構圖

(資料來源:本報告附錄之住友電工相關資料)

3.1.1 VRFB 電池簡介

全釩氧化還原液流電池(Vanadium Redox Flow Battery, 以下簡稱為VRFB 電池)，是一種利用液態釩在不同化學勢能價態型態下，可經由氧化還原簡單作用充放電，亦可利用不同化學勢能保存能量的蓄電池，其工作狀態如圖 2。基本來說，VRFB 電池可以簡單地使用堅固安全的電解液儲存槽，經由控制泵(pump)抽取儲存槽中內部的全釩電解液至外部的質子交換膜進行氧化還原反應，因此若無限建置多數儲存槽，VRFB 電池幾乎可以提供無限的電池容量，而反應過後的電解液則存放至另外一個儲存槽中，待下次充電時再經由控制泵抽取至外部的質子交換膜，進行氧化反應，若沒有充電亦可安全穩定地長時間置放電解液儲存槽內，VRFB 電池的主要優缺點分析詳如表 1。而若是無外部電源可為 VRFB 電池充電，則可將整個儲存槽中的電解液置換為新的，則可以立即供電，故亦可當作電力系統崩潰時(如馬祖、金門、綠島地區等孤島電力系統)，全黑啟動的備用電源之一。

另外值得一提的是，VRFB 電池與一般電池不同，其可輸出最大功率與可儲存能量沒有直接關係，換句話說，VRFB 電池可輸出最大功率是依照控制泵的抽取速度、質子交換膜的接觸面積及電解液的液體傳輸管徑大小決定，而可儲存能量則是依照電解液儲存槽的容量大小決定。

照片 2、位於橫濱製作所的 VFRB 電池示範系統

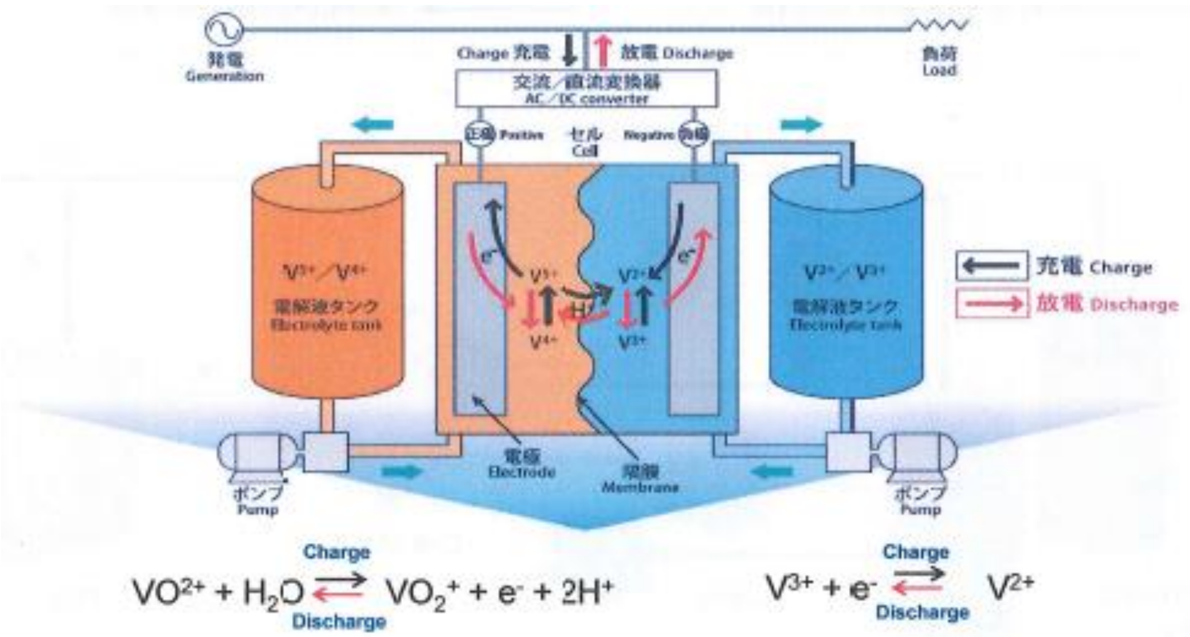


圖 2、全釩氧化還原液流電池(VRFB)工作示意圖

(資料來源:本報告附錄之住友電工相關資料)

表 1、全釩氧化還原液流電池(VRFB)優缺點分析表

優點	缺點	備註
1.擁有長期壽命	1.單位能量體積大	經洽其質子交換膜約可使用 17~20 年,其他設備如電解液儲存槽,若無受損則可繼續沿用。
2.安全性極佳	2.造價成本較為高昂	經洽其 SOC[1]可經由測試電解液之酸鹼度得知,故準確度高,亦可保障其安全性。
3.電力供給響應速度快	3.電解液中若混入其他液體將造成不可逆的嚴重損害	經洽橫濱製作所示範型單儲存槽規格為 35kW,電壓為 100 ~ 150V,最大放電電流為 600A,儲存槽容量可依需求客製化。
4.充放電循環次數可擴充	-	經洽若設備接近使用年限,電解液效率約仍

[1] SOC 為 State of Charge 之縮寫,係為電池架構中用來檢測電池儲存能量的重要指標之一。

		可維持 70~80%，只需更換質子交換膜即可。
5.溫度工作範圍大	-	可在室溫下操作，不需特別加溫或降溫。
6.可依需求客製化	-	經洽其可輸出最大功率與可儲存能量皆可分別依客戶需求設計。

3.1.2 VRFB 電池儲能系統與電能管理

此次來到 2014 年住友電工位於橫濱建置完成的電池製作所，據悉該製作所為是國際上重要的 VRFB 電池儲能示範系統，該示範系統結合製作所內的 100kWp 集中型地面太陽光電系統、4MW 的汽電共生系統及 5MWh 的 VRFB 電池儲能示範系統，如圖 3，針對製作所的電力調控，並擁有數種不同的調控模式，且已擁有實際一年的運轉維護經驗上，可對本公司未來規劃離島配置整合再生能源發電系統有很大的幫助；本公司綜合研究所及再生能源處也多次派人前往觀摩，故這次出訪得以一睹風采實屬幸運。

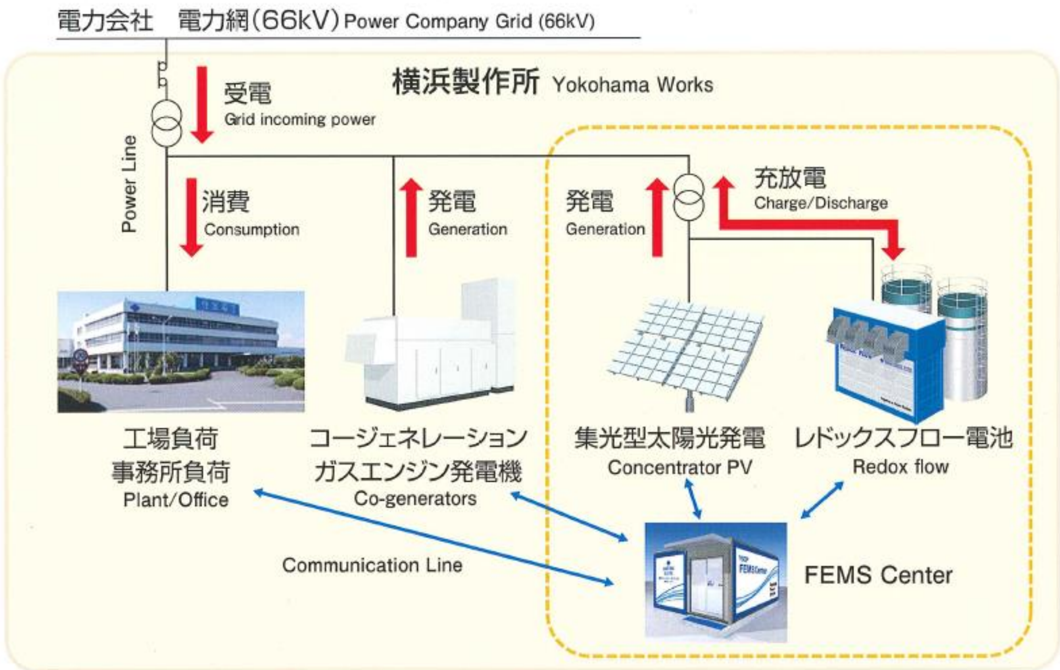


圖 3、橫濱製作所內 FEMS 系統架構圖
(資料來源:本報告附錄之住友電工相關資料)

該 VRFB 電池儲能示範系統展示中心及系統架構圖，如照片 3 及圖 4，擁有數種不同的調控模式，如(1)成本最佳化、(2)孤島運行模式、(3)符合電力契約容量、(4)孤島模式、(5)輸出平滑化等模式，意即在不同電價時段或目的下，應用上述的不同調控模式，能針對負載平滑化(Load Peak shaving)，並即時量測市電端的電壓、電流及頻率等資訊，以決定儲能設備的輸出功率，故可應用於加強再生能源發電系統的輸出平穩化，另外亦可與外界調度中心配合運作，如 SCADA 等所發出的指令來執行。

照片 3、VRFB 電池儲能示範系統展示中心(FEMS center)

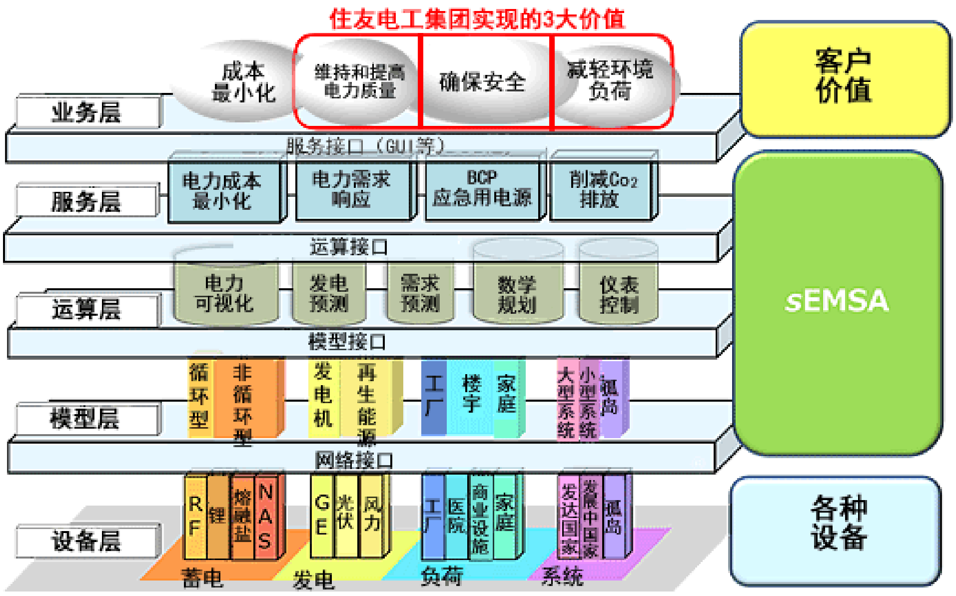


圖 4、sEMSA(Sumitomo Energy Management System Architecture)系統架構

(資料來源: http://global-sei.cn/company/press/2015/01/prs002_s.html)

3.2 日本礙子(NGK)株式會社

當天行程前往日本礙子株式會社(以下簡稱 NGK)位於沖繩縣宮古島設置的智慧電網社區，經洽宮古島總人口數約 55,000 人，總面積為約 205 平方公里，主要產業為農業、漁業及觀光業，年平均氣溫約 23.8 度 C，可謂氣候宜人，亦為日本國內著名的旅遊觀光勝地；島上設有兩座柴油發電廠，分別是 19,000kW 的宮古發電所及 70,000kW 的宮古第二發電所，總裝置容量為 89,000kW，並設有 1 座 600kW 示範型風力發電機組及 4 座 900kW 風力發電機組，地理位置如圖 5。另外，NGK 在 2009 年時運用日本當年度的經濟產業省「平成21年度離島獨立型系統新創導入實證事業費補助金」，建置完成智慧電網示範社區，包括 4,000kWp 太陽光電系統及 28,800kWh 鈉硫電池(NaS)儲能系統，島上配置如圖 6。此示範社區為國際知名的離島智慧電網專案計畫，並已有多年的實際運轉維護經驗，非常值得一看。

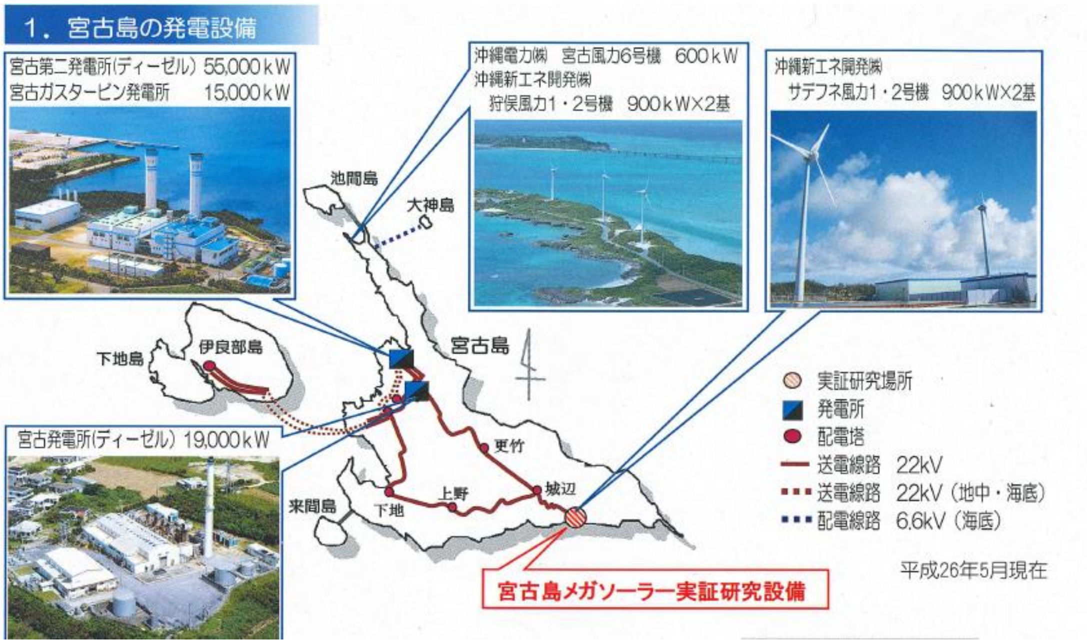


圖 5、宮古島電力系統配置圖

(資料來源:本報告附錄之 NGK 相關資料)

圖 6、宮古島智慧電網示範系統
(資料來源:<u>本報告附錄之 NGK 相關資料</u>)

另外隔天前往 NGK 於東京近郊的千葉縣柏葉車站，與三井不動產合作設置的柏葉智能城市專案計畫參訪，該智能城市為三井不動產與千葉縣政府合作開始的城市再造專案計畫，由 2000 年東京大學開始在柏葉設立校區開始，以「官、產、學」三方合作，作為下一代城市轉變為一座進行各項學術性實驗的先進都市示範型專案計畫，歷經建置各項健康領域科學中心、都市設計中心、電動車停車場及智慧能源調控中心等，並設有 250kWh 的 NaS 電池儲能系統及 720kWp 的屋頂型太陽光電系統，如圖 8，迄至 2014 年 4 月計畫主體的柏葉 GATE SQUARE 完成後，整體計畫終告完成，柏葉智能城市架構如圖 8。

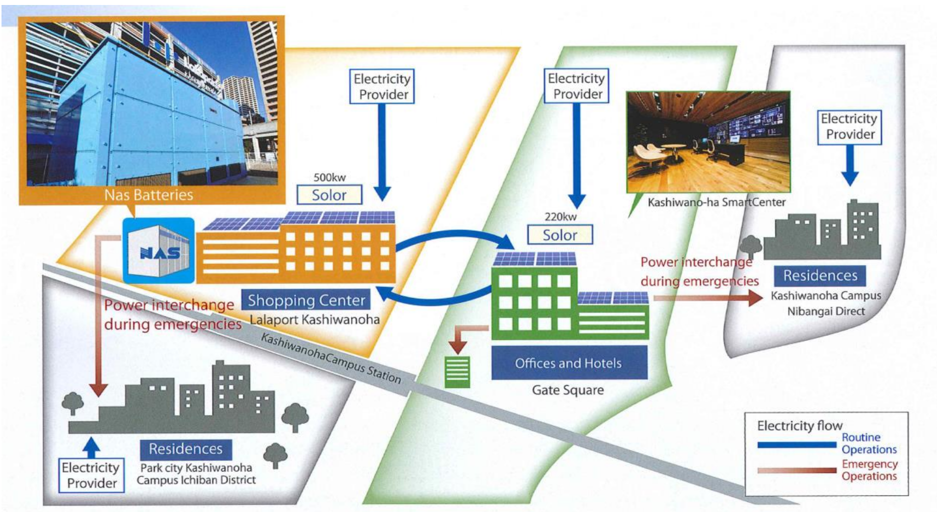


圖 7、NaS 電池在柏葉智能城市中的應用範圍
(資料來源:<u>本報告附錄之 NGK 相關資料</u>)

圖 8、柏葉智能城市架構圖

(資料來源:本報告附錄之 NGK 相關資料)

3.2.1 NaS 電池簡介

鈉硫電池(NaS Battery，以下簡稱為 NaS 電池)是美國福特公司率先於 1967 年發明，優點是能量體積密度比高，並擁有大電流大功率充放電的特性，惟其缺點為需要在高溫的工作環境(約 300 度 C)下運作，其後經過日本東京電力公司與日本礙子株式會社(NGK)合作開發作為電力儲能系統的重要元件之一，可應用於 UPS 不斷電系統，供應緊急備用電源，並可擴充至大型電力系統，負責中調節負載維持供需平衡。

NaS 電池工作原理與傳統儲能鋰電池並無太大差異，其陽極與陰極材料分別為固態的鈉及硫，並經由 β-氧化鋁陶瓷作電解質，以氧化還原反應進行充放電，其運作原理如圖 9。

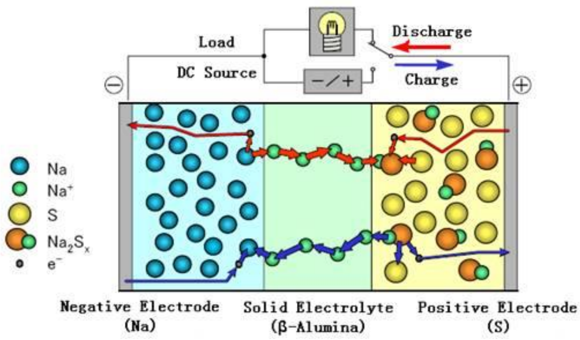


圖 9、鈉硫電池運作原理圖

(資料來源: http://www.cgcpower.com/266.html)

表 2、NaS 電池優缺點分析表

優點	缺點	備註
1.擁有長期壽命	1.單位能量體積大	經洽約可使用 10~15 年，若屆齡則須將電池芯組更換。
2.高充放電率、無自放電率	2.造價成本較為高昂	經洽因其陽極與陰極材料(鈉與硫)未運作時保持在固態結構，需加熱後轉為液態才可進行充放電，故無自放電率，保存期限長。最大放電電流約為 $2k\sim3kA/m^2$，瞬間放電電流可達 3C[2]。
3.電力供給響應速度快	3.須保持在高溫運作	經洽須保持在約 300 度 C 左右溫度運作，高溫容易引起金屬結構等在陰極材料硫化物影響下的劣化。
4.可依需求客製化	4.安全性較低	經洽其可輸出最大功率與可儲存能量皆可分別依客戶需求設計。

3.2.2 NaS 電池儲能系統與電能管理

NaS 電池擁有著高能量密度及可允許高充放電流的特性，但由於需要熱解其中的陽極與陰極材料(鈉與硫)，使其保持在高溫液態下始能開始運作，故在整體系統中，空調也是一個需要考量的因素，並在電池架構中增設加溫器，在這次參訪當中，宮古島的 NaS 電池儲能系統皆建置於室內，經洽是考量到海島氣候，必須針對鹽害、颱風、劇烈的高低溫差等施作預防措施，故建置於鋼筋混泥土結構的室內是比較安全的做法，如照片 4 及照片 5。

[2] Current，簡稱為 C：在電池架構中代表電池的額定放電電流，如 2000kAh 容量的電池，1C 的放電電流為 2000kA，2C 的放電電流為 4000kA，以此類推。

照片 4、沖繩宮古島的 NaS 電池儲能系統

照片 5、沖繩宮古島的 NaS 電池儲能系統單櫃規格

宮古島的智慧電能控制中心，主要針對當地的電網頻率調控，考量當地主要產業為農業、漁業及觀光業，並無大型工廠等負載，最高約為 55,000kW，故主要以儲存太陽光電的電能與其輸出平滑化，及穩定電網頻率(當地電網頻率為 60Hz)為主，並在白天用電較少的離峰時段，將太陽光電系統電能儲存，轉作至晚上家庭用電尖峰時段供電，如圖 10。

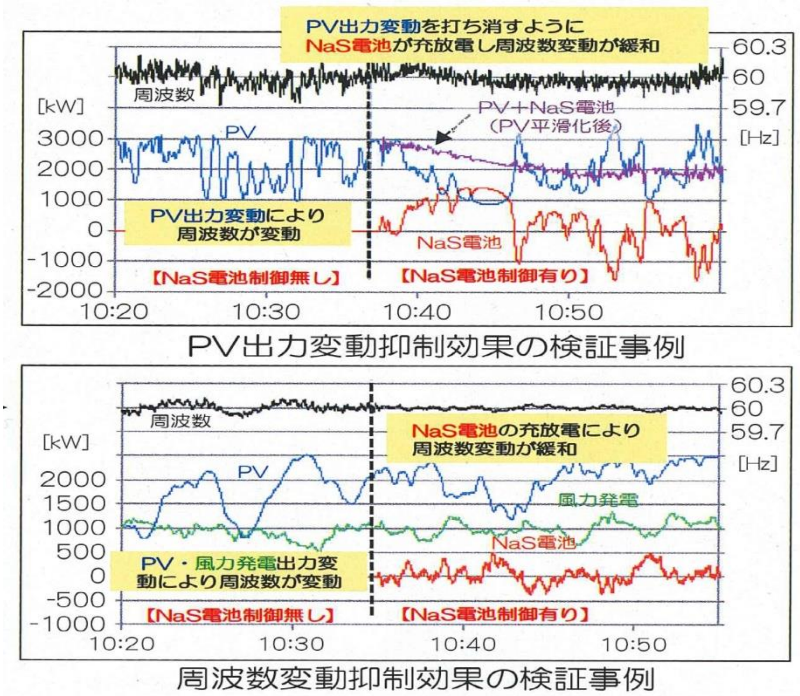


圖 10、宮古島 NaS 電池儲能系統控制計畫
(資料來源:本報告附錄之 NGK 相關資料)

另外在柏葉智能城市專案計畫中，NaS 電池儲能系統的智慧電能控制中心(主要由三井不動產公司管理)主要針對柏葉智能城市內的能源運作調節，並同時監控區域內的住宅、店家及商辦等設施的用電情形，以提供更節能的生活方式，如：經洽柏葉智能城市內同時有商辦區及住宅區，故根據假日與工作日人們生活型態的不同，共享彼此儲存的電能，意即在工作日時住宅區將多餘電力傳輸至商辦區，假日時則相反；另外在區域內發生災害時，亦能針對能源進行控制管理，重新進行電力調節，依重要優先次序卸掉負載以保持電網穩定。智慧電能控制中心如照片 6。

另外，值得一提的是，該棟大樓為減少能源消耗，平常白天時的照明燈源為戶外日光，並使用光纖引導至室內，不須採用電氣日光燈，除了可提供足夠的照明外，亦可用來栽植室內盆栽，如照片 7，就本次參訪經驗，當天天氣為陰天，室內光源仍然感覺很充足。該區域內為提升其發電率，大樓外牆及人行步道遮雨棚等，亦皆安置太陽光電板，惟該系統發電效率未知，但仍有推廣綠能效果，如照片 8。其他詳細項目因屬商業機密，故無法詳細攝影及呈現於本出國報告中，相關參訪照片如下。

照片 6、柏葉智能城市的智慧電能控制中心

照片 7、柏葉智能城市的日光引導案例

照片 8、柏葉智能城市大樓外牆及人行步道遮雨板

3.3 日本電氣(NEC)株式會社

NEC 創立於 1899 年，是日本國際著名的電子電氣公司，全球員工數高達約 10 萬名，其事業版圖橫跨衛星系統、電視訊號設備、電纜、建築事業、光纖海纜、電動車充電及家用儲能系統等等。當天前往日本電氣株式會社(Nippon Electric Company，簡稱為 NEC)位於橫濱的總公司參訪聽取該公司的再生能源發電與儲能相關簡報，並參訪明電舍株式會社(MEIDENSHA)主導之橫濱智能城市，NEC 在其中則扮演著提供儲能系統的角色。

當天在 NEC 總公司共介紹 4 種再生能源發電系統的相關解決方案，簡述如下：

(1) 再生能源發電預測系統 (Heterogeneous Mixture Learning Technologies)：在大數據(Big Data)與基因演算法的基礎上，並加入機組、氣候、歷史數據及需量反應等相關資訊，可預測未來再生能源發電資訊，經洽平日誤差率約 1.6%，最大電力需求量正確率約 50%。

(2)再生能源設備監測系統(Smart Maintenance)：結合平板電腦與 RFID 技術，可統一管理再生能源監測系統，並簡化運維檢測程序，加速巡修速度，優化運維人力。

(3)微電網運維系統(Small Grid Intelligence)：該系統在前述再生能源發電系統預測的基礎上，預測隔天太陽光電及風力發電機組的發電量，以安排運維人力並將再生能源發電極大化。

(4)再生能源發電管理系統(Situational Intelligence Overview)：以視覺化系統管理，並結合地理圖資系統，可在電腦上即時監控各發電站運轉、機組運維、及發電成本等資訊，以利中央調控中心管理。

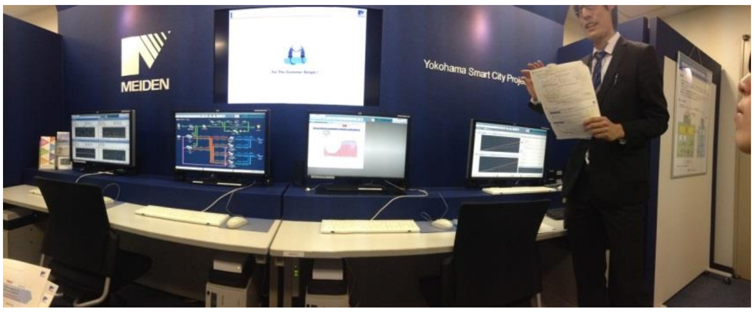
上述解決方案詳細資料均可在本出國報告中的附錄詳閱。

另外當天順道參訪 NEC 參與建置儲能系統的橫濱智能城市專案計畫(Yokohama Smart City Project, YSCP)，該智能城市在 2015 年 3 月建置完成，

設有 6.6kV 的汽電共生系統，裝置容量為 1,560kW，其中亦設置了 NEC 的 GBS 電池，裝置容量為約 250kWh，如照片 9，以及在需量反應的基礎結合 BEMS(Buidling Energy Management System)的 PCS(Power Conversion System)，以控制建築物內能源消耗管理，如照片 10，並於建築物中設置了智慧電能調控中心，以接受 YSCP 專案計畫的中央電力調控，如照片 11。

照片 9、YSCP 的 NEC 儲能系統

照片 10、YSCP 中 NEC 的 PCS 設備(置於受電盤配電箱中)



照片 11、YSCP 的智慧電能控制中心

3.3.1 GBS 電池簡介

電網級儲能系統(Grid Battery System，簡稱為 GBS)為 NEC 發展的貨櫃式電池儲能設備，其中配備了自有的 PCS 系統，以及 NEC 鋰錳電池，可提供快速安裝，施工相對簡易，待貨櫃安裝好後只需電纜併接電網即可。經洽該電池技術係併購美國 A123 電池大廠，並擴大發展為貨櫃式池組，電池現有相關規格如表 3。

表 3、NEC 的 GBS 電池相關規格表

	長效型 GBS			高放電率 GBS
型號	GBS-C53-LD40	GBS-C40-LD28	GBS-C20-LD12	GBS-C53-HR20
裝置容量	4MWh	2.8MWh	1.2MWh	575kWh
額定功率	最大 4MW	最大 2.8MW	最大 1.2MW	最大 2MW
尺寸	16.2mx2.6mx2.9m	12.2mx2.6mx2.9m	6.1mx2.6mx2.9m	16.2mx2.6mx2.9m
效率	97%			96%
DC 端輸出電壓	944V (電壓輸出範圍為 750V~1050V)			960V (電壓輸出範圍為 750V ~ 1050V)
操作溫度	-30℃ ～ ＋50℃			
備註	皆配備空調系統及 PCS(Power Conversion System)。			

鋰錳電池楊極材料是金屬鋰，陰極材料是二氧化錳，並通過電解液無機鹽高氯酸鋰（LiClO4）發生氧化還原反應，以進行充放電；電池結構一般分成全密封式及半密封式兩種，NEC 所發展的 GBS 電池則屬於全密封式，安全性與使用期限較長。另外，基本來說鋰錳電池的放電電壓曲線相對一般鋰電池較為平穩，故用其 SOC 來檢測儲存電量有一定的準確性，與一般鋰電池相比，也有輸出功率大及低自放電率的特性，但若以大型的電網級儲能系統的角度來看，則需要眾多的鋰錳電池，以串併接方式組成高電壓及大電流的電池模組，而若其中一顆電池出現故障或損害，就需要整組更換，故其中的電池管理系統(Battery Management System, 簡稱為 BMS)就相對非常重要。NEC 的 GBS 電池優缺點分析如表 4。

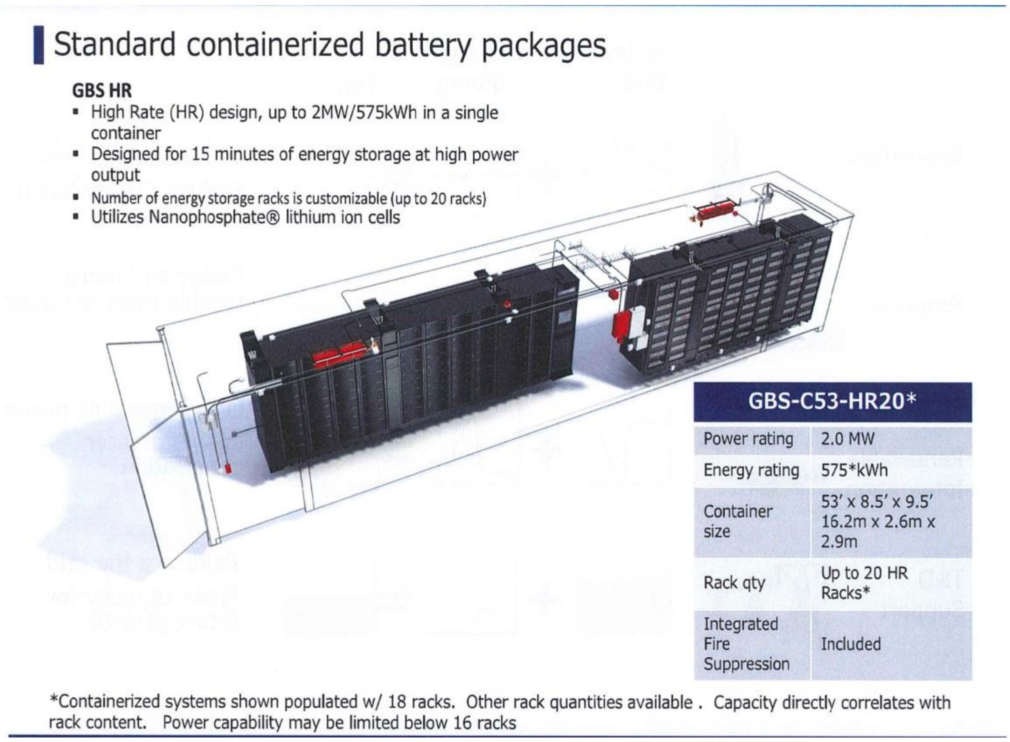


圖 11、高放電率 GBS 儲能系統結構圖

(資料來源:本報告附錄之 NEC 相關資料)

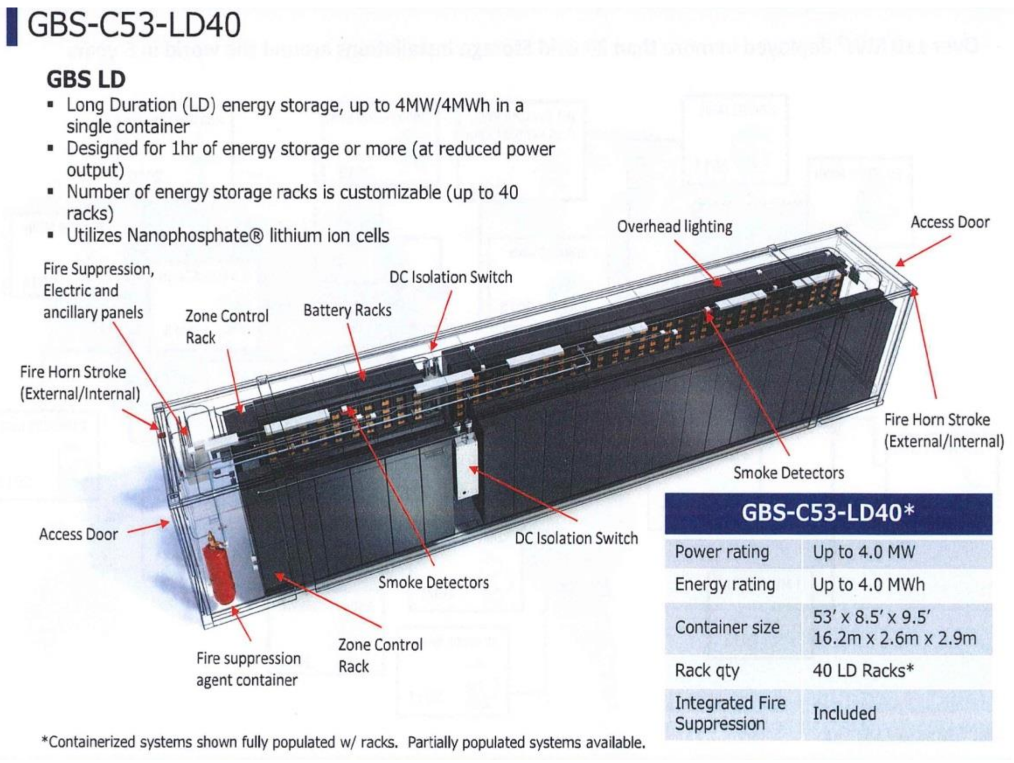


圖 12、長效型 GBS 儲能系統結構圖

(資料來源:本報告附錄之 NEC 相關資料)

表 4、GBS 電池優缺點分析表

優點	缺點	備註
1.成本較低	1.相較前述的 VRFB 電池及 NaS 電池，單位能量密度及體積較小	經洽該電池系統符合家庭使用，目前為日本國內居家儲能系統市占率第一名。保固期約 1~2 年。
2.高放電率、低自放電率	2.因鋰電池過度充電放電恐導致設備毀損，BMS 系統設計需求較高。	經洽以日常的充放電頻率使用，10 年後約可保有 80%的儲能效率。
3.工作溫度為約-20 度 C 至 60 度 C	3.須遠離熱源	經洽為避免高低溫影響電池傳輸電力效率，GBS 電池系統在貨櫃內皆配置空調系統。
4.可依需求客製化	4.安全性較低，不建議長期存放。	經洽其可輸出最大功率與可儲存能量皆可分別依客戶需求設計。

3.3.2 GBS 電池儲能系統與電能管理

NEC 將自有的鋰錳電池串併接，組成許多單一的電池模組後，由其所開發的 BMS 管理各電池芯，並將空調系統、變流器、網路資訊傳輸模組等包含在單一系統貨櫃中，待併接電網後，可在電網端執行下列四種調控功能：

(1) 穩定頻率：在電網端即時監測電力品質，並調控功率因素。

(2) 充作備用電源：在市電端發生故障無法供電時，緊急供電以維持電網穩定。

(3) 輔助再生能源(Peak shaving)：維持電網端穩定的傳輸功率。

(4) 釋放線路容量：若既有電力傳輸線路容量不足，則可以在不足之處增建 GBS 儲能系統，在離峰用電時段，利用剩餘的傳輸線路容量儲存電能，並於尖峰用電時段供給當地用電。

四、 心得及建議

本次參訪前往日本地區，主要為住友電氣工業株式會社(住友電工)、日本礙子株式會社(NGK)及日本電氣株式會社(NEC)，期間了解了日本政府對於再生能源的支持可說是不遺餘力，經洽上述公司表示，日本政府產業經濟省每年皆會編下大筆預算，用於支持國內再生能源示範型系統或研究計畫，如本次參訪的橫濱智能城市(YSCP)以及柏葉智能城市，皆是經由政府大力支持下的產物，惟大型儲能系統相對於現今的電力系統來說仍未成熟，故仍需要經由多方的驗證以及實際操作，相關技術才能越臻成熟。

本次參訪的儲能系統，除了宮古島智慧社區內 NGK 的 NaS 電池附近配有 2 作 900kW 風力發電機組外，大致上皆是配合太陽光電系統設置，分析應是考量太陽光電發電曲線大致符合一般用戶負載曲線，故儲能系統設計可以較為彈性，也可初步驗證儲能系統實際功效；若以風力發電機組搭配儲能系統，因本公司風力發電機組多以 2MW 為主，需搭配電網級儲能系統，相關電力傳輸及系統衝擊等安全門檻也會較為嚴苛。基於前述參訪經驗，建議本公司可加以仿效初步建立示範型儲能系統，先期以搭配太陽光電為主，待技術及經驗成熟後，後期再搭配風力發電機組。

另外，考量近年來再生能源發電系統的設置成本逐年下降，舉例而言，以往本公司在2008年太陽光電第一期計畫平均每kW投資金額約34萬元，但在 2011 年建置完成 10.4MWp 後，因在建置過程中設置成本，也在同時下降的因素，工程節餘款高達 15 億元，遂利用該節餘款持續增建，至 2014 年底累積裝置容量已達 18.2MWp，平均每 kW 投資金額約 19 萬元，短短幾年時間，價差幾乎達 1 倍；基於前述經驗，本公司未來在推行計畫時，若未能在規劃階段時加入研究建置儲能系統之可行性，亦可在計畫執行期間，利用計畫結餘款規劃建置相關儲能系統，俾改善發電效率，以及再生能源發電系統為人詬病的不穩定間歇性特質。

附錄一

住友電工相關資料

事業所・工場向け

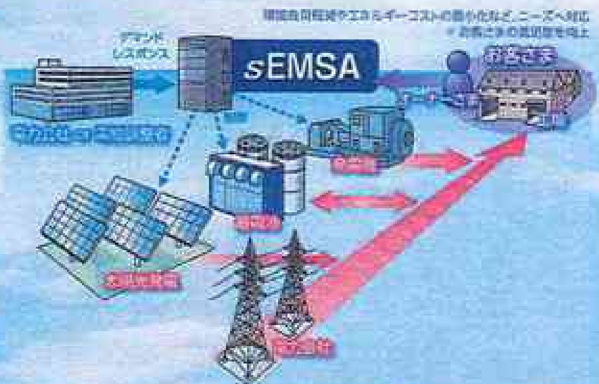
新エネルギー・マネジメント・システム sEMSA®

sEMSA®ってなに？

sEMSA®について パワーシステム研究開発センターのPS犬がご紹介します。

sEMSA®とは当社が開発した、再生可能エネルギーを含む多様な分散電源を使って需要家にとって最適となるように電力を運用できるエネルギー・マネジメント・システムのことです。発電設備と蓄電設備の機能を最適に管理・制御することで、電力コストの低減や省エネ効果を発揮することができます。

たとえば、電力消費が少なく低コストの夜間電力を貯めておき、電力が逼迫してコストも高い昼間にそれを利用して電力消費の平準化（ピークカット）や、電力コストの低減を図ることができます。また、電力消費を含む各種情報をリアルタイムで見える化し、事業所・工場の操業改善にも活用できます。さらに、電力会社の予備電力確保や負荷平準の手段であるデマンドレスポンスにも自動で対応することが可能です。

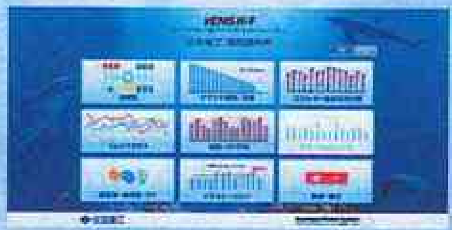


近年、省エネルギーに対する社会的要請とともに、工場や企業などの大規模需要家において、再生可能エネルギーなどを使用した分散型の電力システムの活用がますます高まっています。

環境負荷軽減やコスト最小化のためのエネルギーの高効率運用が可能なsEMSA®は、こうした大規模電力システムにおいてより効率的なエネルギー運用を行うための重要な役割を果たします。

sEMSA®でどんなことができるの？

sEMSA®は、有線および無線のハイブリッドネットワークを介して、発電量、蓄電量および消費量を収集し、最適な需給バランスが得られるように電力の流れを管理します。消費者の利便性を損なわずに経済メリットを得られるように発電・蓄電設備および負荷機器の制御を行います。計測データは中央制御サーバで一括管理され、発電・蓄電・消費のリアルタイムの状況や、過去の発電や消費データのトレンドをディスプレイで確認することができます。



sEMSA®の特長

1 幅広い顧客ニーズに対応可能な、新しい独自方式を開発

当社はエネルギーマネジメントにおける機能を階層化し、右図に示すアーキテクチャに沿って開発を進めています。層内における各機能はモジュール※1化されており、sEMSA®は必要なモジュールを組み合わせて構成することが可能です。これにより、大規模需要家から家庭まで多様な顧客ニーズや分散電源に対して短納期・低コストに対応することができます。

現在、当社横浜製作所にて複数台の分散電源とsEMSA®を使っており、デマンドレスポンスに対応して地域の電力需給調整に役立てています。

2 デマンドレスポンス（DR）にも瞬時に対応

複数の分散電源の運用を最適化する手法として数理計画法※2が一般に知られています。この数理計画法において、当社は電力を最適に運用する計画を短周期で立案し、それと並行してリアルタイムで計画との誤差を吸収するフィードバック制御を行う高速計算アルゴリズムを新規に開発し、電力コストの予測誤差を縮め、かつリアルタイムレベルでの運用を実現しました。電力会社の予備電力確保や負荷平準の手段として、DRへの関心が高まる中、sEMSA®はDR発令を受けて瞬時に対応することも可能です。

3 電力消費の最適運用と契約電力の遵守を両立

sEMSA®は、短周期で再計算する電力最適運用計画を参照しながら、急な電力需要の変動に対するフィードバック制御をかけますので、電力最適運用と契約電力の遵守を理想的に両立させます。

4 投資回収条件などの各種シミュレーションもサポート

分散電源導入前の事業所にあっては、投資回収額条件での分散電源設備仕様をご提案し、設備導入後にはその条件にそった電力運用をsEMSA®が実現します。

March 24, 2015

Sumitomo Electric Industries, Ltd.

Demand Response Demonstration Test for Negawatt Trading Successfully Completed Using an Energy Management System, "*s*EMSA™"

Under a national demonstration project, the Next-Generation Energy and Social Systems Demonstration Project led by the Ministry of Economy, Trade and Industry for negawatt trading,[*1] Sumitomo Electric Industries, Ltd. has successfully delivered appointed negawatt power within 15 minutes after the issuance of a demand response (DR) request by using an energy management system "*s*EMSA™" developed by the company.

The demonstration test was conducted at Sumitomo Electric Yokohama Works (located in Sakae ward, Yokohama) using 3 largest redox flow (RF) batteries in Japan (totaling 5 MWh), 6 co-generation systems (CGS) (totaling 4 MW), 15 concentrated photovoltaic (CPV) units (totaling 100 kW) and an energy management system "*s*EMSA™" developed by Sumitomo Electric, which controlled these generators (Figure 1).

The *s*EMSA™ responded to a DR signal within 10 seconds after receiving the signal from EnerNOC, an aggregator, and delivered the appointed amount of electricity (640 kW x 1 h) within 15 minutes fully automatically. By doing so, the *s*EMSA™ reduced the power from the grid during the DR hour (Figure 2). Meanwhile, the DR request was issued using the international standard OpenADR 2.0 protocol.[*2]

Sumitomo Electric implemented the demonstration program jointly with EnerNOC Japan, KK (headquartered in Chiyoda ward, Tokyo and led by David Brewster, President), which is a member of a consortium of power companies and aggregators. EnerNOC Japan is working on a DR demonstration program for peak-hour supply and spinning reserve[*3] led by the Ministry of Economy, Trade and Industry. Sumitomo Electric took part in the demonstration program as a customer of EnerNOC Japan.

The *s*EMSA™ is an energy management system developed by Sumitomo Electric and has the following features:
1) Conforms to a flexible and expandable architecture that meets diverse customer needs and a variety of power equipment requirements
2) Adapts instantaneously to DR requests
3) Manages generators, including renewable energy generators, optimally and comprehensively to minimize energy costs and achieve other goals
4) Performs contract power and various other simulation functions
The following press release provides an overview of the *s*EMSA™:
(http://global-sei.com/news/press/14/prs113_s.html)

In the project, the *s*EMSA™ connected itself to EnerNOC using the international standard OpenADR. On the basis of this result, Sumitomo Electric will promote the *s*EMSA™ to our customers as a standard negawatt trading tool in the domestic market.

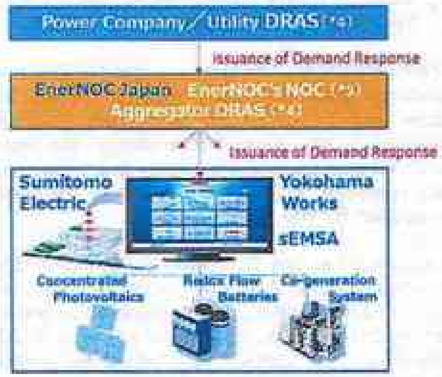


Figure 1 — System configuration used in the DR demonstration program

Figure 2 — *s*EMSA™ screen of optimal plan responding to a DR request (Jan 21, 2015)

横浜スマートシティプロジェクト（Yokohama Smart City Project）

FEMSセンター（FEMS center）

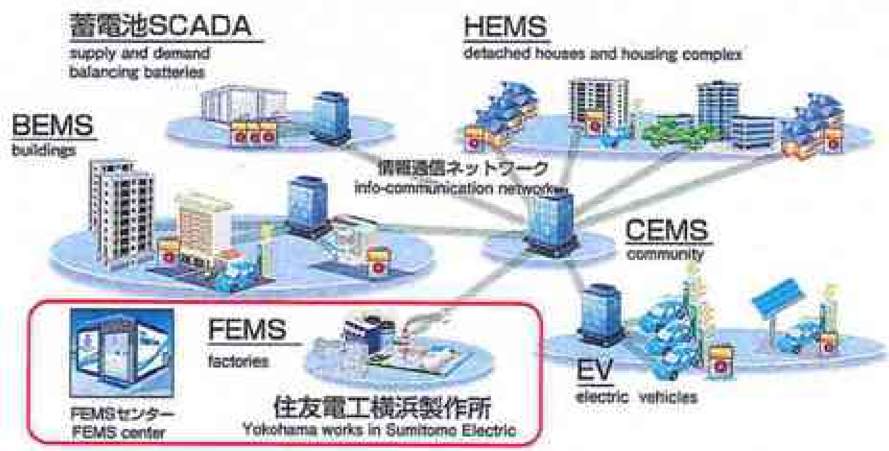
住友電気工業株式会社　■研究統括本部 パワーシステム研究開発センター　■インフラ事業推進部

- 本事業は、平成24～26年度次世代エネルギー・社会システム実証事業として、明電舎様との共同事業で「レドックスフロー電池を活用したEMSの研究開発」をテーマに採択されたものです。
- 当社は、大規模工場（横浜製作所）を対象にコジェネレーション、レドックスフロー電池、集光型PVを統合制御するFEMSの研究開発を行います。
- YSCPでは、CEMSとHEMS・BEMS・FEMS・EV・蓄電池SCADAが連携し、横浜市内で地域エネルギーマネジメントシステムを構築し、デマンドレスポンス等の社会実証を行います。
- 当社は、YSCP唯一のFEMSとして、デマンドレスポンスに参加します。
  - Sumitomo Electric joined YSCP with MEIDENSHA in June 2012 as a large scale factory equipped with redox flow batteries.
  - The role of Sumitomo Electric includes 1) participation in demand response trial and 2) optimal control of multiple power sources of different features for both daily operation and irregular event.


FEMSセンター外観（FEMS center exterior）


FEMSセンター内部（FEMS center inside）

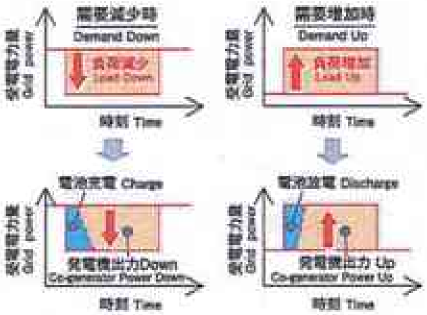
横浜スマートシティプロジェクトのシステム構成　YSCP whole image



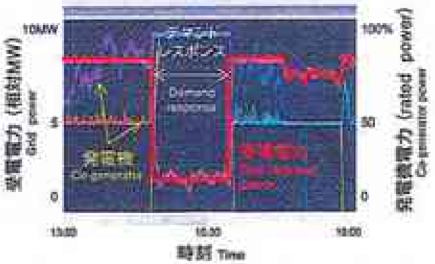
FEMSのシステム構成　Factory Energy Management System

検証内容　Optimal charge/discharge control of Redox Flow Batteries

- コージェネレータ、RF電池を統合して最適に制御します。
  - Co-generators and RF batteries are controlled jointly and optimally.



- YSCPのFEMS参加企業として、デマンドレスポンスに参加します。
  - Participated in YSCP demand response trial, 2013-07-31.
  - Grid incoming power was shifted from constant to minimum.



お問い合わせ先

住友電気工業株式会社

パワーシステム研究開発センター　TEL. (06)6466-5790　FAX. (06)6466-5705

インフラ事業推進部　TEL. (06)6220-4170　FAX. (06)6222-6035

Ingenious Power System

Responding to New Social Needs

Taking advantage of our assets accumulated in a wide range of business fields, we will contribute to the establishment of a new social infrastructure

Utilizing our assets accumulated in a wide range of business fields explained so far, our group will present solutions for future social needs.

An example of such efforts is the development of a smart energy system, which is necessary for establishing a new power and energy infrastructure. Taking advantage of our strength as a manufacturer of a full range of products in a value chain consisting of power transmission, distribution, storage, and use, we are able to present proposals ranging from concepts and designs to solutions.

Smart Energy System Proposed by the Sumitomo Electric Group

Providing high-quality electricity and energy that is safe, secure, stable, and environmentally friendly

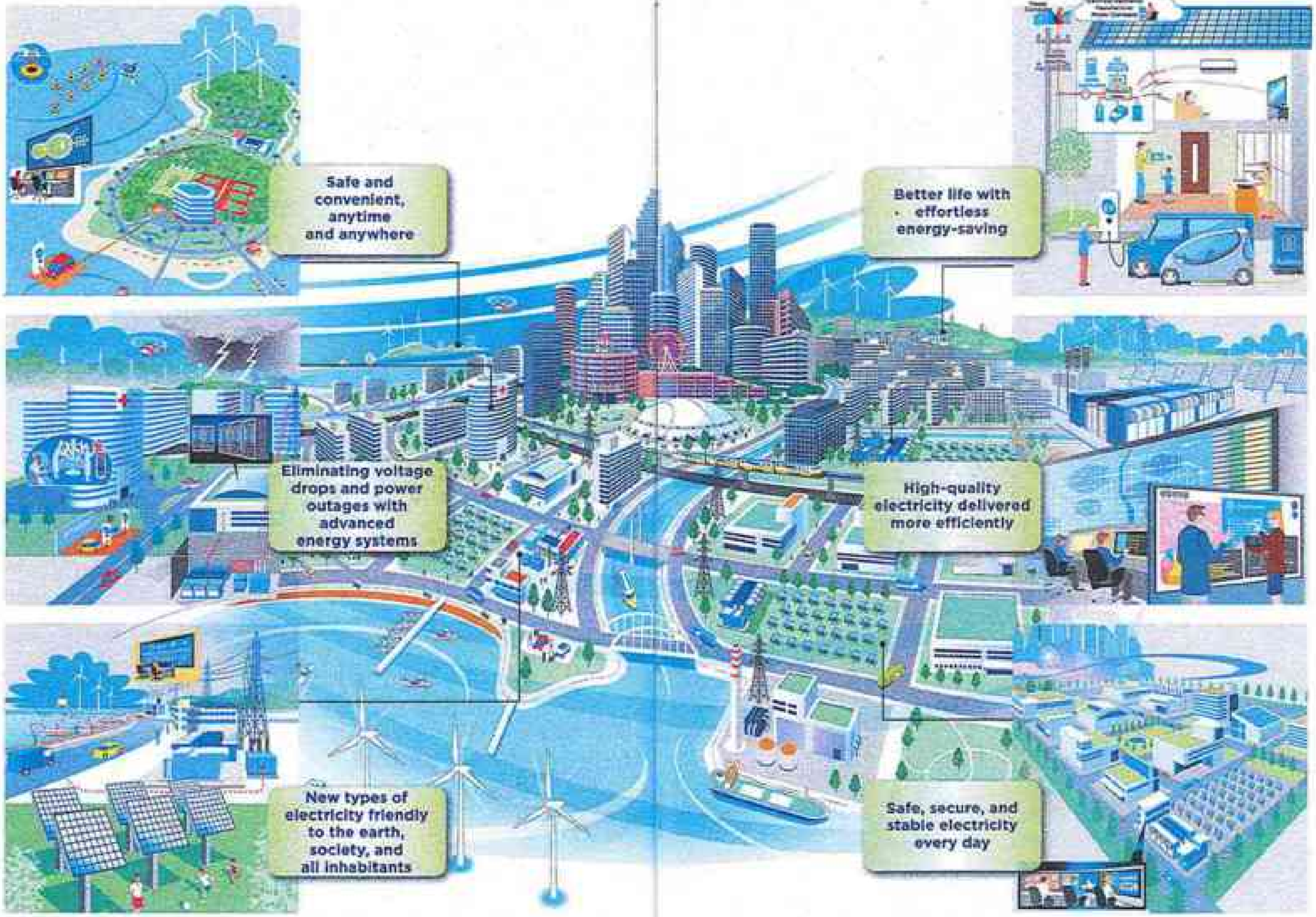

Energy Management System (EMS)

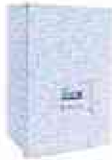

Superconductor Electric Vehicle


Photovoltaic Systems
(Photo credit: Tokyo International Air Cargo Terminal Ltd.)


Concentrator Photovoltaic (CPV) Systems


Maritime Wind Powered Generators

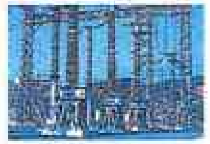



Power Conditioner for Photovoltaic System


Small Battery "POWER DEPO™"


Smart Distribution Board


Redox Flow (RF) Battery System


Capacitor Voltage Transformer


Harmonic Filter Equipment


Power Capacitor

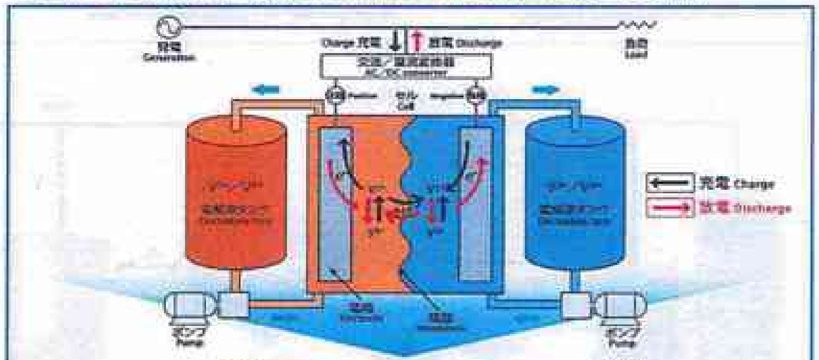
SUMITOMO ELECTRIC

Proposal for Energy Storage and EMS Installation in Isolated Islands

Sumitomo Electric Industries
January, 2016

Vanadium Redox Flow Battery - Principle

REDOX: "Reduction" (to gain electron) & "Oxidation" (to lose electron)



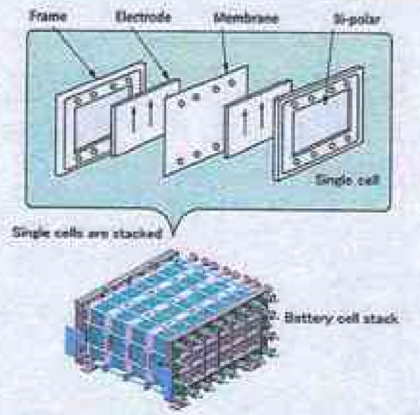
$VO^{2+} + H_2O \underset{Discharge}{\overset{Charge}{\rightleftarrows}} VO_2^+ + e^- + 2H^+$

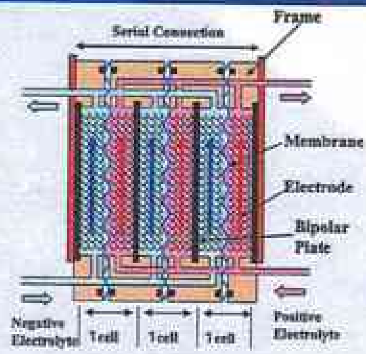
$V^{3+} + e^- \underset{Discharge}{\overset{Charge}{\rightleftarrows}} V^{2+}$

-Utilizing ionic state-of-charge difference of Vanadium Ions in electrolyte

-No degradation of electrolyte occurs during charge/discharge cycle

Cell Stack



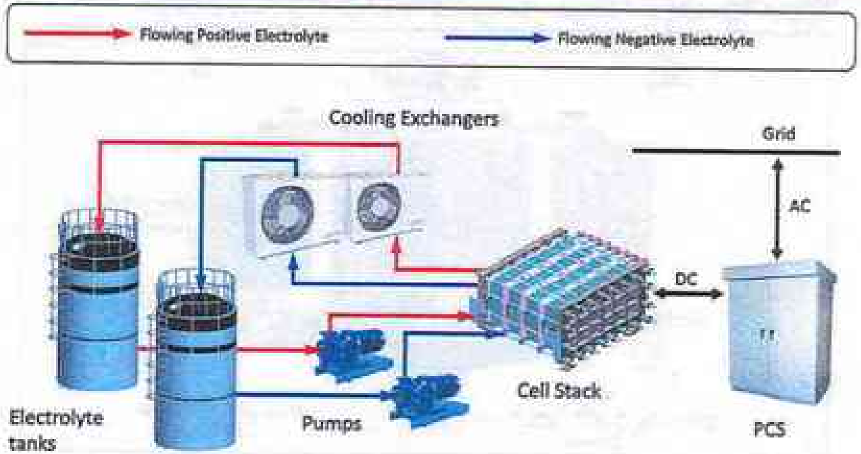


Current Cell Stack

Current generation
Rated Output: 38kW (DC)
Dimension: 1.0m^W x 1.2m^L x 0.6m^H

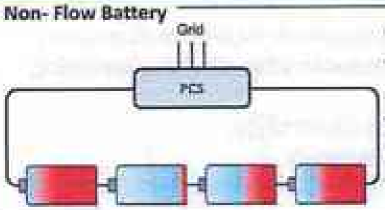
New generation (from 2017)
Rated Output: 75kW (DC)
Dimension: similar to current

System Configuration



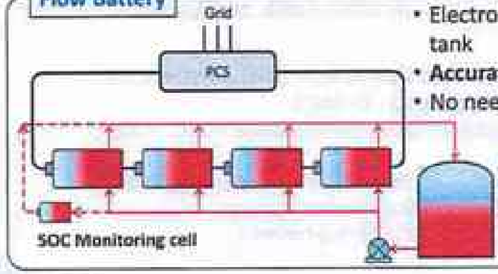
Accurate SOC Monitoring

Non- Flow Battery



- Electrolyte stored inside individual cells
- Monitoring and Re-balancing SOC among many cells is NOT so simple
- Scale up with large energy is challenge
- To avoid over-charge is important for safety

Flow Battery

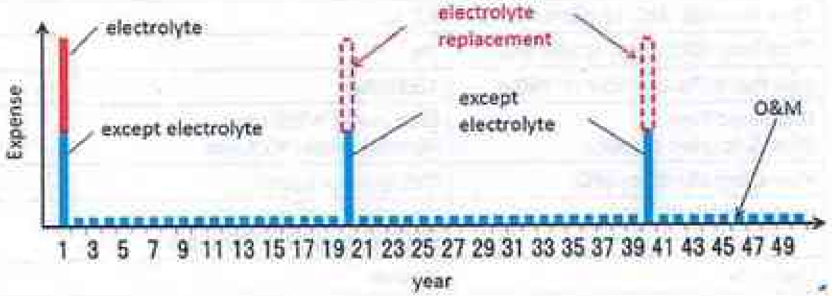


- Electrolyte stored outside cells in common tank
- **Accurate & Real-time SOC monitoring**
- No need of Re-balancing of SOC

- **Easy operation**
- **Easy scale up with long duration**
- **Wide range of SOC utilization for charge/discharge cycle**

Reuse of Electrolyte within Long-term Operation

➢ Since electrolyte has negligible degradation during charge and discharge, it makes the reuse of electrolyte possible within a long-term operation.



Vanadium Redox Flow Battery - Key Features

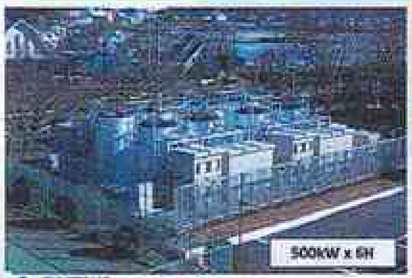
1. Long Life Cycle	·Unlimited Charge/Discharge cycle (>100,000 cycles) ·Electrolyte is reusable after decommissioning
2. Safety	·Non-flammable Electrolyte ·Flame Retardant Materials ·Accurate and Reliable SOC Management
3. Multi-Purpose	·Fast Response & Long duration Applications → Hybrid Application such as Flexible Capacity
4. Easy Operation	·Accurate and Real-time SOC Acquisition · Operational DOD : 0~100% · Operation Ambient Temperature : -5°C – 45°C
5. Design Flexibility	· Separation of Power (MW) and Energy (MWh) · Easy to build large-scale systems e.g. 60MWh (15MW x 4 hours)

Specification

For : 1MW x 4hr system

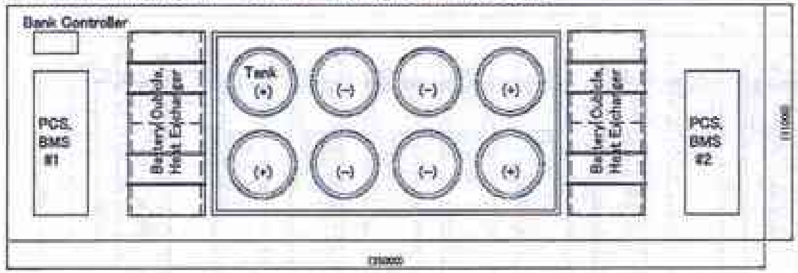
Max Power (Pmax)	1MW
Min Power (Pmin)	-1MW
Max Storage Capacity	4MWh
Ambient Temperature	-5 to +45℃
Min SoC	0%
Time from Min SoC to 100%	5.7 hr
Time from 100% SoC to Min SoC	4hr
Max Ramp Rate (-1MW → 1MW)	10MW/sec
Response Time (from 0 to rated output)	Stop mode: <300 sec. Standby mode: <0.1 sec.
Round trip efficiency (AC)	70% (typical figure)
Designed Life Time	Electrolyte: almost permanent Major components: 20 years
Cycle life	No limit
Efficiency degradation per cycle	Negligible

Plant Type Battery System

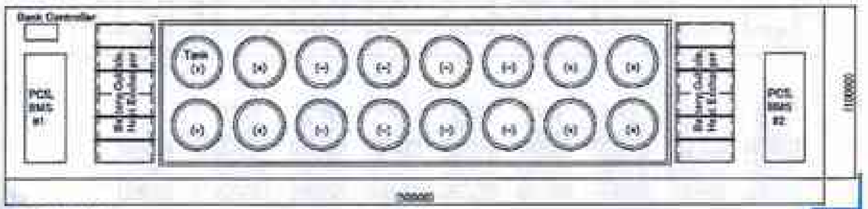


Footprint (Plant Type)

- 1MW x 4hr System: 35m x 11m (height : 6.7m), 650Mt



- 1MW x 8hr System: 50m x 11m (height : 6.7m), 1100Mt



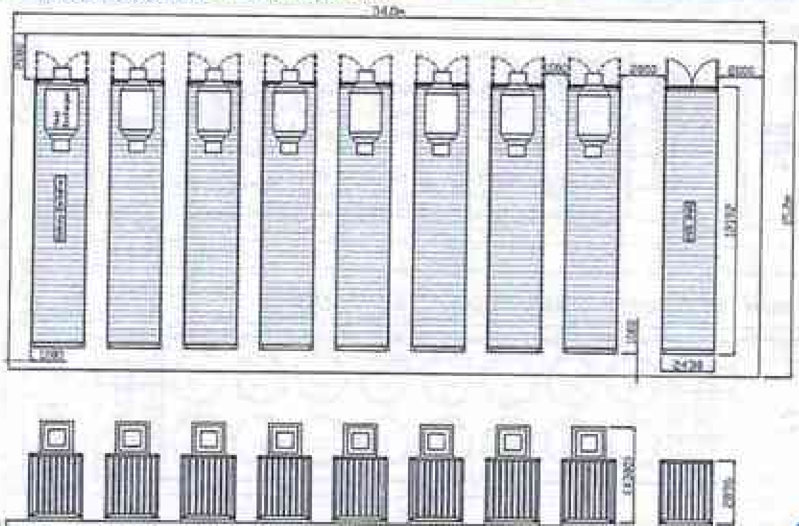
Containerized Solution (launch in early 2017)

Demonstration @ SEI Osaka Works

Item	Spec
Container	40ft Standard Container
Size (L × W × H)	12.2 × 2.4 × 2.9(m)
Capacity	125 kW
Energy	4 hours (500kWh)
Ambient Temperature	-5～45℃

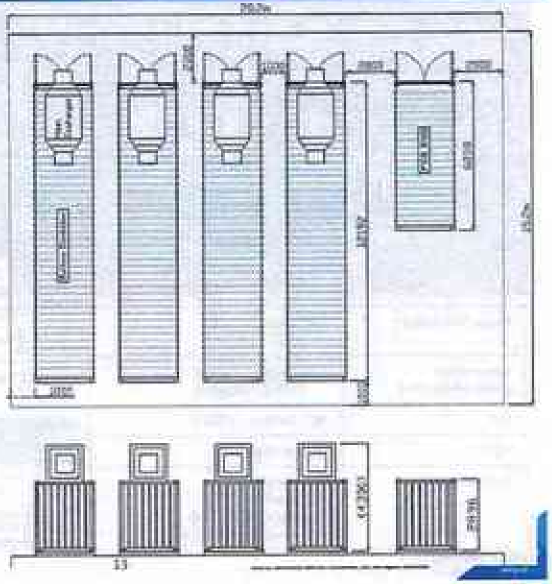
Footprint (Container Type)

- 1MW x 4hrs system: 34m x 15m, 600 Mt



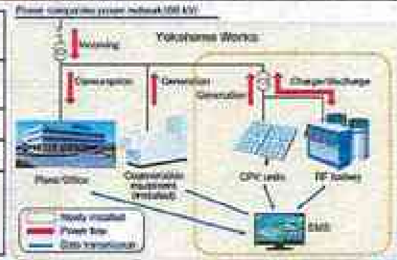
Footprint (Container Type)

- ➢ 500kW x 4hrs system
  20m x 15m, 300 Mt



Use Case: Demand Side Management System

Redox Flow Battery	Max. Output: 1MW Capacity: 5MWh
Concentrator photovoltaic (CPV)	Max. Output: 100kW (7.5kW x 15 units)
CGS	Max. Output: 3.5MW
EMS	Developed by SEI
Applications	Renewable Firming, Peak Shaving, Demand Response (DR) (Yokohama Smart City PJ)

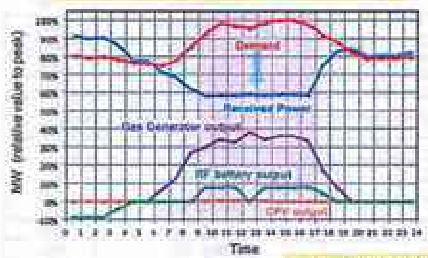


Project Reference: 20+projects, 27MW/100MWh

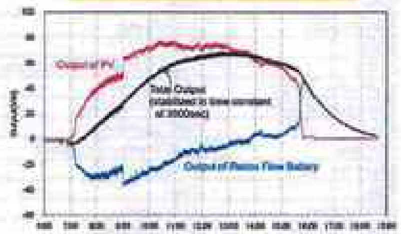
Customer	Application	Capacity	Installation
Utility	R&D	450kW × 2H	1996
Office building	Load leveling	100kW x 8H	2000
Utility	R&D	200kW x 8H	2000
NEDO	Power stabilization of wind power	170kW x 6H	2000
Construction company	R&D with solar	30kW x 8H	2001
Semiconductor factory	UPS, peak shaving	3MW x 1.5sec, 1.5MW x 1H	2001
Utility	UPS, peak shaving	250kW x 2H	2001
University	Load leveling, peak shaving	500kW x 10H	2001
Laboratory	Load leveling	42kW x 2H	2001
Utility	R&D	100kW x 1H	2003
Office building	Load leveling	120kW x 8H	2003
Railway company	UPS, load leveling	30kW x 3H	2003
Office building	R&D	100kW x 2H	2003
Data center	UPS, emergency power supply	300kW x 4H	2003
Laboratory	Load leveling	170kW x 8H	2004
Office building	Load leveling, emergency power supply	100kW x 8H	2004
University	Load leveling, emergency power supply	125kW x 8H	2004
Museum	Load leveling, emergency power supply	120kW x 8H	2005
Utility	R&D with solar	100kW x 4H	2005
NEDO power plant	Power stabilization of wind power	4MW x 1.5H	2005
SEI	Demonstration with solar	1MW x 5H	2012
Utility (Taiwan)	Demonstration with solar	2kW x 5H	2012
Construction company	Demonstration with solar	500kW x 6H	2015
Utility	FR, renewable generation mitigation	15MW x 4H	2015
Utility (USA)	Time shifting, FR, spinning reserve	2MW x 4H (under construction)	2016

Operation Mode

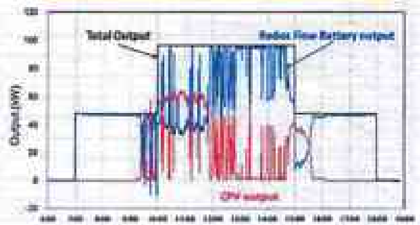
A. Load Leveling/Peak shaving



B. Stabilizing Fluctuation



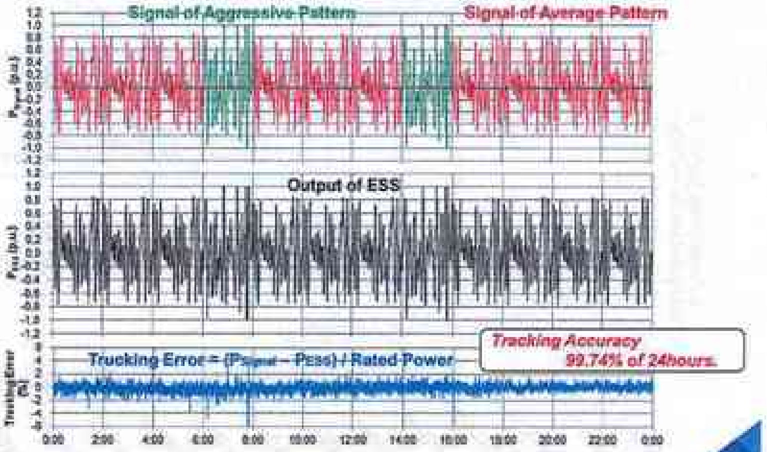
C. Scheduled Power Generation



Operation Mode

➢Frequency Regulation Test (PNNL-22010 Rev.1) is performed in "Yokohama" system. (Using a Bank (#3), Rated Power is 250kW)

➢The system was controlled for one day by external command continuously.

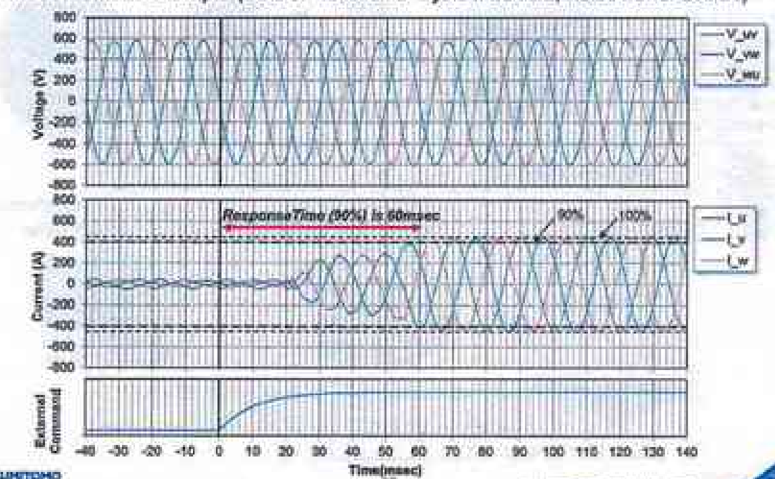


Response Time

➢Response Time of Flow Battery << Response Time of PCS

➢System Response is the Issue of PCS & System Design (not Battery Issue)

➢Measurement Example (Data of "Yokohama" System Bank#2, Rated Power 250kW)

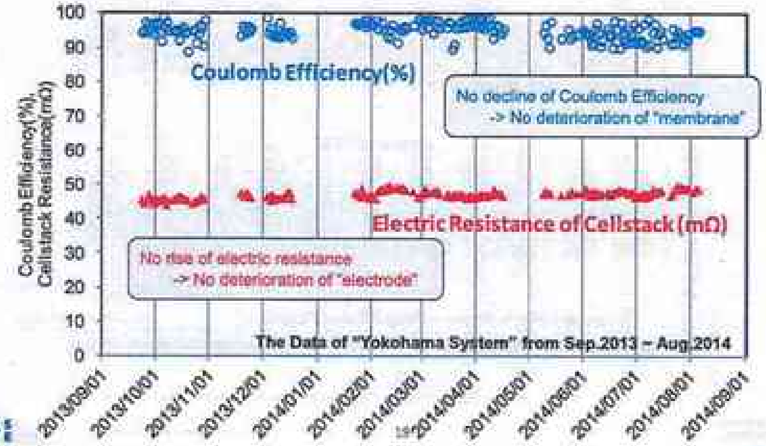


Continuous Long Term Performance

➢**Long term performance test is undergoing in "Yokohama" system.**

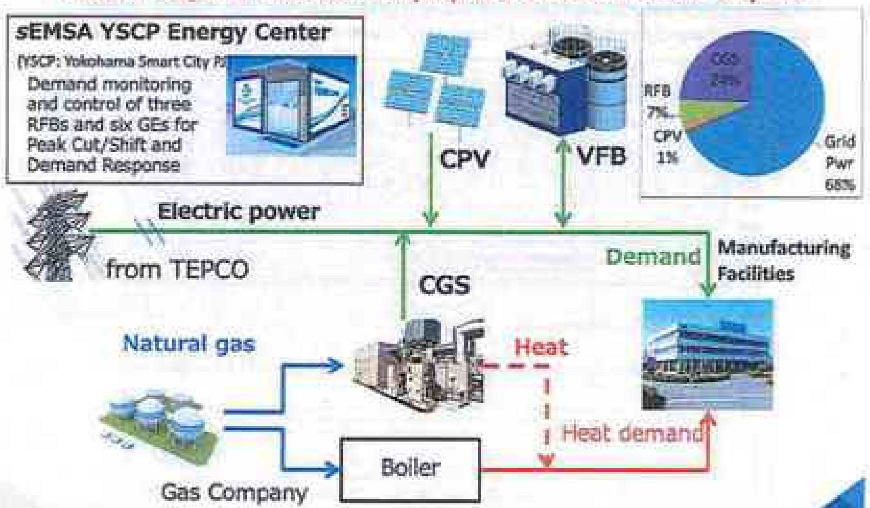
➢**In operation of 1 year, there is no significant deterioration.**

(The decrease of system efficiency and capacity caused mainly by "deterioration of membranes", and "deterioration of electrodes".)



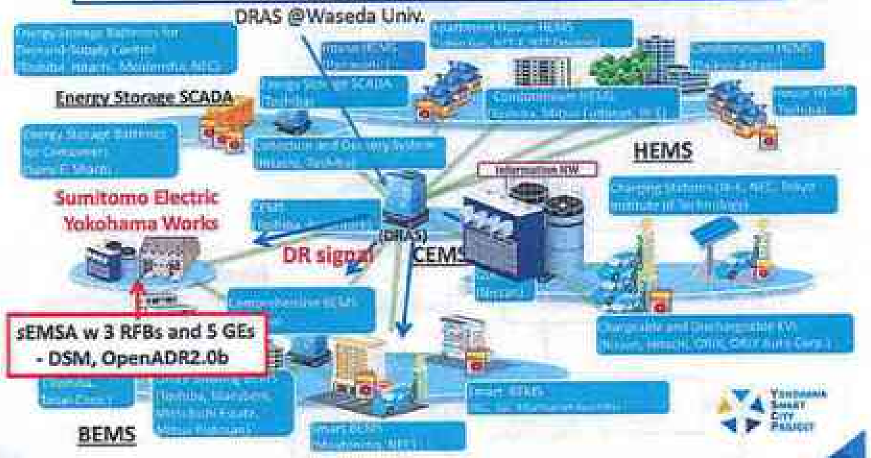
EMS & Demand Side Management in Factory

*s*EMSA®: Optimal control of multiple power sources & Demand Response



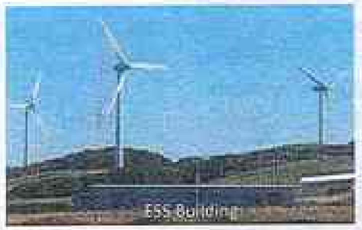
Yokohama Smart City national PJ (YSCP)

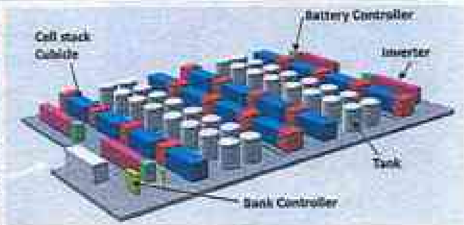
- City scale trial of Demand Response Service under support of Utility
- Aggregation of Home, Apartment, C&I (Sumitomo's Factory) and PEV

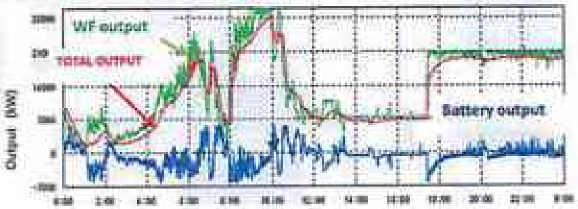


Use Case: Renewable Generation Firming

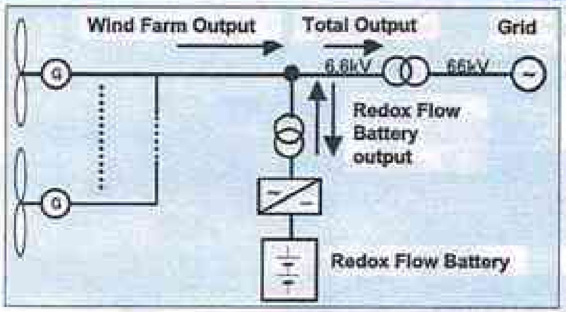
Tomamae Wind Villa National PJ (J-POWER, funded by NEDO)
- Stabilizing Wind Turbine's total output of 31MW
- VFB System: 6MWh (4MW x 1.5hr)



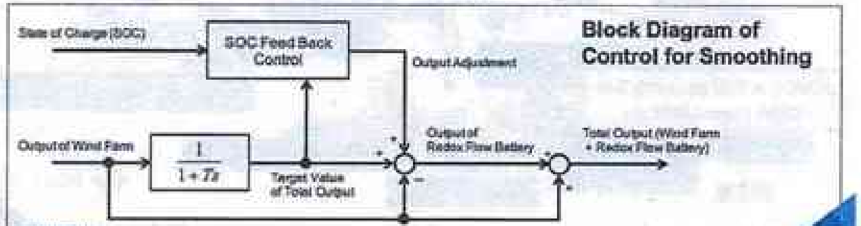




Use Case: Renewable Generation Firming (Control Method)



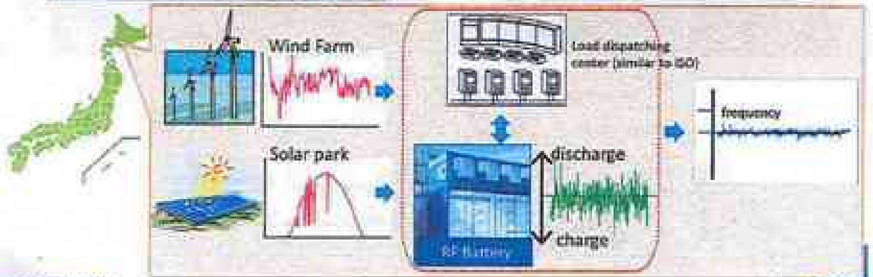
Conceptual Diagram of Interconnection to Grid



Block Diagram of Control for Smoothing

Use Case: Grid ESS for Hokkaido Electric Power Co.

- ➢ Funded by Japanese government
- ➢ Capacity : **15 MW**
- ➢ Energy : **60 MWh**
- ➢ Location: Substation of HEPCO
- ➢ Application: Multi-purpose
  - Frequency control
  - Renewable generation mitigation



Use Case: Grid ESS for Hokkaido Electric Power Co.

Confidential

Meaning of HEPCO Project

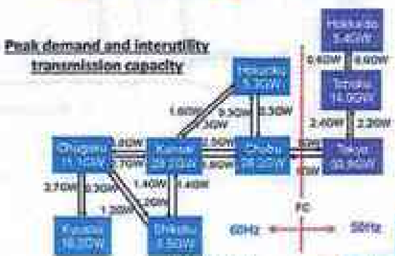
■ Renewables installation

	National	Hokkaido
Peak demand (GW)	162.9	5.4
Installed renewables as of Aug. 2015 (GW)	31.8	1.1
% (Renewables / peak demand)	19.5%	20.3%
Approved applications (GW)	87.1	3.1

■ Measures for Hokkaido's grid stabilization

1. Energy storage
15MW/60MWh flow battery installation at HEPCO's substation.

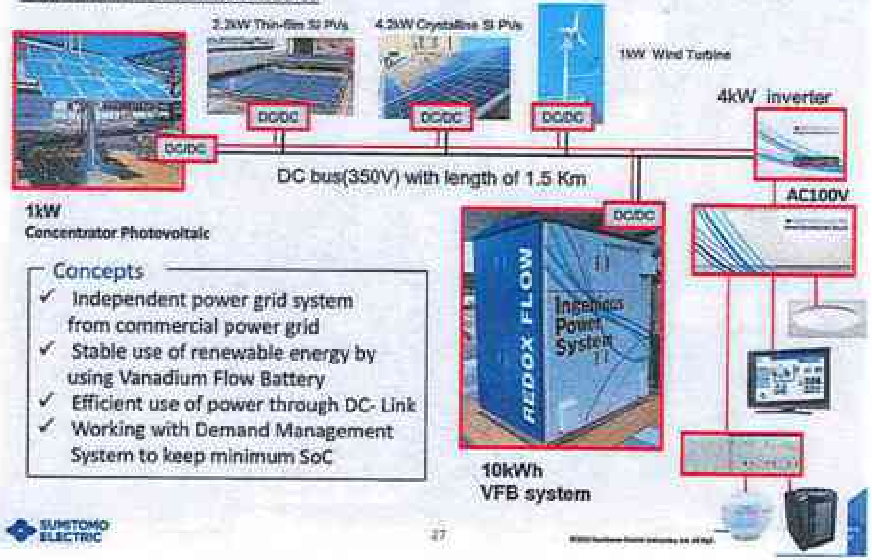
2. Inter-utility connection
Raise transmission capacity from 600MW to 900MW in 2019.



Confidential

Use Case: AC/DC Hybrid Micro-grid System

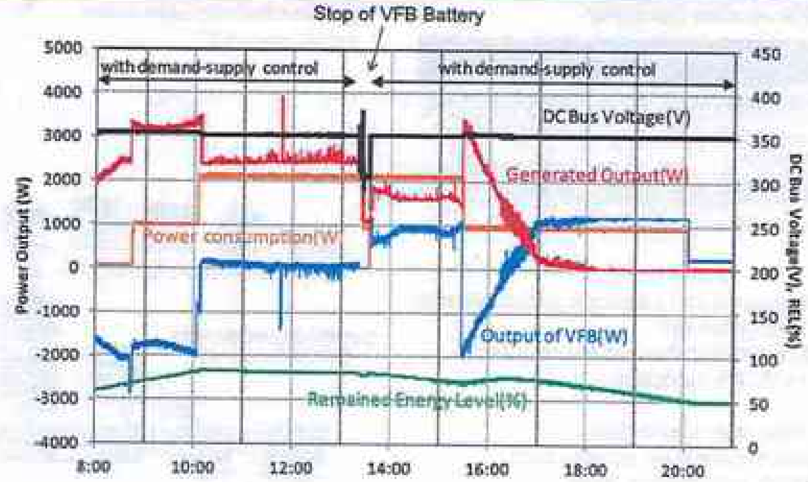
Power sources are all Renewables



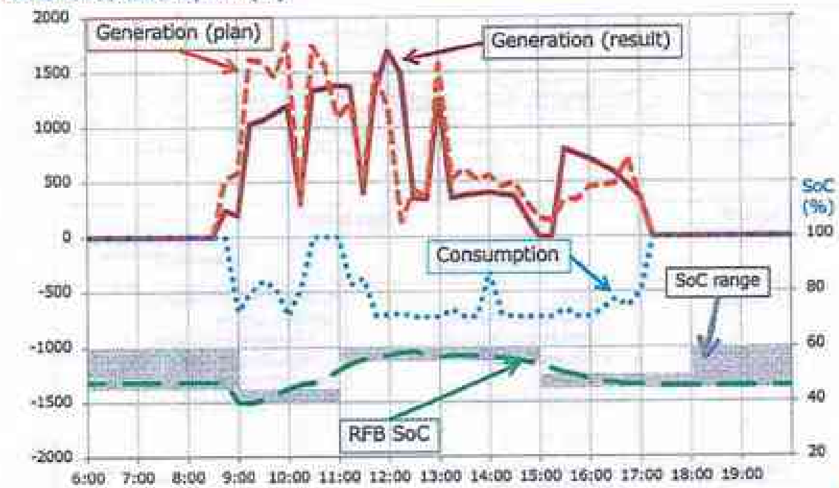
Concepts

- ✓ Independent power grid system from commercial power grid
- ✓ Stable use of renewable energy by using Vanadium Flow Battery
- ✓ Efficient use of power through DC- Link
- ✓ Working with Demand Management System to keep minimum SoC

Use Case: AC/DC Hybrid Micro-grid System



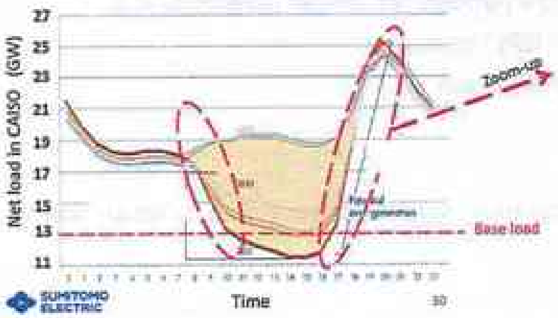
Use Case: AC/DC Hybrid Micro-grid System

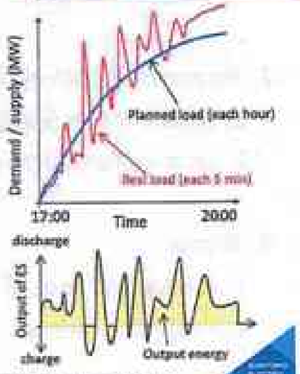


SUMITOMO ELECTRIC

Use Case: Demonstration Project in California

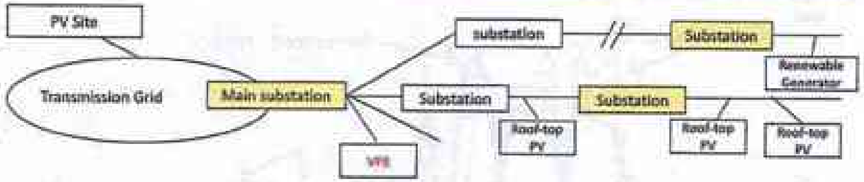
- ✓ Joint demonstration project with a utility in California
- ✓ **2MW x 4H** system in utility's substation
- ✓ Expected to be commissioned in middle of 2016.
- ✓ To demonstrate VFB can be used for both fast response and long duration applications and would be the best solution to address issues caused by increased use of renewable energy resources.





SUMITOMO ELECTRIC

Applications



Active(P) / Reactive(Q)	Applications	
	Distribution	Market (ISO)
Active (P)	Time shift • Renewable time shift • Night to day/peak shift • Congestion relief • Deferral Active power regulation	Energy supply (Time shift) Ancillary service •Frequency regulation •Spinning reserve Resource Adequacy Flexible resource adequacy
Reactive (Q)	Reactive power regulation (Voltage regulation)	

SUMITOMO ELECTRIC

Confidential

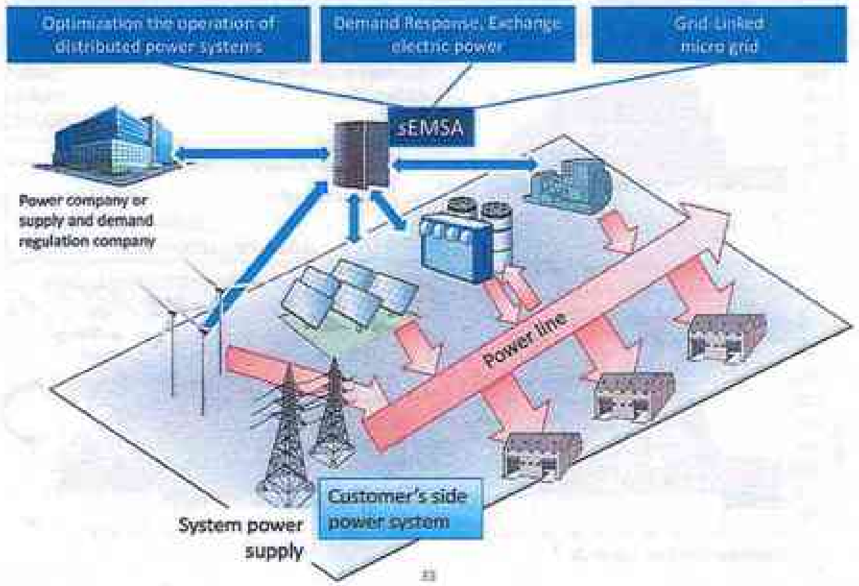
EMS Contents

1. Overview of sEMSA basic functions
   1. sEMSA system overview
   2. Optimal Planning and Dynamic Reallocated Control
   3. Optimizing system configuration
   4. Weather forecast service

2. Proposal of EMS and RFB package for Taiwan isolated island
   1. Smart Power Supply (SPS) system
   2. Grid-Linked micro grid system

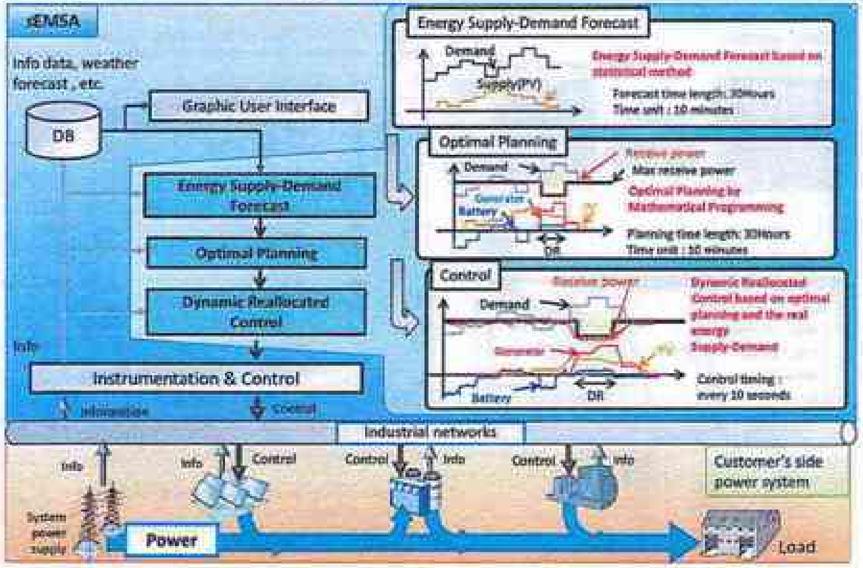
3. Works
   1. A Proposal case of optimum system configuration for smart town
   2. Project Reference

sEMSA System Overview



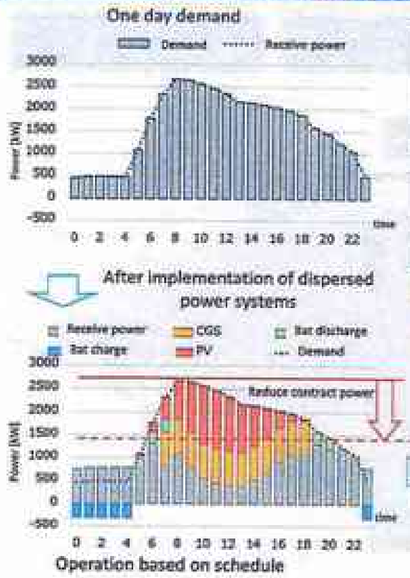
33

Optimal Planning & Dynamic Reallocated Control



34

Optimizing System Configuration



Renewable and Dispersed power systems

Photovoltaic (PV) power system :	1200kW
Gas Engine Generator (CGS) :	750kW
Battery (Bat) :	300kW
	1300kWh

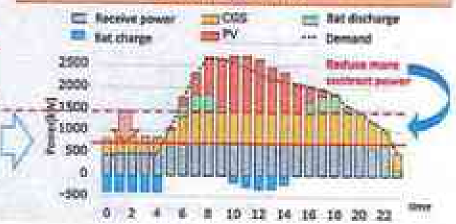
Operation based on schedule

Gas Engine Generator: 7:00~18:00 750kW

Battery :23:00~4:00 Charge

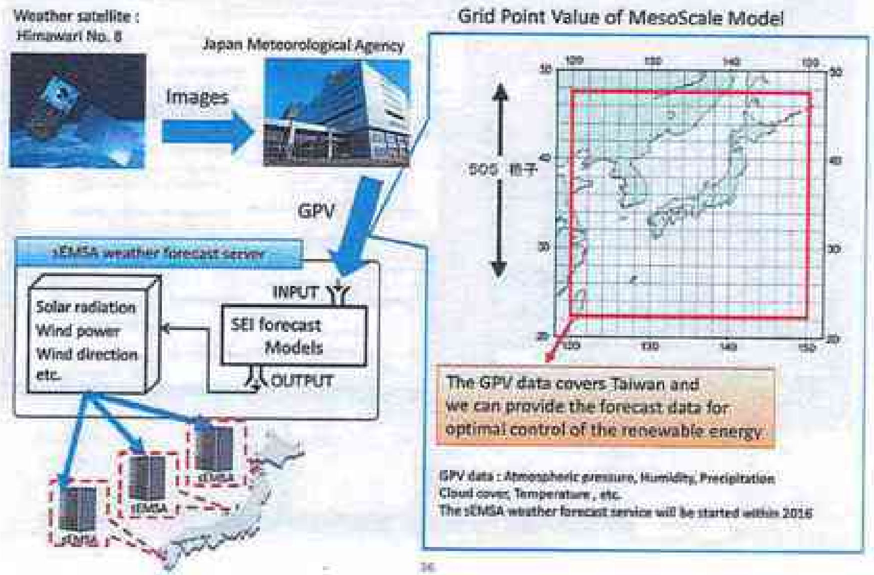
6:00~7:00,19:00~20:00 Discharge

Controlling Renewable and Dispersed power systems by sEMSA



35

Weather Forecast Service



The GPV data covers Taiwan and we can provide the forecast data for optimal control of the renewable energy

GPV data : Atmospheric pressure, Humidity, Precipitation

Cloud cover, Temperature , etc.

The sEMSA weather forecast service will be started within 2016

36

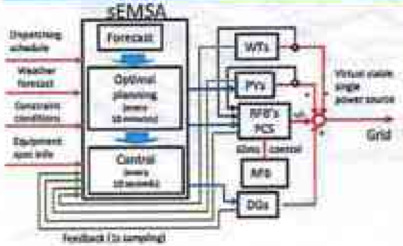
Smart Power Supply(SPS) System

1.Features :

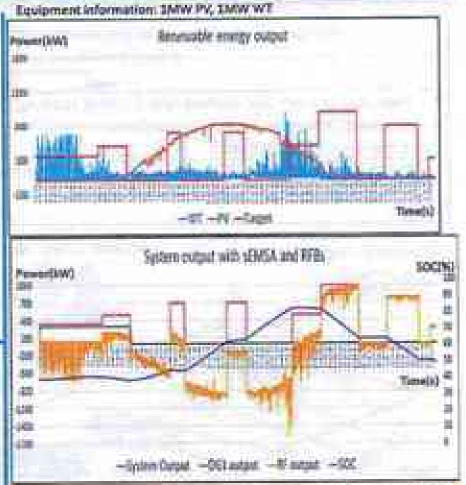
1. A EMS that aggregates Photovoltaic power generation systems (PVs) , Wind Turbine generator systems (WTs), Redox Flow Battery systems (RFBs), Diesel Generator systems (DGs) and controls them to provide as a stable single power source.
2. Able to cooperate with the existed central load dispatching system or run on a dispatching schedule.

2. Use case:

1. Reduce the number of Diesel Generator in the grid by replace Diesel Generator by SPS in order to reduce the power generation cost.



Equipment information: 1MW PV, 1MW WT



Stabilizing fluctuation of renewable energy by sEMSA and RFB provides a stable and complete controllable single power source

Equipment information: 1MW PV, 1MW WT, 300kW DGx1(DG1), 1625kWx7H RF , The RF's SOC control range 10%~90%

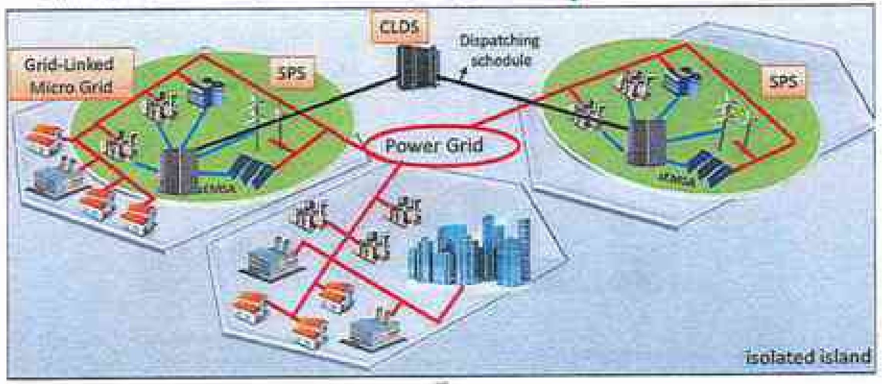
Grid-Linked Micro Grid System

■ Features :

- A EMS aggregates Photovoltaic power generation systems (PVs) , Wind Turbine generator systems (WTs), Redox Flow Battery systems (RFBs), Diesel Generator systems (DGs) and controls them to exchange electric power to other grids while supply power to its own load.
- Able to cooperate with the existed Central Load Dispatching System(CLDS) of the other grid or run on a dispatching schedule.

■ Use case:

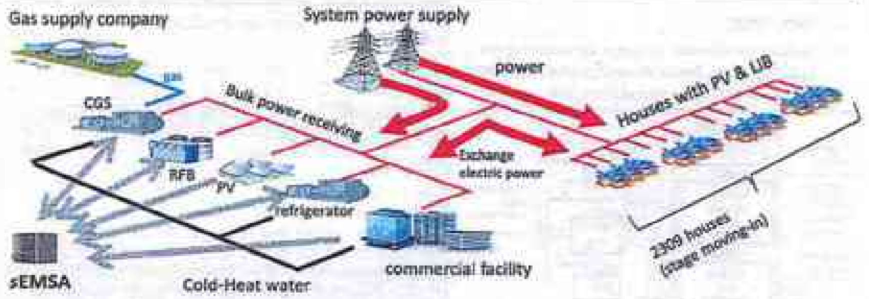
- Optimum power generation cost of a micro grid by renewable energy sources and also able to exchange electric power to other grids.



An Optimizing System Configuration for Smart Town

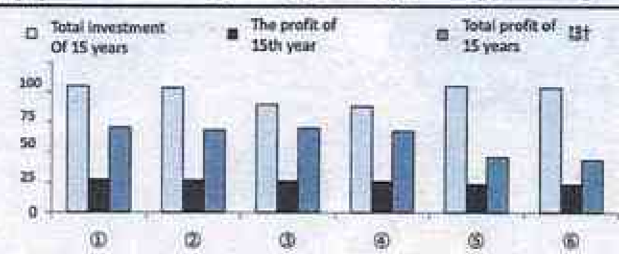
A smart town with renewable energy and dispersed power system is developing by house developer (a 15 years long project)

- Detached houses and commercial facilities is going to build step by step in a 15 years long project .
- Renewable energy and dispersed power system which is optimized capacity and implementation timing is the target of simulation
- The power demand and also the cold-heat demand and the exchange electric power between houses and commercial facilities need to be optimized



Simulation Result (1)

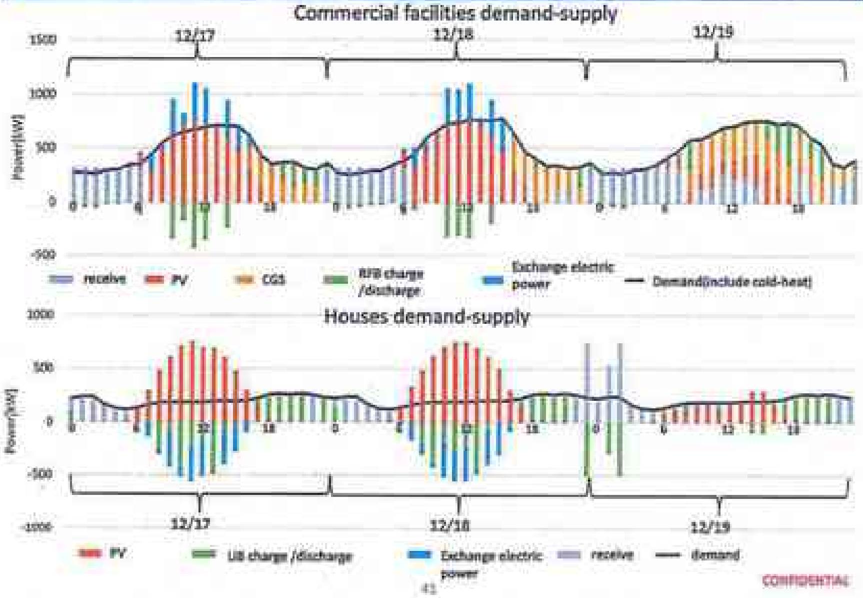
Simulation conditions	①	②	③	④	⑤	⑥
Houses with LIB	Yes	Yes	No	No	Yes	Yes
Exchange electric power	Yes	Yes	Yes	Yes	No	No
Commercial facilities with PV	Yes	No	Yes	No	Yes	No
Total Investment Of the 1st year	26.76	25.34	18.37	16.93	26.76	25.34
Total Investment Of 15 years	100.00	98.57	85.47	84.05	100.00	98.57
The profit of 15th year	25.95	25.73	24.98	24.77	22.86	22.63
Total profit of 15 years	67.06	65.01	66.51	64.34	43.86	41.63
15th year**IRR(%)	13	13	16	16	9	9



*The value of the above table and chart is just for example

**IRR :Internal Rate of Return

Simulation Result (2)



CONFIDENTIAL

Project Reference

http://global-sei.com/news/press/12/prs046_s.html

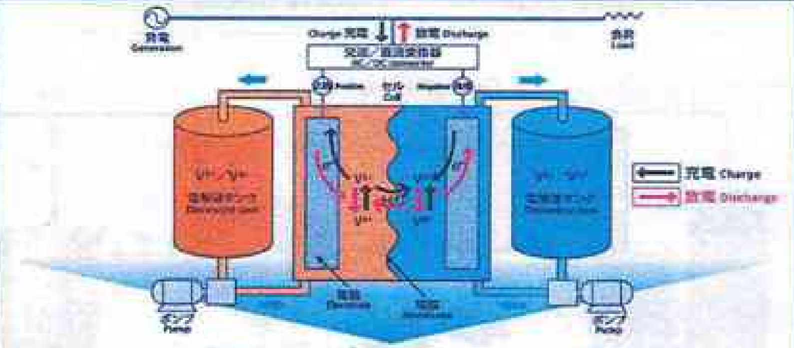
SUMITOMO ELECTRIC

Vanadium Redox Flow Battery System and Applications

Sumitomo Electric Industries
December, 2015

Vanadium Redox Flow Battery - Principle

REDOX: "Reduction" (to gain electron) & "Oxidation" (to lose electron)



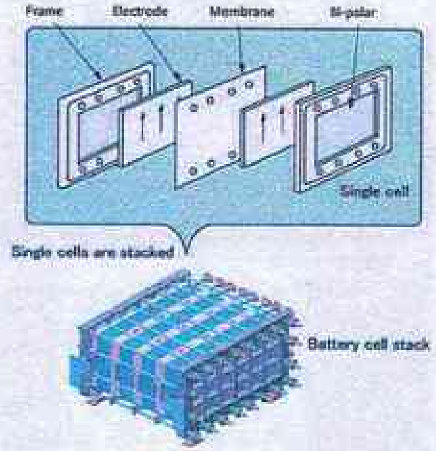
$VO^{2+} + H_2O \rightleftarrows VO_2^+ + e^- + 2H^+$ (Charge / Discharge)

$V^{3+} + e^- \rightleftarrows V^{2+}$ (Charge / Discharge)

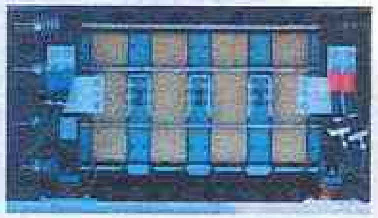
-Utilizing ionic state-of-charge difference of Vanadium Ions in electrolyte

-No degradation of electrolyte occurs during charge/discharge cycle

Cell Stack

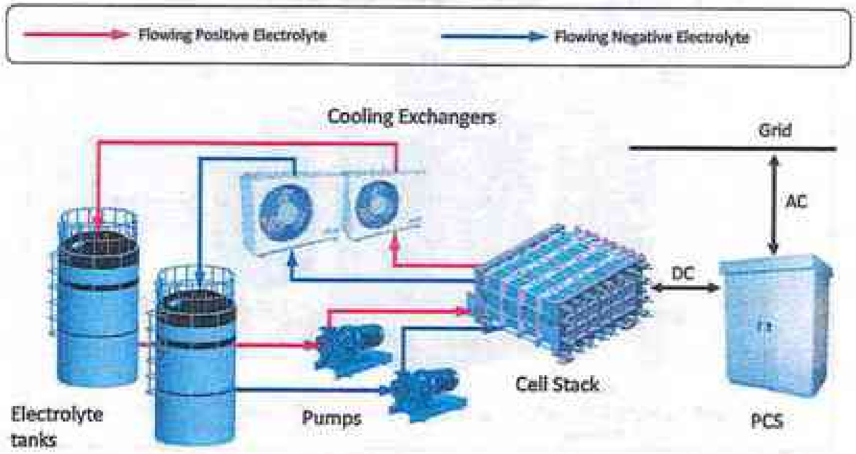


Cell Stack

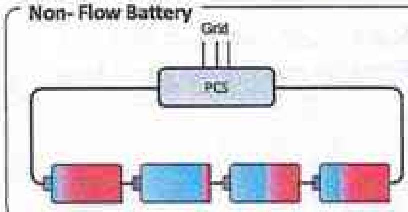


Rated Output: 35kW (DC)
Dimension: $1.0m^W \times 1.2m^L \times 0.6m^H$

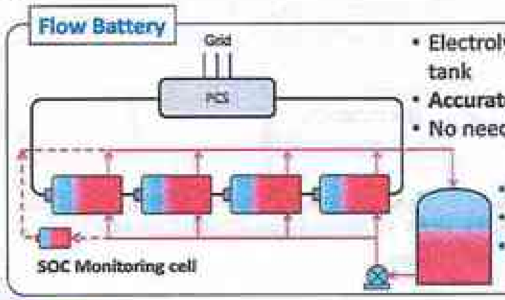
System Configuration



Accurate SOC Monitoring



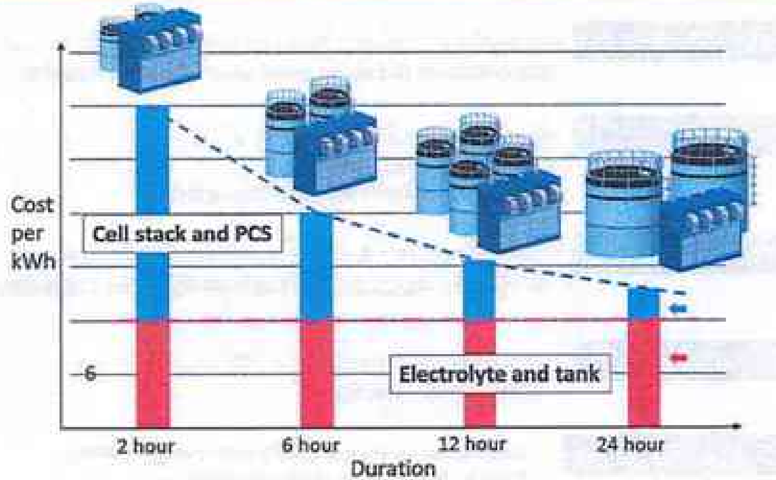
- Electrolyte stored inside individual cells
- Monitoring and Re-balancing SOC among many cells is NOT so simple
- Scale up with large energy is challenge
- To avoid over-charge is important for safety



- Electrolyte stored outside cells in common tank
- **Accurate & Real-time SOC monitoring**
- No need of Re-balancing of SOC

- **Easy operation**
- **Easy scale up with long duration**
- **Wide range of SOC utilization for charge/discharge cycle**

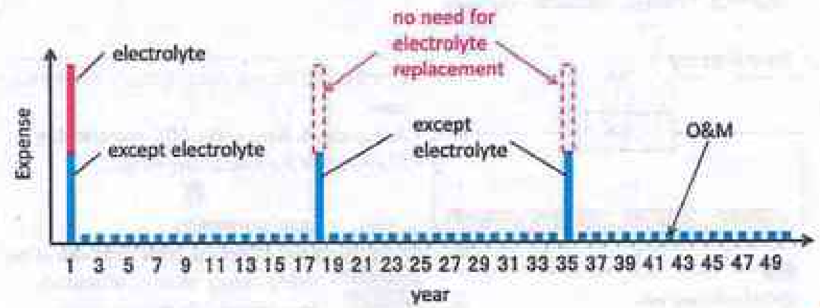
Cost Advantage on Long Duration



Longer duration, lower cost per kWh.

Reuse of Electrolyte within Long-term Operation

➢ Since electrolyte has almost no degradation during charge and discharge, it makes the reuse of electrolyte possible within a long-term operation.



Vanadium Redox Flow Battery - Key Features

1. Long Life Cycle	·Unlimited Charge/Discharge cycle of Electrolyte ·Electrolyte is Reusable even after decommissioning
2. Safety	·Non-flammable Electrolyte ·Flame Retardant Materials ·Accurate and Reliable SOC Management
3. Multi-Purpose	·Fast Response & Long duration Applications → Hybrid Application such as Flexible Capacity
4. Easy Operation	·Accurate and Real-time SOC Acquisition · Room Temp. operation
5. Design Flexibility	· Separation of Power (MW) and Energy (MWh) · Easy to build large-scale systems

Vanadium Redox Flow Battery - Applications

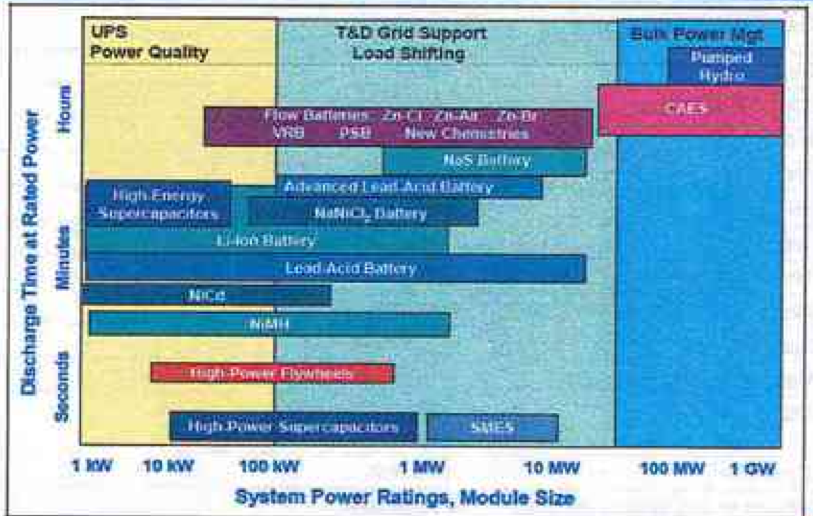
VRFB is suitable to following applications.

- ✓ Time shifting
- ✓ Peak shaving
- ✓ Frequency regulation
- ✓ Reactive power regulation (voltage regulation)
- ✓ Voltage compensation
- ✓ Spinning reserve
- ✓ Black start
- ✓ ……

And following business models.

- ✓ Renewable power generation integration
- ✓ Microgrid (mining, remote community etc.)
- ✓ Demand response
- ✓ Transmission line congestion mitigation
- ✓ Transmission capacity enhancement deferral
- ✓ ……

VRFB's Position among Energy Storage



Source: Electricity Energy Storage Technology Options, EPRI: 2010

Benchmark

Battery variety	SEI VFB	NAS	Lithium ions	Lead acid
Volume of energy	○	○	○	○
Long duration	◎	◎	○	△
Fast responsiveness	◎	○	◎	○
Battery life	○ (17 years)	○ (15 years)	△ (6-10 years)	○ (17 years)
Cycle lifetime	◎ (Unlimited)	○ (4,500 cycles)	○ (3,500 cycles)	○ (3,150 cycles)
Safety	◎	△	△	○
Operating temperature	○ (Room temperature)	△ (Above 300°C)	○ (Room temperature)	○ (Room temperature)
Accurate management of state of charge	◎	△	△	△
Footprint	△	○	◎	△

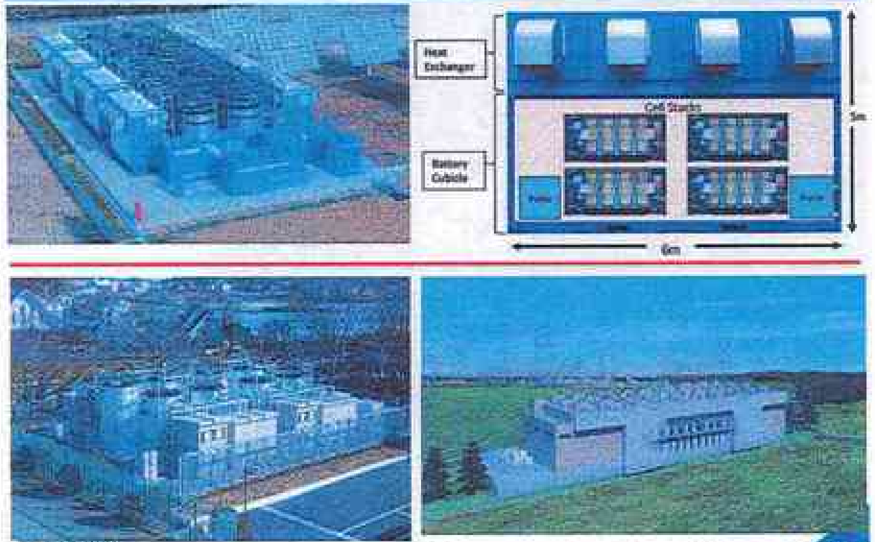
◎Excellent ○Good △Weak

Characteristics

For : 1MW x 4hr system

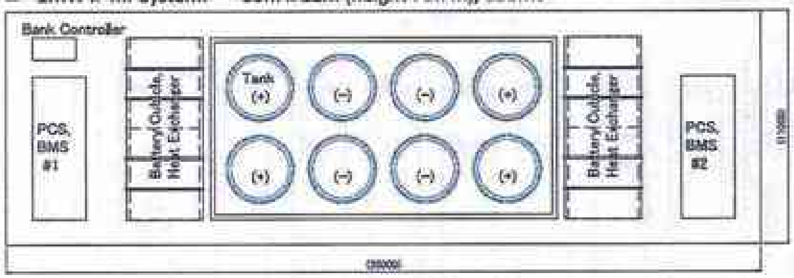
Max Power (Pmax)	1MW
Min Power (Pmin)	-1MW
Max Storage Capacity	4MWh
Ambient Temperature	-5 to +42°C
Min SoC	0%
Time from Min SoC to 100%	5.7 hr
Time from 100% SoC to Min SoC	4hr
Max Ramp Rate (-1MW → 1MW)	10MW/sec
Start up time (Shutdown → Pmin)	<300 sec.
Round trip efficiency (AC)	70% (typical figure)
Designed Life Time	Electrolyte: almost permanent Major components: 20 years
Cycle life	No limit
Efficiency degradation per cycle	Negligible

Plant Type Battery System

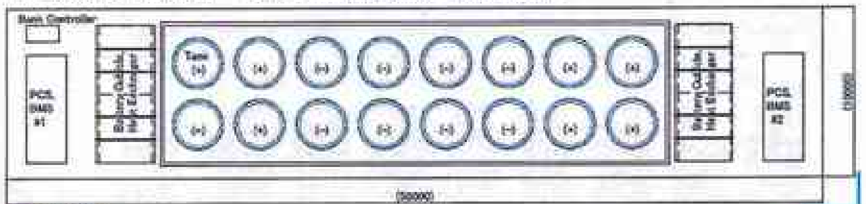


Footprint (Plant Type)

- 1MW x 4hr System: 35m x 11m (height : 6.7m), 650Mt



- 1MW x 8hr System: 50m x 11m (height : 6.7m), 1100Mt



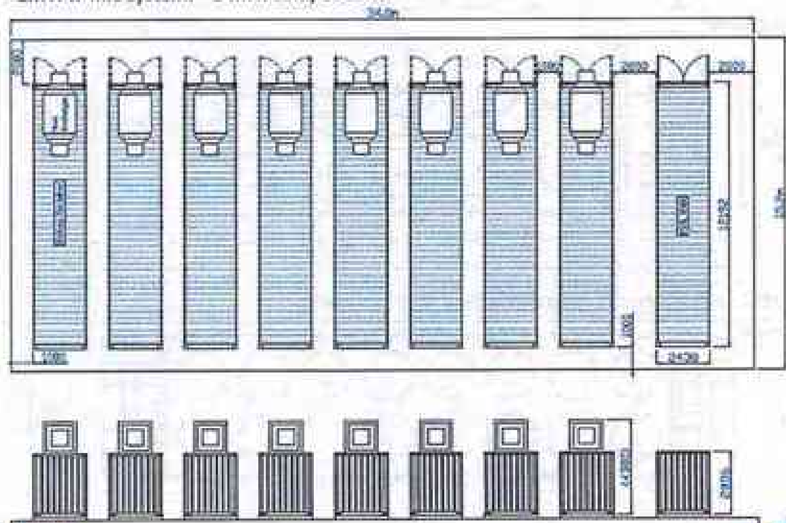
Containerized Solution (from early 2017)

Demonstration @ SEI Osaka Works

Item	Spec
Container	40ft Standard Container
Size (L×W×H)	12.2×2.4×2.9(m)
Capacity	125 kW
Energy	4 hours
Ambient Temperature	-10~40℃

Footprint (Container Type)

- 1MW x 4hrs system: 34m x 15m, 600 Mt



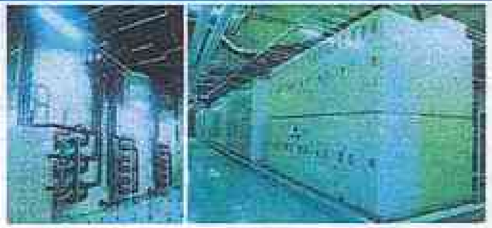
Project Reference: 20+projects, 25MW/92MWh

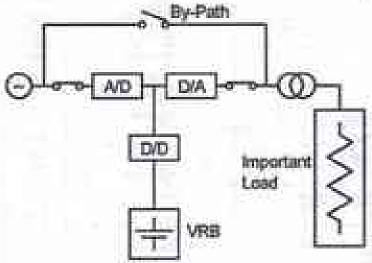
設置先 Customer	用途 Application	出力・容量 Capacity	運転開始
電力会社 Electric power company	研究、実証 R&D	450kW × 2H	1996
オフィスビル Office building	負荷平準化 Load leveling	100kW x 8H	2000
電力会社 Electric power company	研究、実証 R&D	200kW x 8H	2000
NEDO NEDO	風力発電出力平滑化実証(単品) Power stabilization of wind power	170kW x 6H	2000
建設会社 Constructor	研究開発(太陽光とのハイブリッド) R&D with solar panel	30kW x 8H	2001
工場 Factory	瞬低補償、ピークカット UPS, Peak cut	3MW x 1.5sec, 1.5MW x 1H	2001
電力会社 Electric power company	瞬低補償、ピークカット UPS, Peak cut	250kW x 2H	2001
大学 University	負荷平準化、ピークカット Load leveling, Peak cut	500kW x 10H	2001
研究所 Laboratory	負荷平準化 Load leveling	42kW x 2H	2001
電力会社 Electric power company	研究開発 R&D	100kW x 1H	2003
オフィスビル Office building	負荷平準化 Load leveling	120kW x 8H	2003
鉄道会社 Railroad company	瞬低補償、負荷平準化 UPS, Load leveling	30kW x 8H	2003
オフィスビル Office building	研究開発 R&D	100kW x 2H	2003
データセンター Data center	瞬低補償、非常用電源 UPS, Emergency power supply	300kW x 4H	2003
研究所 Laboratory	負荷平準化 Load leveling	170kW x 8H	2004
オフィスビル Office building	負荷平準化、非常用電源 Load leveling, Emergency power supply	100kW x 8H	2004
大学 University	負荷平準化、非常用電源 Load leveling, Emergency power supply	120kW x 8H	2004
博物館 Museum	負荷平準化、非常用電源 Load leveling, Emergency power supply	120kW x 8H	2005
電力会社 Electric power company	研究開発(太陽光とのハイブリッド) R&D with mega solar	100kW x 4H	2005
NEDO Power plant	風力発電出力平滑化実証(ウィンドファーム) Power stabilization of wind power	4MW x 1.5H	2005
住友電工社内 SEI	実証設備(太陽光併設検証) Demonstration with solar panel	1MW x 5H	2012
電力会社 Electric power company	実証設備(太陽光併設検証) Demonstration with solar panel	2kW x 5H	2012
建設会社 Constructor	実証設備(太陽光併設検証) Demonstration with solar panel	[illegible]	2015
電力会社 Electric power company	実証設備(ギガワット、下げ代対策) Demonstration with solar panel	15MW x 4H	2015

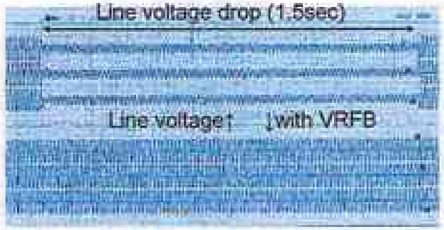
SUMITOMO ELECTRIC

Use Case: Voltage Compensation & Peak Shaving

- ✓ Installed in a semiconductor factory
- ✓ 3MW x 1.5sec, 1.5MW x 1H
- ✓ Compensate voltage drop caused by lightening
- ✓ Peak shaving at normal time



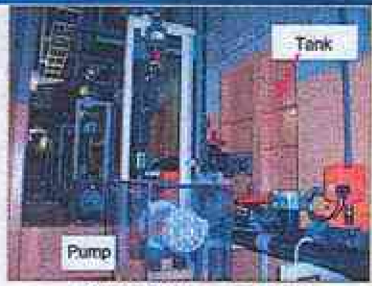




SUMITOMO ELECTRIC

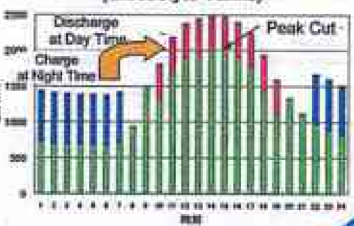
Use Case: Load Leveling

500kW System at an Univ.
(Cell Stack Cubicle)



500kW System at an Univ.
(Electrolyte Tanks)

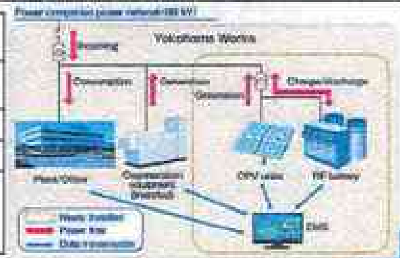
- ✓ Eco campus purpose
- ✓ 500kW x 10H
- ✓ Load Leveling
- ✓ 2001 – 2011



SUMITOMO ELECTRIC

Use Case: Demand Side Management System

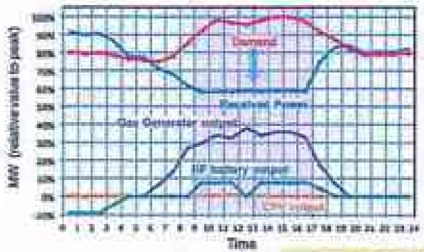
Redox Flow Battery	Max. Output: 1MW Capacity: 5MWh
Concentrator photovoltaic (CPV)	Max. Output: 100kW (7.5kW x 15 units)
CGS	Max. Output: 3.6MW
EMS	Developed by SEI
Applications	Renewable Firming, Peak Shaving, Demand Response (DR) (Yokohama Smart City PJ)



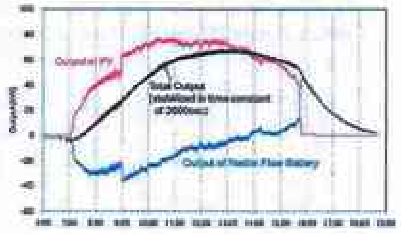
SUMITOMO ELECTRIC

Operation Mode

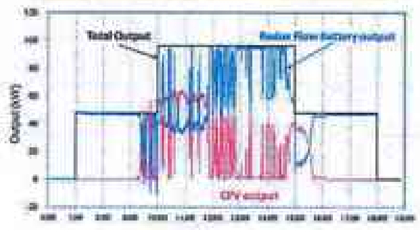
A. Load Leveling/Peak shaving



B. Stabilizing Fluctuation



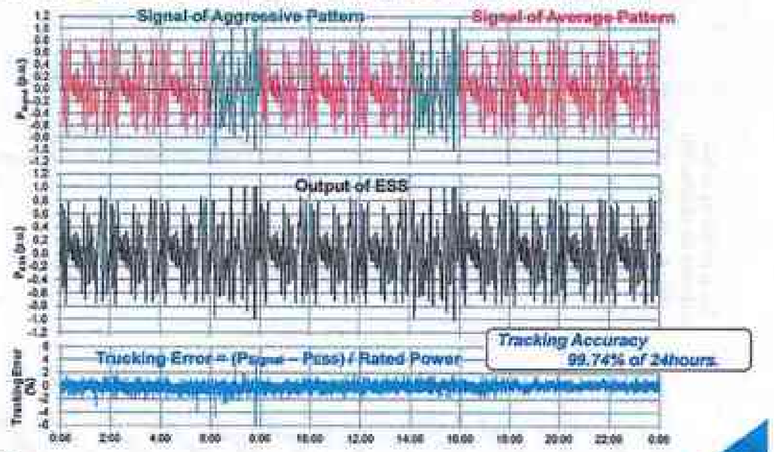
C. Scheduled Power Generation



Operation Mode

➢Frequency Regulation Test (PNNL-22010 Rev.1) is performed in "Yokohama" system. (Using a Bank (#3), Rated Power is 250kW)

➢The system was controlled for one day by external command continuously.

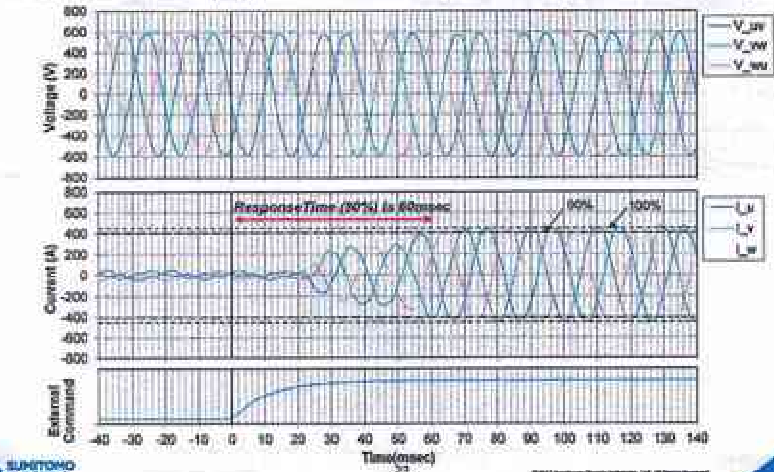


Response Time

➢Response Time of Flow Battery << Response Time of PCS

➢System Response is the Issue of PCS & System Design (not Battery Issue)

➢Measurement Example (Data of "Yokohama" System Bank#2, Rated Power 250kW)

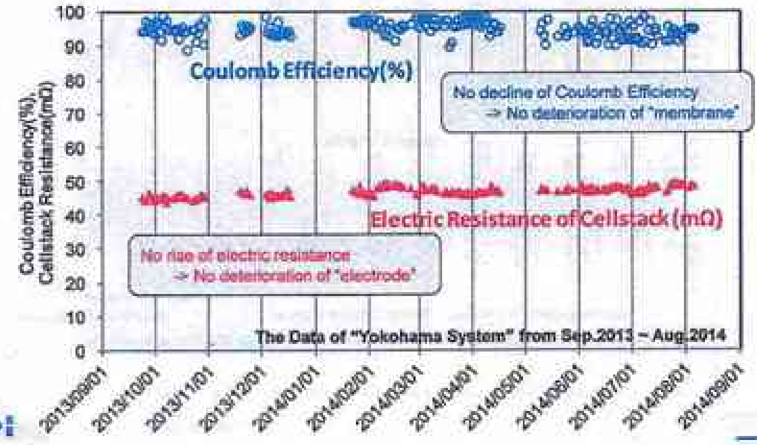


Continuous Long Term Performance

➢Long term performance test is undergoing in "Yokohama" system.

➢In operation of 1 year, there is no significant deterioration.

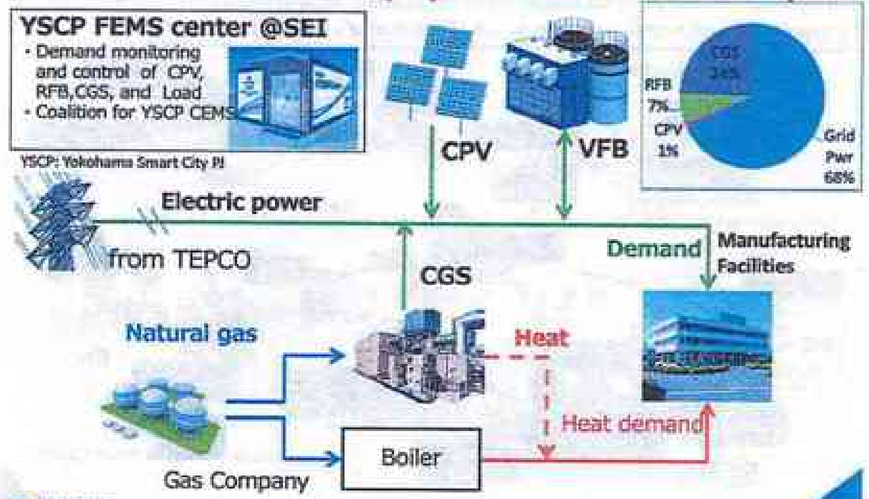
(The decrease of system efficiency and capacity caused mainly by "deterioration of membranes", and "deterioration of electrodes".)



SUMITOMO ELECTRIC

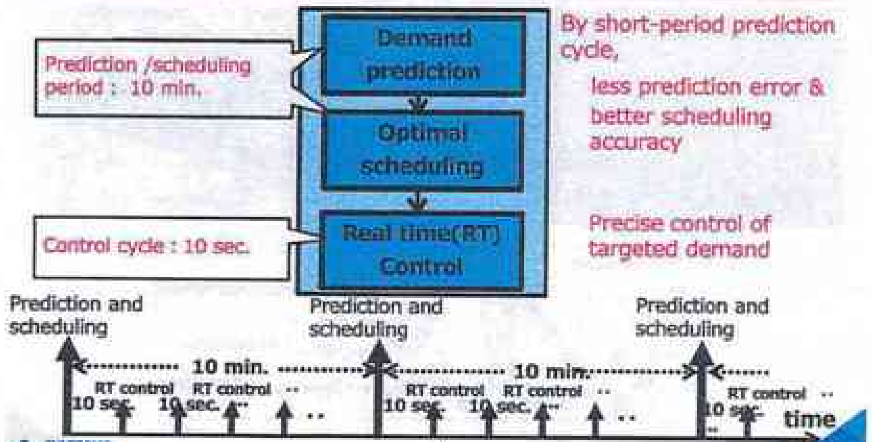
EMS & Demand Side Management in Factory

FEMS: optimal control of multiple power sources & Demand Response



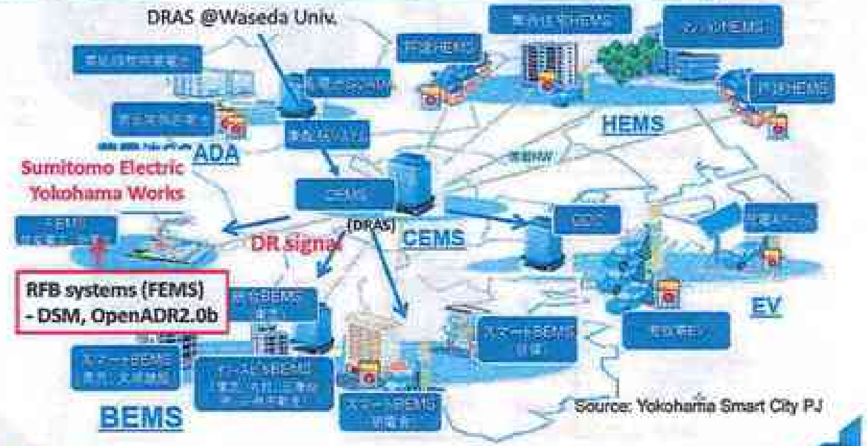
Demand Optimization & Real Time Control by sEMSA®

Short-period Demand Prediction & Scheduling cycle enables better accuracy of scheduled output of power sources, and **Real-Time control** achieves precise targeted demand to optimize an incoming contract power from Utility.



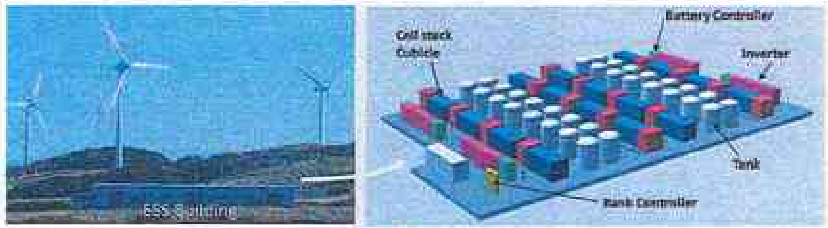
Yokohama Smart City national PJ (YSCP)

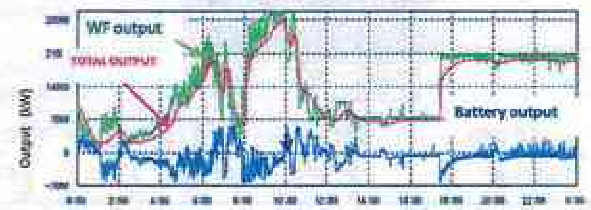
- City scale trial of Demand Response Service under support of Utility
- Aggregation of Home, Apartment, C&I (Sumitomo's Factory) and PEV



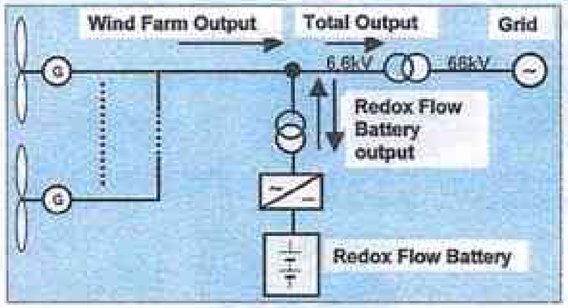
Use Case: Renewable Generation Firming

Tomamae Wind Villa National PJ (J-POWER, funded by NEDO)
- Stabilizing Wind Turbine's total output of 31MW
- VFB System: 6MWh (4MW x 1.5hr)

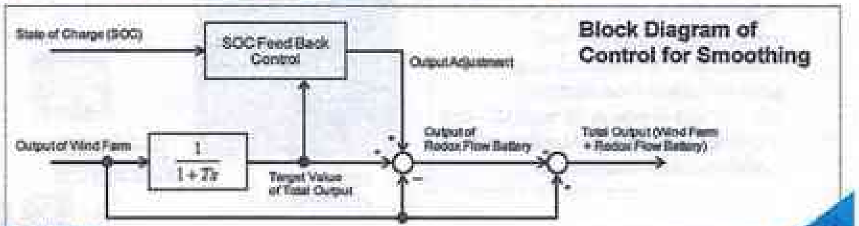




Use Case: Renewable Generation Firming (Control Method)



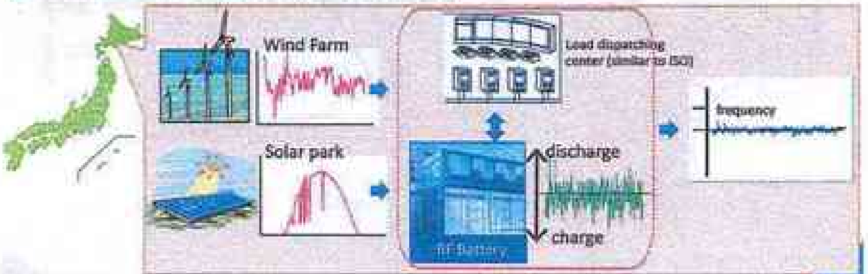
Conceptual Diagram of Interconnection to Grid



Block Diagram of Control for Smoothing

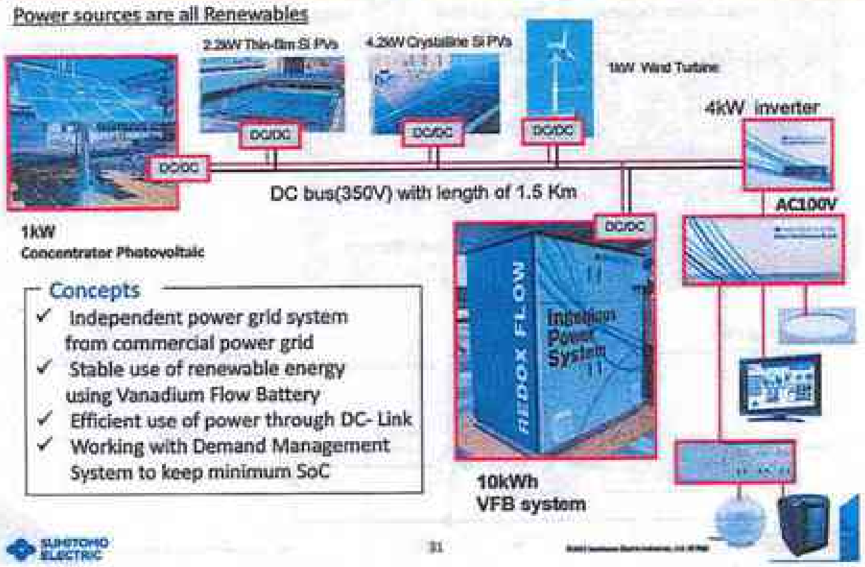
Use Case: Grid ESS for Hokkaido Electric Power Co.

- ➢ Funded by Japanese government
- ➢ Capacity : 15 MW
- ➢ Energy : 60 MWh
- ➢ Location: Substation of HEPCO
- ➢ Application: Multi-purpose
  - Frequency control
  - Surplus power adjustment



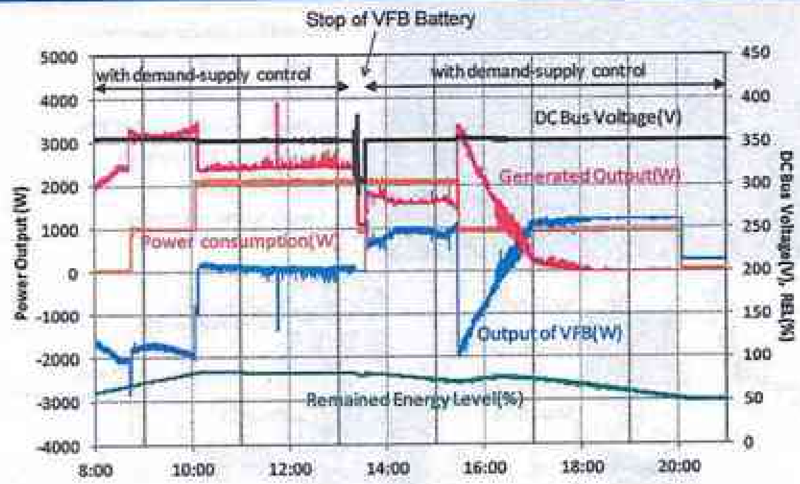
Use Case: AC/DC Hybrid Micro-grid System

Power sources are all Renewables



Concepts
- ✓ Independent power grid system from commercial power grid
- ✓ Stable use of renewable energy using Vanadium Flow Battery
- ✓ Efficient use of power through DC- Link
- ✓ Working with Demand Management System to keep minimum SoC

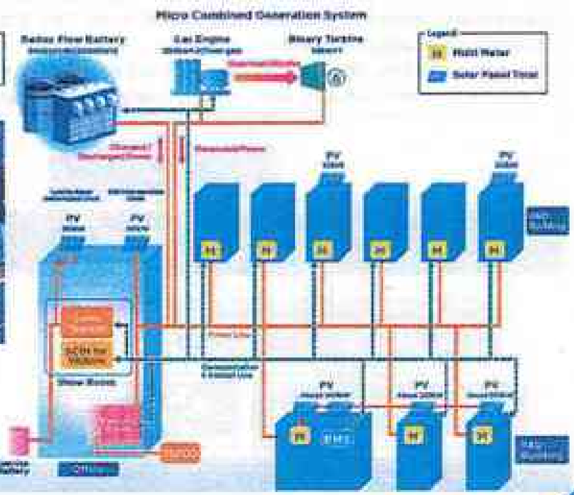
Use Case: AC/DC Hybrid Micro-grid System



Use Case: Smart Building

Obayashi Corporation

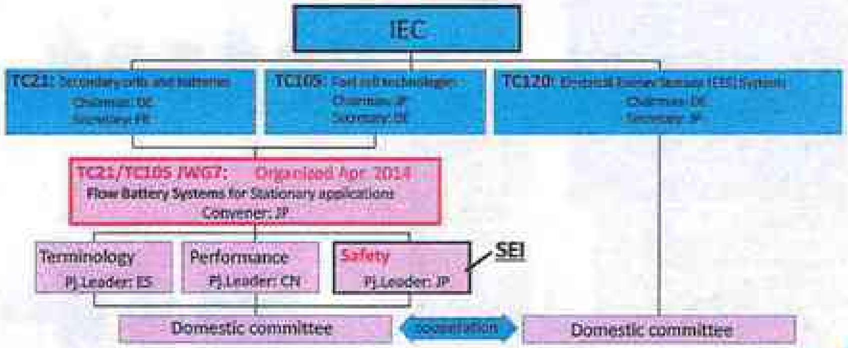
Output capacity	500kW,3MWh



Application
- Peak shaving / time shifting
- Storage of PV surplus generation
- Measure for outage (autonomous operation with RE&DG)

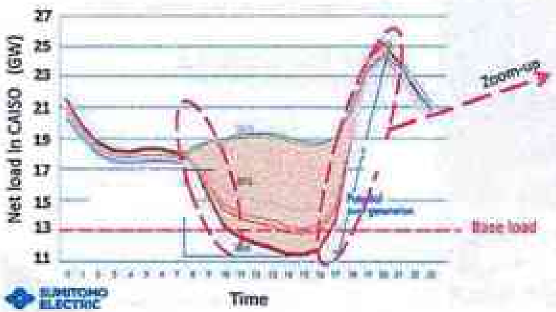
Contribution to International Standardization Activity

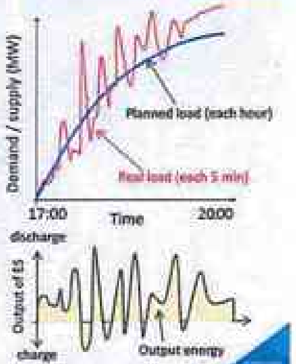
Importance to make quality/safety standards of Redox Flow Battery so that...
- Customers can adopt safe and secure system
- Lower the cost thru. harmonizing standards and certification system btw. countries
- Promote its related industry such as parts/materials by unifying system design.



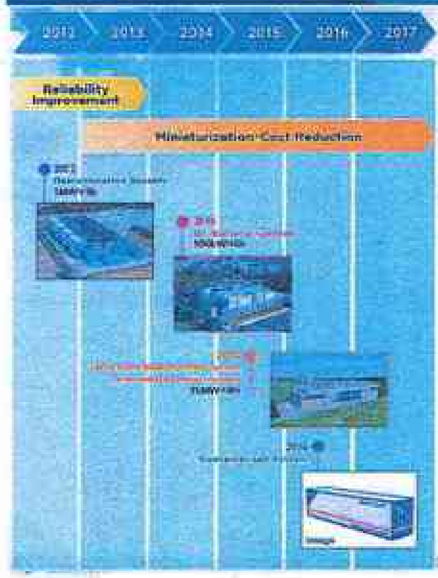
Use Case: Demonstration Project in California

- ✓ Joint demonstration project with San Diego Gas & Electric Company and supported by mutual governments.
- ✓ 2MW x 4H system in a substation
- ✓ Expected to be commissioned in middle of 2016.
- ✓ To demonstrate VFB can be used for both fast response and long duration applications and would be the best solution to address issues caused by increased use of renewable energy resources.





Road Map for VFB



Contact person:

Kelvin MOU
Infrastructure Business Promotion Div.
Sumitomo Electric Industries, Ltd.

Email: mou-ka@sei.co.jp
Tel: +81-6-6220-4170

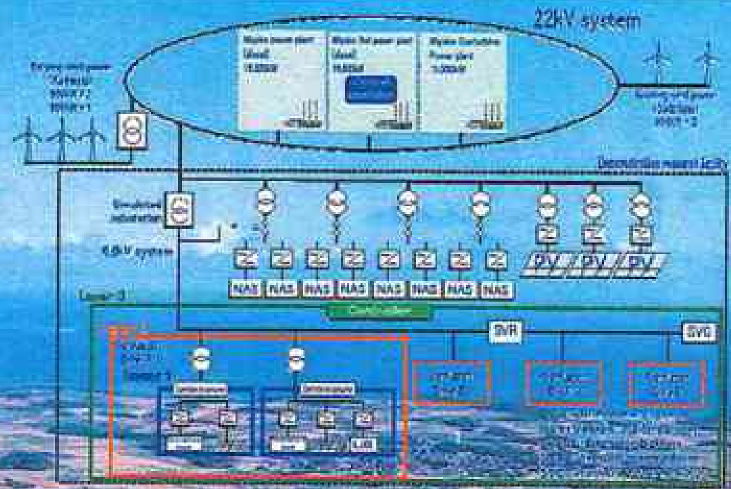
附錄二

NGK 相關資料

Overall View of the Miyako Island Mega-Solar Demonstration Research Facility

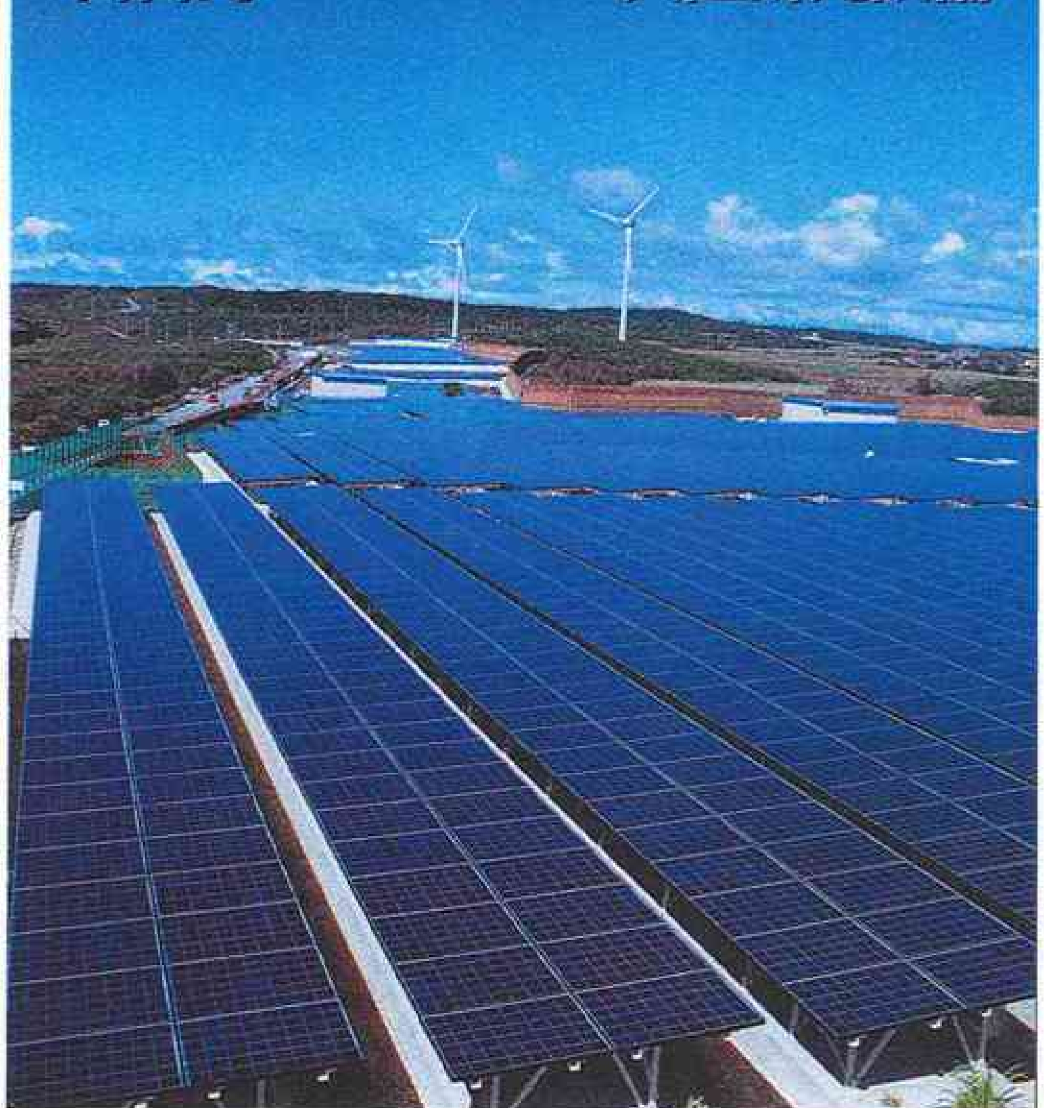
The OEPC are committed to evaluate the impact on the power system, caused by extensive introduction of Photovoltaic equipment into the Independent Grid of isolated islands, which are different in size. Furthermore, we are making validation research on stabilization of power system, by analyzing the operation data of the Photovoltaic equipment and storage batteries.

We are entrusted with subsidies for this research under Demonstrative Project of Renewables on Off-Islands with Small Independent Grid in 2009 from the Ministry of Economy, Trade and Industry.



Location of the demonstration research facility	: Miyako island
Coverage of the PV system	: 8%
Capacity of the system	: Approx. 50,000 kW
Newly established PV system	: 4,000 kW
New electric storage device	: 4,000 kW (NAS)
	100 kW (LiB)
Estimated CO2 emission reduction with the new PV system	: Approx. 4,000t/yr
Existing internal combustion power generation facility	: 74,000 kW
Existing facility owned by New Energy Development	: Wind power 4,200 kW
Area of the site	: 38,023 m²
Area of PV panels	: 28,771 m²
PV panels	: [illegible]

宮古島メガソーラー実証研究設備



地域とともに、地域のために

沖縄電力

宮古島メガソーラー実証研究設備の概要

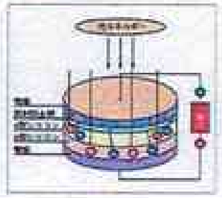
1. 宮古島の発電設備

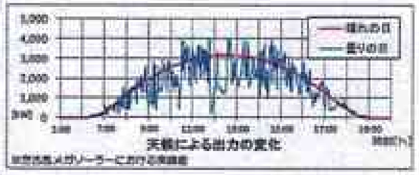
平成26年5月現在

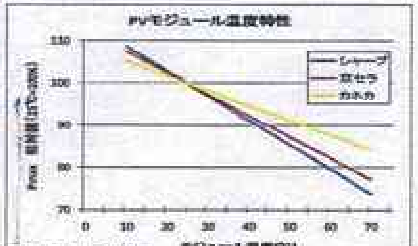
2. 太陽電池の原理・パネルの種類と特徴

太陽電池は、一般にp型とn型のシリコンを接合した半導体から作られており、これに太陽光があたると正の電荷と負の電荷が発生します。正の電荷はp型へ、負の電荷はn型へ分離され電極に電圧が生じ、電極間に負荷を接続すると電気が流れます。

天候によっては、太陽光発電出力は大きく変動し、電圧や周波数等、電力の品質に影響を及ぼす可能性があります。







※メーカーカタログ値

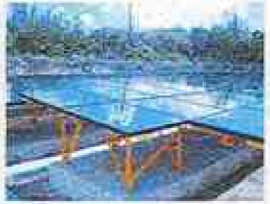
種類	多結晶シリコン		薄膜シリコン
メーカー	シャープ	京セラ	カネカ
変換効率※(モジュール)	14.7%	14.0%	9.2%
最大出力※(モジュール)	190W	208W	115W
特徴	コストと性能のバランスが良く、現在の主流となっている。		高温時も出力が落ちにくい特性を持っている。

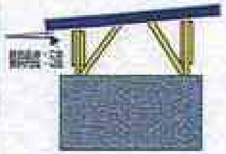
※変換効率、最大出力はメーカーカタログ値

一般的に太陽光はモジュール温度(外気温)が上昇すると、出力が低下します。多結晶(シャープ、京セラ)と比較して、薄膜(カネカ)はモジュール温度が上昇しても相対的な出力低下が小さくなります。

3. 太陽光パネルの台風対策等

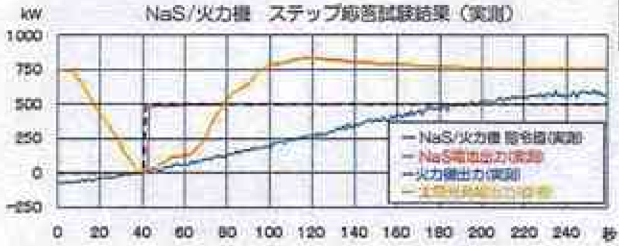
① 台風常襲地域であるため、太陽光パネル架台の強度は基準風速46m/秒（瞬間最大風速73m/秒を考慮した強度）としています。
② 強風からの対策と設置面積低減の為、太陽光パネルの角度を設置角度を5度としています。
③ 塩害対策の為、太陽光パネルおよび架台は、重耐塩塗装仕様としています。





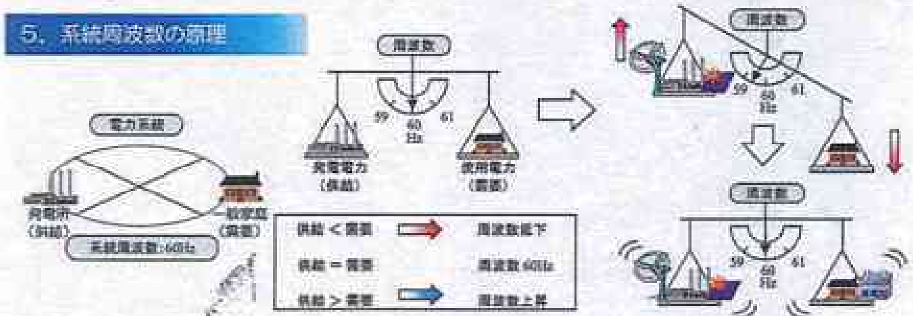
4. ナトリウム硫黄電池（NaS電池）の特徴

ナトリウム硫黄電池（NaS電池）は、ナトリウムと硫黄を電極とした二次電池です。大容量化の実績があり、自己放電も無く、高出力（放電時間：定格出力で7.2時間）、高エネルギー密度（鉛蓄電池の約2～3倍）、小スペース（鉛蓄電池の1/3）という特徴があります。
また、ナトリウムと硫黄は液体の状態で使用するため、ヒーターによる内部電池の温度保持（300℃程度）が必要です。



NaS電池の応答性能
NaS電池は応答速度が速いため、火力機では追従できない太陽光発電の急峻な出力変動を吸収し、系統周波数への影響を緩和することができます。

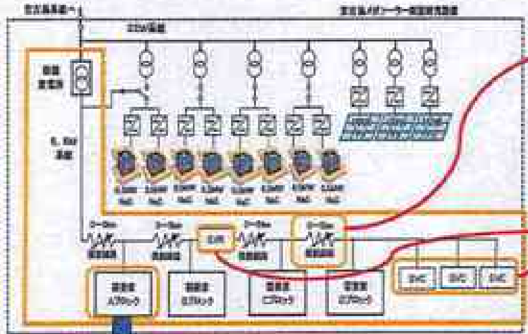
5. 系統周波数の原理



電力の安定供給のためには、需要と供給を時々刻々あわせる必要があるため、発電所（供給）の出力をきめ細かく調整することで周波数を一定（60Hz）に保っています。
供給が需要より小さくなった場合には、周波数は低下してしまい、逆に供給が需要より大きくなった場合には、周波数が上昇してしまいます。需要と供給のバランスが大きく崩れ電力の品質が保持できなければ周波数を一定に保てず、工場などの製品の品質に影響を及ぼす等、電力の安定供給ができなくなる場合があります。
太陽光発電や風力発電などの再生可能エネルギーは、天候により出力が変化し需要と供給のバランスを崩してしまうことがあるため、蓄電池を用いた系統安定化対策の実証を宮古島で実施しています。

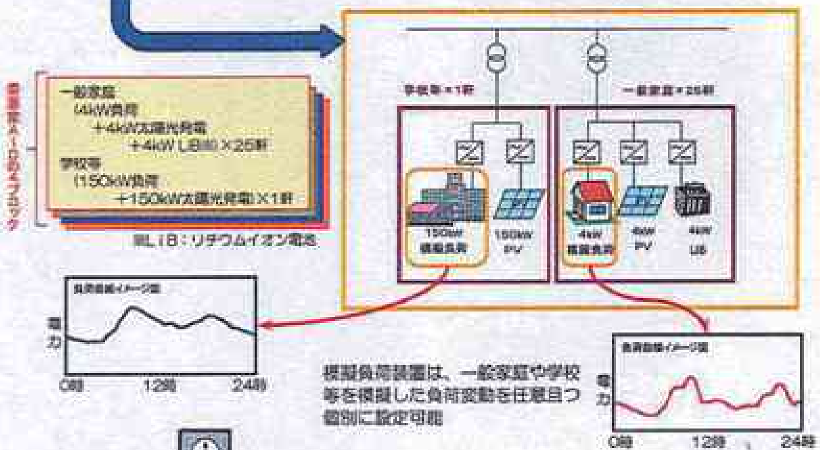
6. 模擬配電系統の特徴

配電系統に太陽光発電が大量導入された場合の影響を把握し、系統安定化対策を実証するため、太陽光発電が併設された一般家庭100軒および学校等4軒が接続する配電系統を模擬できるシステムを導入しました。

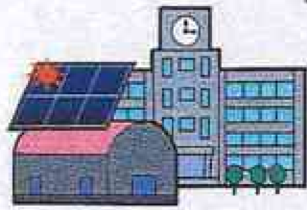


模擬配電系統の線路総長を0km～20kmで任意に設定でき、様々なケースを模擬可能

SVR,SVCにより太陽光発電の出力変動時も配電系統の電圧を維持
PV：太陽光発電設備
NaS：ナトリウム硫黄電池
SVR：自動電圧調整装置
SVC：無効電力補償装置



模擬負荷装置は、一般家庭や学校等を模擬した負荷変動を任意且つ個別に設定可能



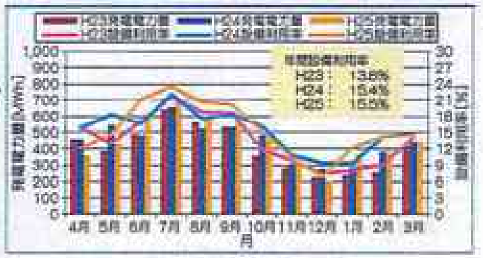
一般家庭は蓄電池(4kWリチウムイオン電池)の併設有無を個別に設定可　※最大25軒まで

7. 太陽光発電電力量の推移

夏季は太陽光発電電力量および設備利用率※が高いですが、日照時間が短くなる冬季は低くなっています。

年間設備利用率は15%前後となっており、国内における太陽光発電設備の一般的な年間設備利用率（約12%）を上回る結果となりました。

※年間設備利用率
＝年間発電量 ÷（定格出力×24時間×365日）

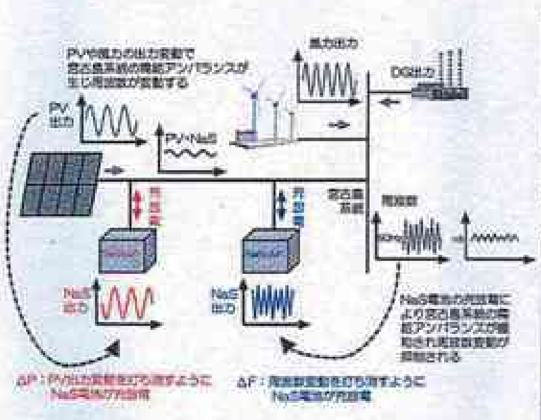


太陽光発電電力量の推移

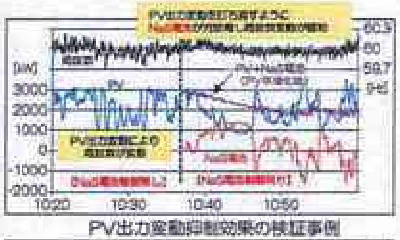
8. 実証研究内容

a.PV出力変動抑制効果の検証
PVの急峻な出力変動を平滑化するような制御機能の検証および蓄電池所要量を明らかにする。

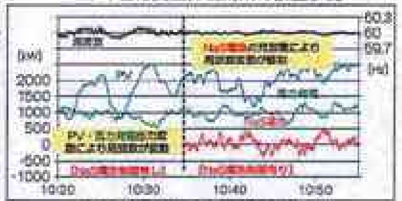
b.周波数変動抑制効果の検証
内燃力発電機の周波数制御に加え、蓄電池による周波数制御機能の検証および蓄電池所要量を明らかにする。



PV出力変動抑制および周波数変動抑制制御の概要

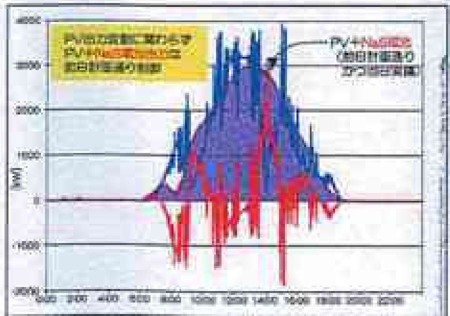


PV出力変動抑制効果の検証事例



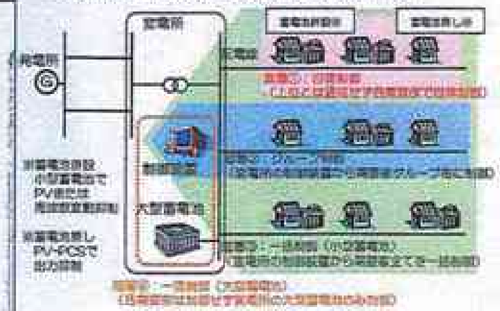
周波数変動抑制効果の検証事例

c.PVのスケジュール運転の検証
PVの出力予測を基に蓄電池＋PVの発電計画を作成し、経済性を考慮したスケジュール運転の実現を目指す。



PVのスケジュール運転の検証事例

d.模擬の配電線路における最適制御階層の検証
一般家庭へのPV大量導入を想定し、各家庭の小型蓄電池（LiB）や変電所の大型蓄電池（NaS電池）による制御等、制御階層別の系統安定化効果を検証する。



模擬配電線路および制御階層の概要

9. 宮古島紹介

沖縄本島より飛行機で約50分

人口	約55,000人　（平成26年4月末現在）
世帯数	約25,000世帯（平成26年4月末現在）
総面積	約205km²
平均気温	23.8℃
主な産業	農業（サトウキビ、タバコ、マンゴー栽培）
	漁業（モズク、クルマエビ養殖、カツオ一本釣り）
	観光業

出典：宮古島市ホームページ、「平成25年度 統計みやこじま」

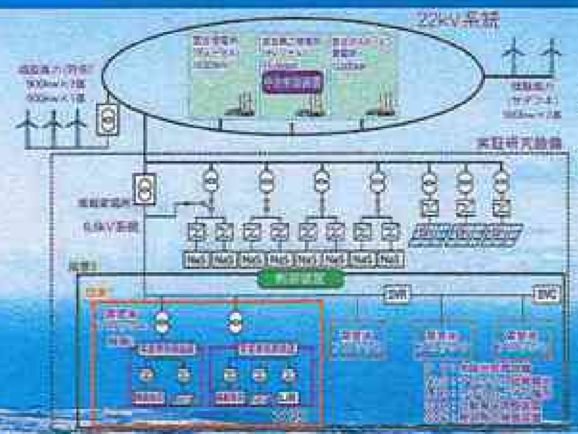
沖縄電力
研究開発部
〒901-2602　沖縄県浦添市牧港5丁目2番1号
TEL 098-877-2341（代表）

2014年5月　改訂（第6版）

宮古島メガソーラー実証研究設備全体図

はじめに

当社は、系統規模の異なる離島の独立型系統へ、太陽光発電設備を大量導入した場合の実系統へ与える影響を把握するとともに、太陽光発電と蓄電池の運用データを解析しながら、系統安定化対策に関する実証研究に取り組んでおります。なお、本実証研究設備は経済産業省の「平成21年度離島独立型系統新エネルギー導入実証事業費補助金」を活用し、構築しました。



設備概要

太陽光発電設備	:	4,000kW
蓄電設備	:	4,000kW、28,800kWh(NaS) 100kW、200kWh(LiB)
推定CO2排出削減量	:	約4,000t/年
用地面積	:	約100,000㎡
太陽光パネル面積	:	約29,000㎡
太陽光パネル枚数	:	21,716枚

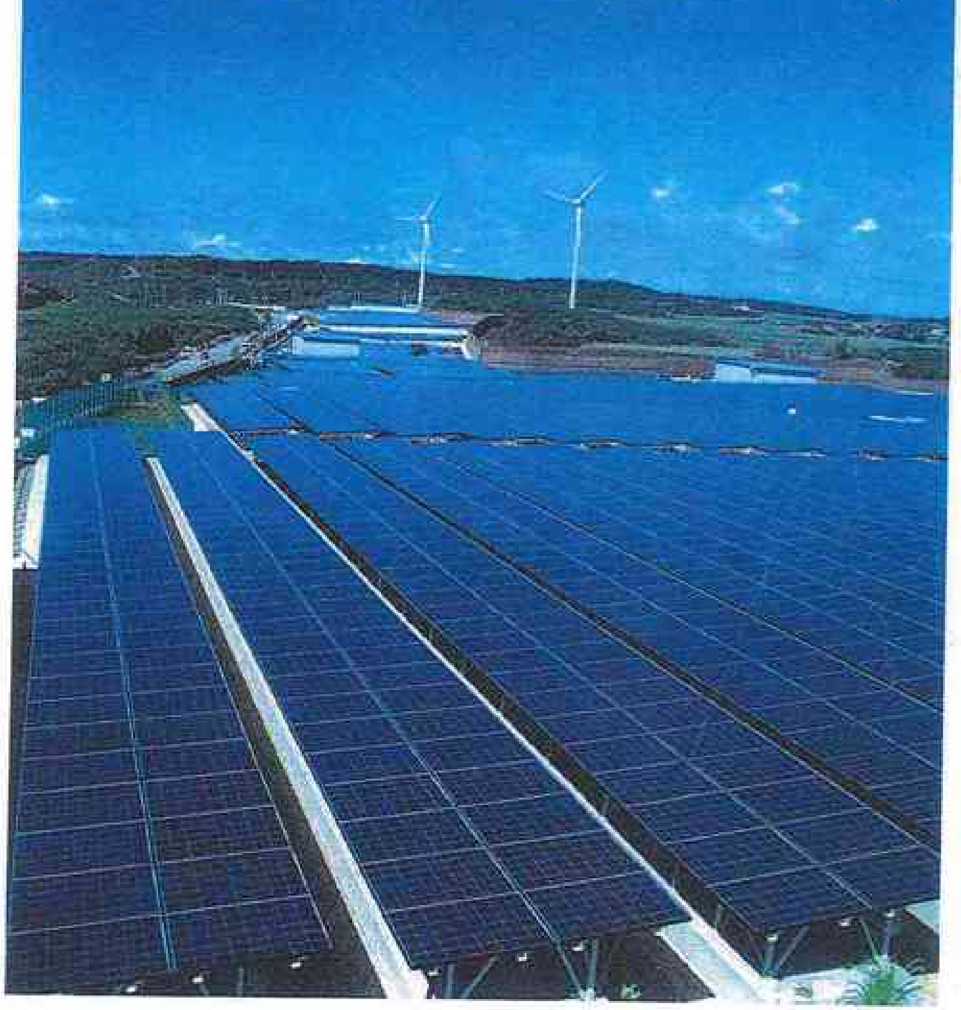
宮古島電力系統概要

内燃力設備	:	89,000kW
風力発電	:	4,200kW
最大需要電力	:	約55,000kW

沖縄電力

教字需更新

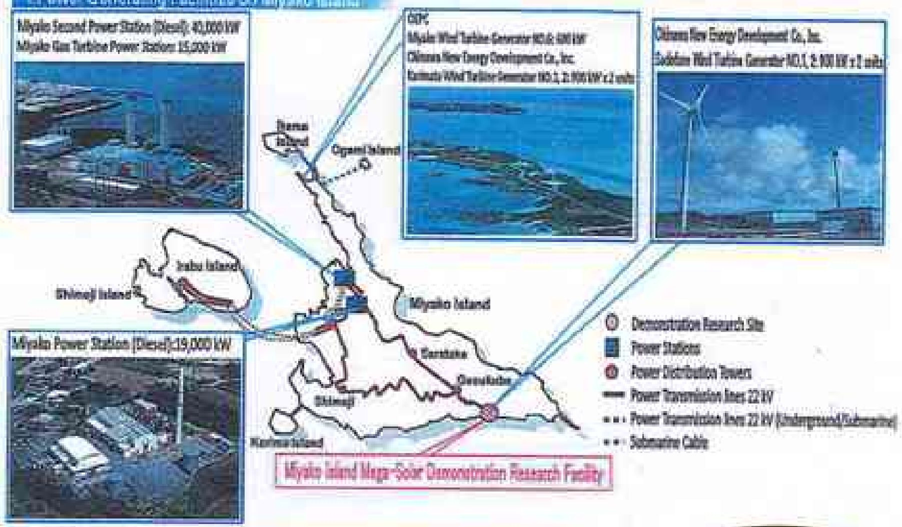
Miyako Island Mega-Solar Demonstration Research Facility



The Okinawa Electric Power Company, Incorporated (OEPC)

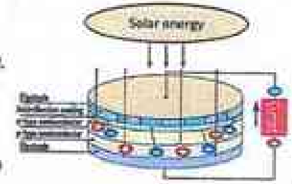
Outline of the Miyako Island Mega-Solar Demonstration Research Facility

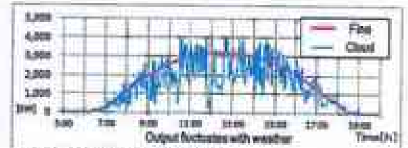
1.Power Generating Facilities on Miyako Island



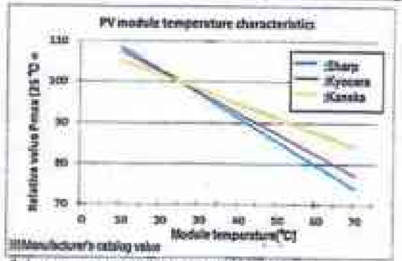
2.The Principle of Solar Cells, and the Types and Characteristics of the Panels

Solar cells are made of the semiconductor junctions of n-type silicon and p-type in general.
Positive charges and negative charges appear when sunlight hits the semiconductor.
Positive charges move to p-type, negative charges move to the n-type, so electromotive force is developed.
And electricity will be flown between the electrodes by connecting to loads. Weather conditions would swing solar power output greatly, this fluctuated output could impact on power quality such as voltage and frequency deviations.





※Actual values in Miyako Island mega solar



※Manufacturer's catalog value

Solar power output decreases with increasing temperature of the module in general.
The decrease rate in thin-film output will be low even if the temperature is increased in comparison with polycrystalline modules.

Characteristics	Polycrystalline silicon		Thin-film silicon
Manufacturer	Sharp	Kyocera	Kaneka
Conversion efficiency※ (per module)	14.7%	14.0%	9.2%
Max.output※ (per module)	198W	225W	115W
Characteristics	Current mainstream techniques because of good cost efficiency.		Less prone to output decline even at high temperatures.

※：Conversion efficiency, the maximum output value of manufacturer's catalog.

3.Typhoon-Resistant Design for Solar Panels

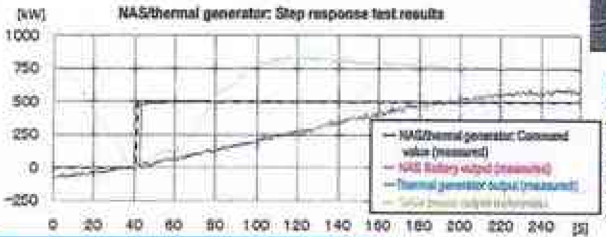
① Since the site is in a typhoon-frequented zone, the PV panel supports were designed with a reference wind velocity of 46 m/sec. (considering a max. instantaneous wind velocity 73 m/sec).

② The installed PV panel inclination is 5 degrees, to protect the facility from strong winds and to minimize the installation area.

③ To avoid salt attack,the PV panel supports were coated with heavy-duty salt-resistant paint.

4.Features of NAS Battery(Sodium-Sulfur Battery)

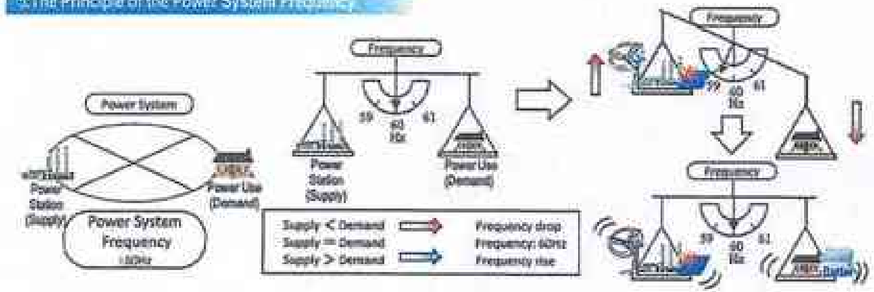
The NAS Battery is a secondary battery with sodium and sulfur electrodes. Large capacity batteries of this type also have been made. The NAS Battery is free of self-discharge, featuring high energy density and high efficiency, small size. It should be noted, however, that it is necessary to maintain specified temperatures in the inner cell by a heater, since sodium and sulfur are used in liquid phase.



Response performance of the NAS Battery

The NAS Battery excellent in response performance can absorb abrupt fluctuations of PV output that cannot be compensated by a thermal generator.

5.The Principle of the Power System Frequency



For stable supply of electricity, there is a need from time to time we adjust the supply and demand equally to maintain nominal frequency (60Hz) constant. In order to do that, we need to fine-tune the output of generators sensitively. If the supply is less than demand, the frequency would decrease if the supply is greater than the demand to reverse, then the frequency would increase.

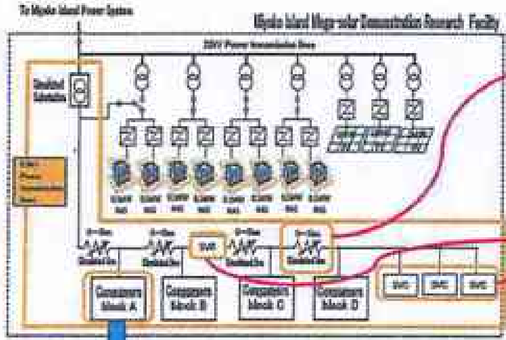
Unless the balance between supply and demand is constant, frequency would be fluctuated.

As a result, power supply would be ceased as huge frequency deviation could affect the quality of the product such as factories. The output powers of renewable energy such as solars and wind turbines are changeable greatly, these fluctuated output could impact on power quality such as voltage and frequency deviations.

We're demonstrating test of systematic stabilization measures using a storage batteries to mitigate their unstable power quality.

6.Features of the Simulated Power Distribution System

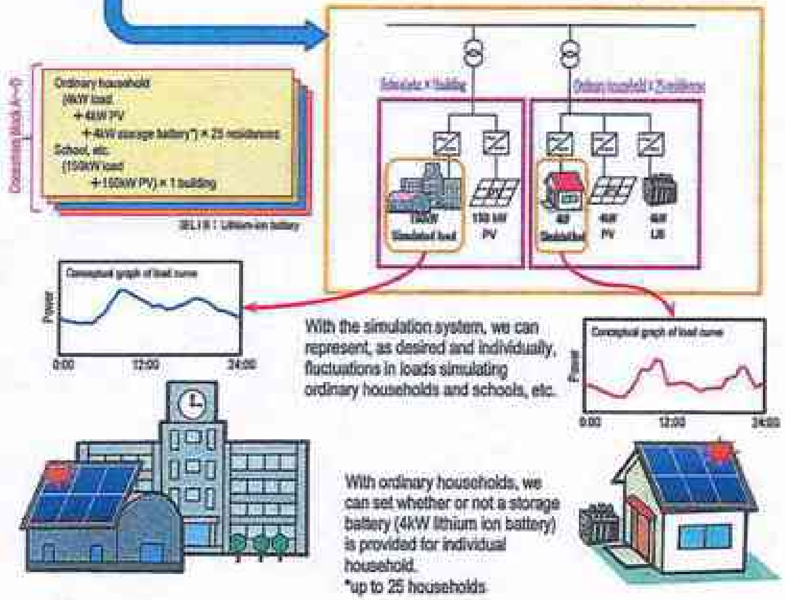
To determine the impact of introduction of a large volume of PV power generation into the distribution system, and to demonstrate the effectiveness of stabilization of the system, a system was created, which can simulate a distribution system provided with PV power generation equipment, serving 100 ordinary households and 4 buildings of school, etc.



The line length of the simulated power distribution system can be set as desired in the range from 0 km to 20 km, representing various cases.

The rated voltage of the distribution system is maintained by the SVR (Step Voltage Regulator) and SVC (Static Var Compensator), even if the PV power output is fluctuating.

PV : Photovoltaic system
NAS : Sodium-sulfur battery
SVR : Step voltage regulator
SVC : Static var compensator



With the simulation system, we can represent, as desired and individually, fluctuations in loads simulating ordinary households and schools, etc.

With ordinary households, we can set whether or not a storage battery (4kW lithium ion battery) is provided for individual household.

*up to 25 households

7. Description of the Demonstration Research

a. Validation of the output fluctuation control effect (storage battery + PV)

·Validate the control effect for smoothing abrupt PV output fluctuations, and determine the required capacity of storage battery.

b. Validation of the frequency fluctuation control effect (storage battery + PV + (existing wind Turbine))

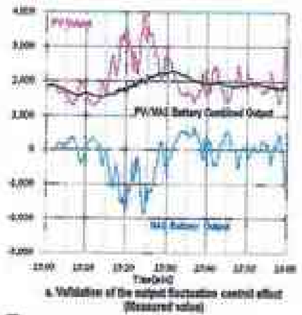
·Validate the frequency stabilizing function of the combination of PV and storing battery (device for actively supporting frequency control), with the frequency control of the existing power source, and determine the required capacity of storage battery.

c. Validation of the PV scheduled operation (storage battery + PV)

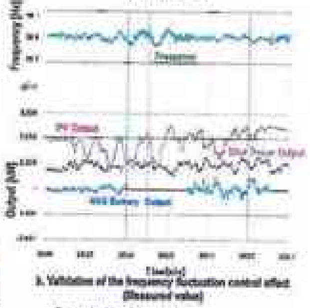
·Study the prediction technique of PV output, and prepare the generation plan based on the predicted PV output and remaining power in the storage battery, for systematic output operation according to the plan.
·Determine the required capacity of storage battery and its operation.

d. Validation of optimum control layers in the simulated distribution line

·In the simulated distribution line, validate the optimum control layers of storage batteries and PV equipment linked to the line.

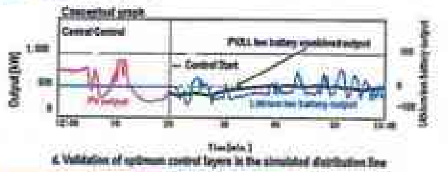


a. Validation of the output fluctuation control effect (Measured value)

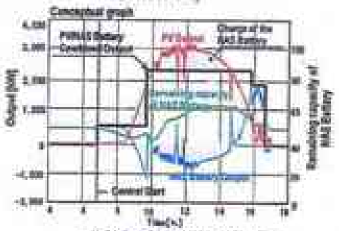


b. Validation of the frequency fluctuation control effect (Measured value)

Cont. : Controller
Conc. : Consumer Control System



d. Validation of optimum control layers in the simulated distribution line

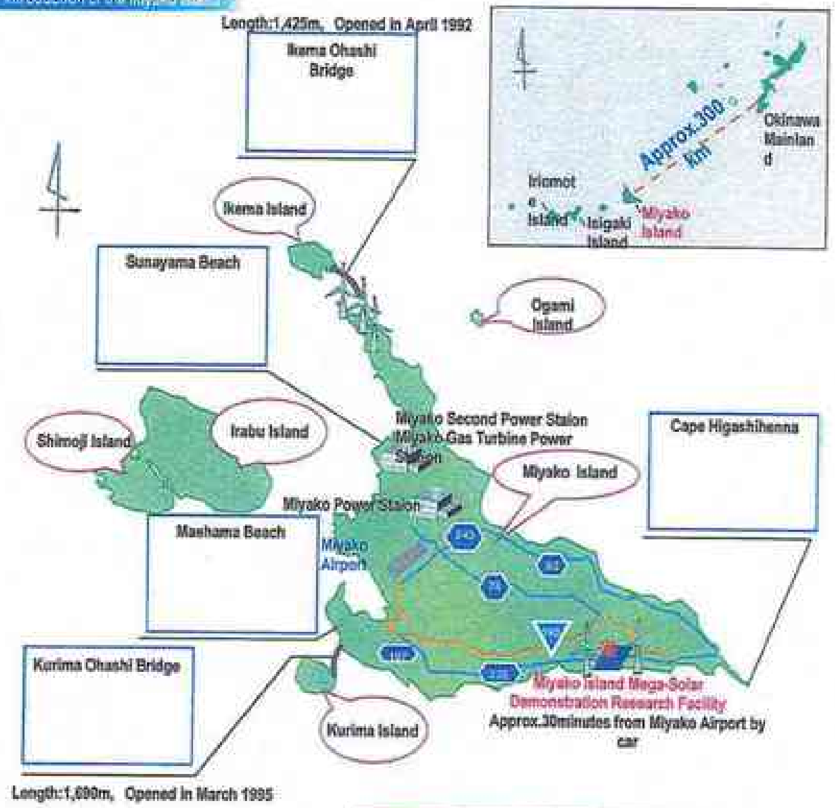


c. Validation of the PV scheduled operation

8. Demonstration Research Schedule

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Manufacture of machinery/equipment installation	■	■			
a. Validation of the output fluctuation control effect		■	■	■	■
b. Validation of the frequency fluctuation control effect		■	■	■	■
c. Validation of the PV scheduled operation				■	■
d. Validation of optimum control layers in the simulated distribution line				■	■

9. Introduction of the Miyako Island



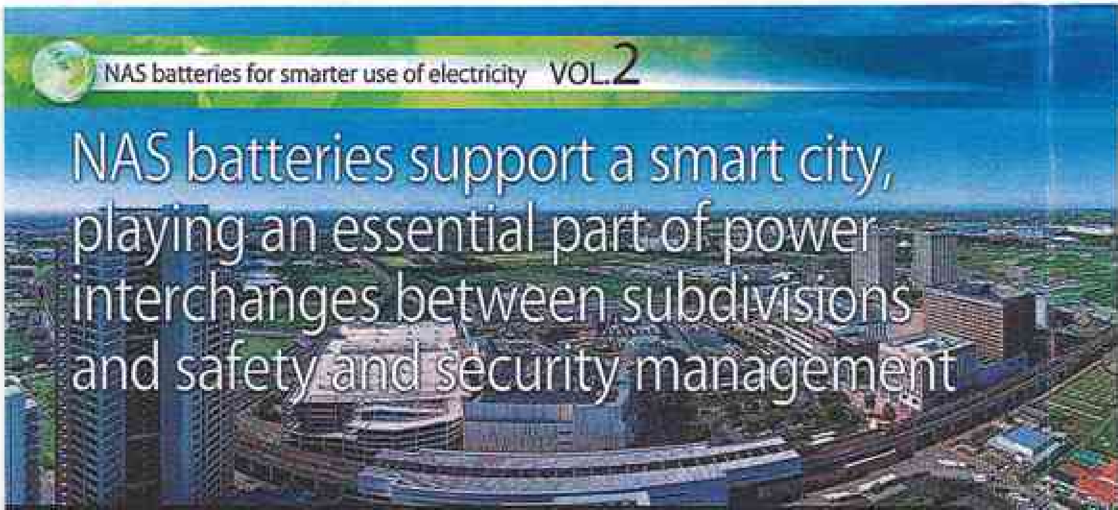
Access: about 50 minutes by air from the Okinawa mainland
Population: about 55,000 people (as of the end of Dec., 2010)
Households: about 24,000 (as of the end of Dec., 2010)
Total Area: about 205 km²
Average temperature: 23 °C
Main Industries: Agriculture (cultivation of sugarcane, leaf tobacco, mango)
Fisheries (Mozuku seaweed, prawn farming, skipjack pole-and-line fishing)
Tourism
Source: "FY 2010 Statistics of Miyakojima" on the website of the Miyakojima City

with the District and for the District
The Okinawa Electric Power Company, Incorporated (OEPC)
Research & Development Dept.

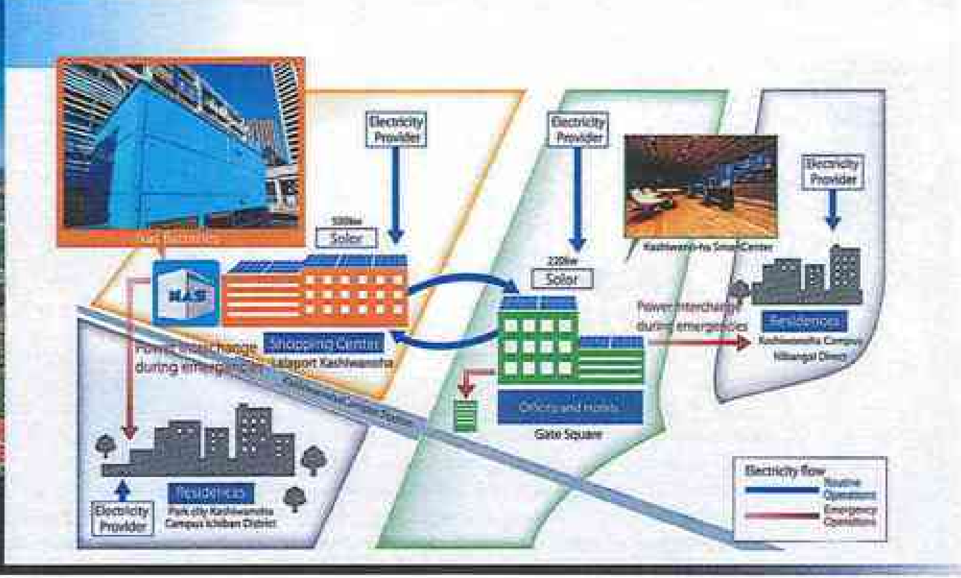
5-2-1 Makiminato, Urasoe City, Okinawa, Japan 901-2602
Tel:+81-98-877-2341 (main)
http://www.okiden.co.jp

Published on March 2012

NAS batteries support a smart city, playing an essential part of power interchanges between subdivisions and safety and security management



"Kashiwa-no-ha Smart City" is the first in Japan that realizes power interchanges between its subdivisions across public roads. NGK Insulators, Ltd. provides "sodium-sulfur (NAS) batteries" to the city as the fundamental technology that supports the operation. NGK's NAS batteries contribute to ensure a stable supply of electric energy and a safe and secure living environment.



A smart city is born aiming to resolve social challenges

The development of safe and secure cities where energy is efficiently harnessed during both normal and emergency conditions while realizing environmental friendliness, for example, by reducing CO2 emissions, has been attracting attention. Mitsui Fudosan has launched a project to develop Kashiwa-no-ha Smart City (Kashiwa City, Chiba Prefecture) in the vicinity of the Kashiwanoha-campus Station on the Tsukuba Express Line. The city has been developed to resolve such social issues as "harmony of people and environment," "health and longevity" and "creation of new industries," based on the infrastructure that ensures a stable supply and efficient use of energy.

Kashiwa-no-ha Smart City makes full use of batteries and other energy management systems to respond to environmental issues, set up disaster planning and improve economic efficiency by reducing utility costs, while maximizing renewable energy sources obtained by solar power generation. As a result, the foundation of a smart city that can produce various added values was established. The effective use of various distributed power sources, such as solar power generation and the batteries that store the solar power, is the key technology for the operation.

Introduction of large-scale batteries allowed the city to harness a distributed power source effectively

The major achievement of the energy system that plays a vital role in the Kashiwa-no-ha Smart City is that it realized, for the first time in Japan, power interchanges between subdivisions across public roads by using independent transmission lines and distributed power sources.

The subdivision of LaLaport Kashiwanoha, a power-consuming commercial facility, had solar panels installed on the roofs of buildings. NGK's NAS batteries were also introduced in the area in January 2015. The batteries provide a combination of a high output of 1,800 kilowatts and a large storage capacity of 12,960 kilowatt hours.

The area across the street is the Gate Square complex subdivision consisting of offices, hotels and rental apartments. This subdivision also introduces a solar power generation system and lithium-ion batteries.

Kashiwa-no-ha Smart Center located in the Gate Square is the hub of all these systems. The smart center connects all of the systems and oversees the entire city to optimize the demand and supply of energy. The center forecasts the electricity demand of each facility based on various conditions such as weather information and accommodates electricity between facilities to level off power peaks.

The introduction of NAS batteries in LaLaport Kashiwanoha this January realized an unprecedented interchanging system. Electricity is shared between the commercial and the complex facilities where the power demand peaks at different times, i.e., holidays for the commercial facility and daytime on weekdays for the complex facility, through the independent transmission lines across the public road.

In addition, the city is equipped with an emergency power supply system. When the power company cuts electric supply under emergencies, the city can obtain electricity from emergency power generators as well as from distributed power supplies and supply it to facilities and equipment in the amount needed to operate offices and maintain the life of residents. The system is capable of supplying about 60 percent of the normal power to the Gate Square for three days. The use of solar power generation in combination with the large-capacity NAS batteries and lithium-ion batteries overcomes the vulnerability of solar power generation to weather conditions and enables a stable power supply.

"Batteries are the important factor in many aspects, such as electric load leveling, disaster prevention and the use of low-cost nighttime power," said Koichi Kato, General Manager of the Operation Group, Kashiwa-no-ha City Development Promotion Department at Mitsui Fudosan. He lists "large capacity" and "space-saving design" as reasons for selecting NGK's NAS batteries as a major player.

NAS batteries feature a large megawatt level capacity in a compact design made possible by their high energy density. The batteries are also free of self-discharge and have a long lifespan. NGK's delivery has reached a cumulative total of 450 thousand kilowatts (at a storage capacity of over 3 million kilowatt hours) in the world, not just in Japan. Many facilities have used NAS batteries for over ten years.

The energy system levels power peaks and brings economic advantages

According to the estimate of Mitsui Fudosan, the introduction of such an energy system allows Kashiwa-no-ha Smart City to cut the peak of the power demand by approximately 26 percent as an entire city. In addition, the peak cut of electricity demand can lower the utility charge on the contract with the power company. Also, the system can store low-cost nighttime power and use it in the daytime. As a result of such measures, the system can save a total of about 10 million yen per year.

The new operation began in the energy system of Kashiwa-no-ha Smart City this January, incorporating NGK's NAS batteries. The system gathers attention from home and abroad and constantly welcomes inspection visitors on a daily basis.

"Almost all visitors from overseas particularly have great interest in the electricity interchanges, the use of renewable energy sources and the disaster planning systems that are realized in Kashiwa-no-ha Smart City," Kato said.

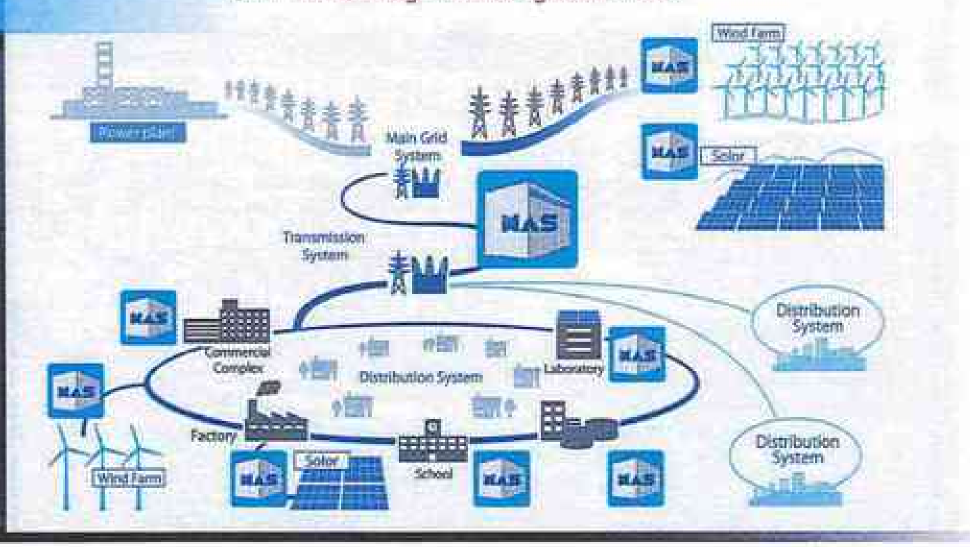
The trend of developing smart cities that are environmentally friendly and strong against disasters has gained momentum not only in Japan but also around the world. Accordingly, the needs for large-capacity batteries that enable a stable supply and efficient use of renewable energy are expanding. In such a trend, NAS batteries, commercialized by NGK for the first time in the world, are attracting expectations of people as a leader of the smarter energy infrastructure, for its proven record in various applications including power stations, substations, distribution systems and large-scale power users.

Full exploitation of renewable energy sources

NAS batteries are the solution for social challenges, opening up the way to the future

Full exploitation of renewable energy sources has become an urgent issue. NGK Insulators, Ltd. provides sodium-sulfur (NAS) batteries that can be applied to power systems from upstream to downstream. Installation of NAS batteries across the power infrastructure will enable efficient storage and use of electricity.

Figure 1 Nas is being used throughout the Grid



NAS batteries can store large amounts of renewable energy

Efficient uses of renewable energy sources such as solar power generation have been gaining social attention. The output of solar and wind power generation, however, can fluctuate considerably depending on various conditions such as the weather.

The output fluctuation of increasing renewable energy sources affect a stable power supply in power grids, failing to efficiently supply distribution power to users, and eventually end up wasting the power. Therefore, efficient use of renewable energy requires measures to control and stabilize the supply-demand balance of electric power.

The full exploitation of renewable energy sources can be considered as a social issue. One of the keys to resolve the issue is battery technology. Storage of electric power in batteries enables a stable power supply.

In particular, the NAS battery, successfully commercialized by NGK Insulators, Ltd., can be installed in various locations in electric energy distributors, including power stations upstream to points of consumption downstream, providing ease of installation in appropriate capacities. NAS batteries are widely introduced across the world, reaching a total output of 450 thousand kilowatts (at a storage capacity of 3 million kilowatt hours). This means that NAS batteries deployed across the world store the amount of power equivalent to the amount generated by solar panels installed in an area of 16.4 km2 in a day (calculated based on annual average).

Typical applications include measures for peak cutting, emergency power supply, and sudden voltage sags for major power users. NAS batteries are also suitable for use on an infrastructure scale to resolve social issues.

NAS batteries are effective in various situations for controlling power supply and power demand

The reason is that the ease of installation of NAS batteries makes it possible to spread the locations of the batteries across the power system (the entire electric facilities including power generators and power users) regardless of the phase of electric distribution, allowing efficient use of electric power in various scales and areas (Figure 1) NAS batteries can pool all the power of renewable energy sources to overcome the output fluctuations that affect power systems, maximize the available power as well as to supply the ideal amount of power in accordance with the power demand curve.

NAS batteries have a wide range of customers. The specific installation locations include power plants, electric transmission facilities, electric substations, microgrid facilities (the localized grid that maintains the balance of power generation and consumption) and large-scale power users, to name a few.

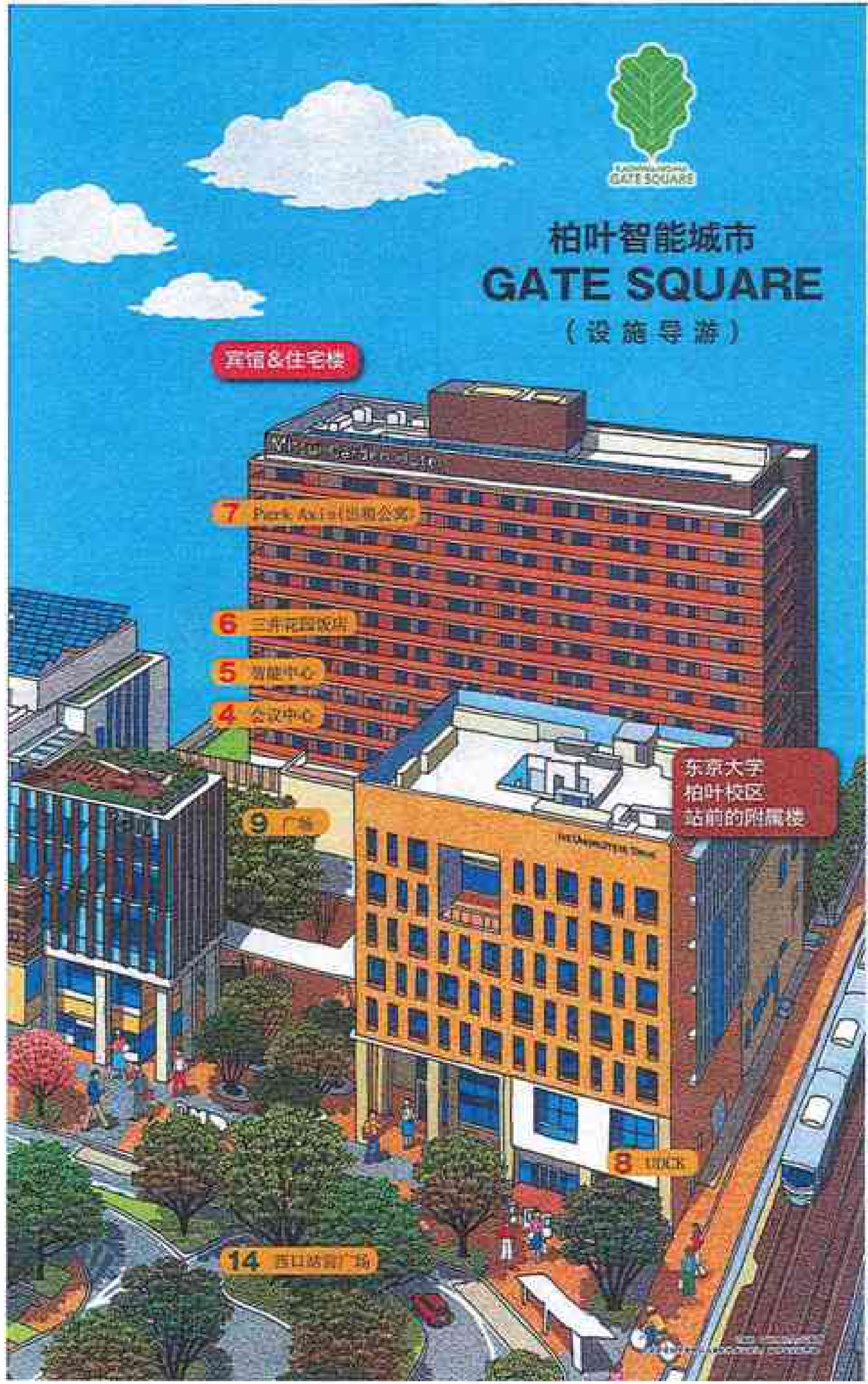
In power plants, for example, the Rokkasho-Futamata Wind Farm (Aomori Prefecture) introduced large-capacity NAS batteries with a storage capacity of 245 thousand kilowatt hours. A fluctuating and unstable power supply resulting from the presence or strength of wind is temporarily stored in NAS batteries to enable a stable power supply that is never affected by fluctuations in power production.

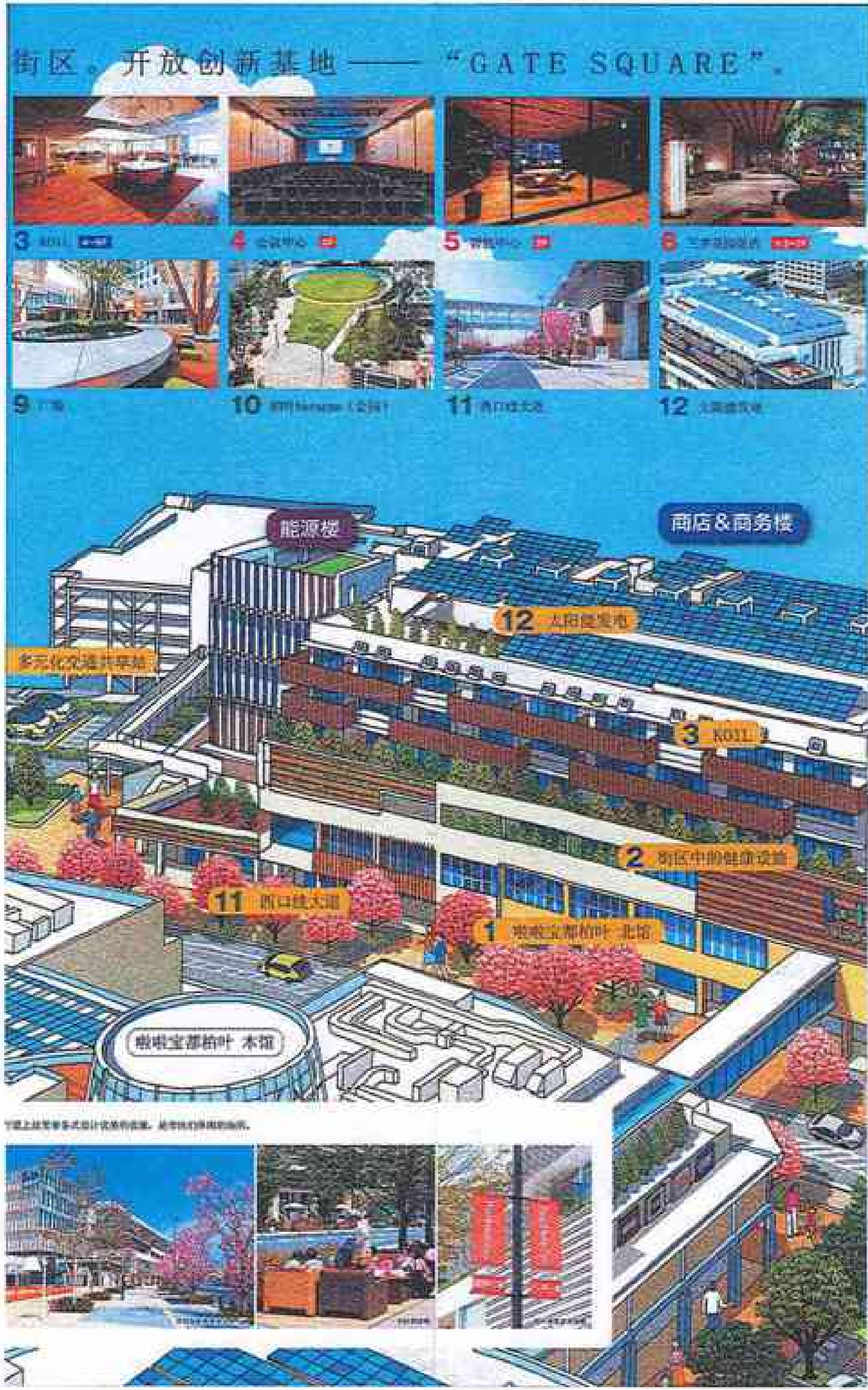
In some cases, the NAS batteries are used to store excessively generated renewable energies in order to avoid interference with transmission grids and adjust the amount of electric transmission. Terna, a major electricity transmission system operator in Italy, is aiming to realize stable power transmission by installing NAS batteries in substations between the urban north region and the rural south region where renewable energy generation is popular, instead of building extra transmission grids. Terna is currently installing large-capacity NAS batteries with a storage capacity of approximately 250 thousand kilowatt hours, which is about to contribute to an improvement in the reliability of the power supply in Italy.

Advanced applications of NAS batteries are expanding

Users of electricity are also introducing advanced applications of NAS batteries. "Kashiwa-no-ha Smart City" in Kashiwa City, Chiba Prefecture employs NAS batteries as a source of distributed power. NAS batteries are incorporated into the integrated energy control structure and contribute to supplying the entire city with efficient and stable electric power. The "Komei Smart Town District Plan" being developed in the southern part of Nagoya City also plans to introduce NAS batteries.

Large-capacity NAS batteries distributed in a wide range of locations from power stations to points of consumption enjoy an ever-increasing popularity. The importance of their roles in society has also been increasing more than ever.

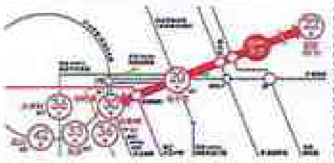

柏叶智能城市
GATE SQUARE
（设施导游）
宾馆&住宅楼
7 Park Axis
6 三井花园饭店
5 智能中心
4 会议中心
9 广场
东京大学
柏叶校区
站前的附属楼
8 UDCK
14 西口站前广场


街区。开放创新基地——“GATE SQUARE”。
3 KOIL
4 会议中心
5 智能中心
9 广场
11 西口线大道
12 太阳能发电
能源楼
商店&商务楼
12 太阳能发电
多元化交通共享站
3 KOIL
2 街区中的健康设施
11 西口线大道
1 啦啦宝都柏叶 北馆
啦啦宝都柏叶 本馆

"GATE SQUARE" 的诞生加速了城市建设。

位于车站2km交通圈内，周围绿树葱笼，大学、公园、研究机构等众多机构选址在此。

直达东京市中心的交通通道



&EARTH 三井不動産

http://kashiwanoha-smartcity.com/

柏叶智能城市的站前核心

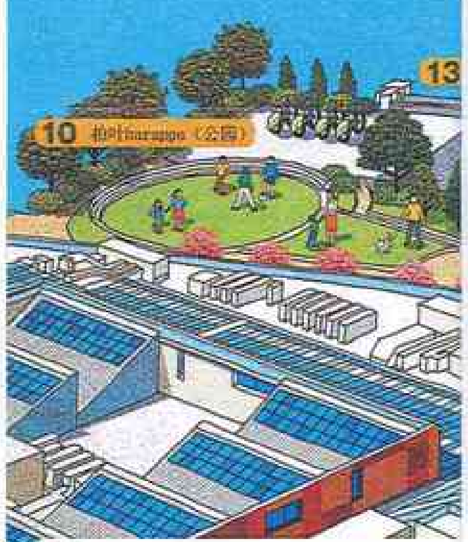
1

2

7 Park Axis

3

13



14 西口站前广场

商店&商务楼

Shop & Office

KOIL

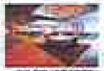
6F

KOIL （柏叶开放创新研究所）

激发创造力的柏叶开放创新研究所

KOIL STUDIO　会议室　Cafe

KOIL PARK（共用工作空间）



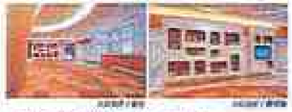
KOIL Factory（工作室）

3F

聪敬宝都柏叶 北馆（1~3F）

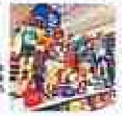
"街区中的健康设施"（3F）

入口大厅



街区中的健康研究所"明・天"

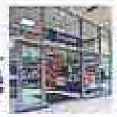
2F



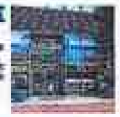
OLD NAVY

mont·bell

1F



LAWSON



●GATE SQUARE平面图

东京大学 柏叶校区站前的附属楼

1F

UDCK

（柏叶都市设计中心）

宾馆&住宅楼

Hotel & Residence

14F

柏叶国际村

8-13F

Park Axis（出租公寓）

1-3-7F

三井花园饭店

mitsui garden hotel

Kashiwa-no-ha

2F

会议中心

KASHIWA-NO-HA CONFERENCE CENTER

智能中心

1F

门厅&餐厅

Empower for new days

Confidential

Our Activities in Yokohama Smart City Project

MEIDENSHA CORPORATION

Pilot Projects for Smart Community in Japan

Demonstration of Next-Generation Energy and Social Systems

This program aims to demonstrate a smart community, which is regional deployment of next-generation energy and social systems that combine in multiple ways concepts such as the "coordinated use" of energy, which means effectively using not only electricity but also heat and untapped energy as well as the transformation of regional transport systems and people's lifestyle.

Through this demonstration program, the Ministry of Economy, Trade and Industry (METI) aims to facilitate the development of next-generation technologies in related industries, establish international standards for these technologies, and eventually strengthen the competitiveness of Japanese environment and energy industries.

2010年. Demonstration Areas . Begin.

★**Yokohama City**
Toyota City
Kansai Science City
Kitakyushu City

What is Yokohama smart city project (YSCP)?

• In the city where the infrastructure is already fixed, we focus on the change of the relationship between energy and citizens to realize a comfortable and low-carbon city by development of a regional energy management system (CEMS) and popularization and promotion of PV etc.

Background
- The necessity for enhanced energy security.
- Industrial development (Green Innovation)
- Reduction of urban CO2 emissions

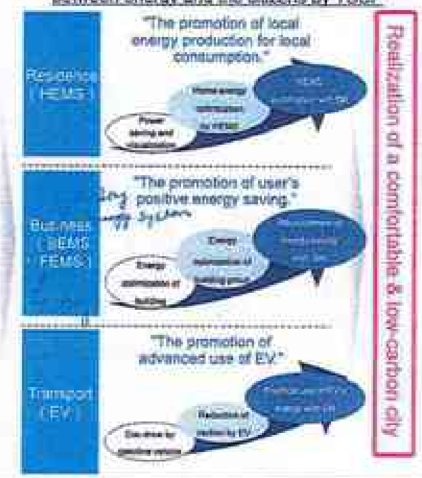
Items of demonstrations in YSCP

Technical development / Operation verification (CEMS)
- Development and operation of an urban type regional Energy Management System in Minatomirai area etc.
  Integration BEMS
  - Control with Various Demand Response (DR : The control request with an incentive)
  - Integration BEMS (Unify Building group and manage energy)
  - Next Generation BEMS (The optimal control of the institution by practical use of battery)
  - Smart FEMS (The optimal control of the institution by practical use of battery)
  - Automatic HEMS with Demand Response function
  - Charge/Discharge of EV (V2H)
  - Energy storage system containing fixed type battery

×

Popularization and practical use with target values
- The popularization of products which mounted stable technology
  - PV 27MW
  - HEMS 4,000
  - EV 2,000
- Recognition of the difficulty to popularization and enforcement of effective measures.

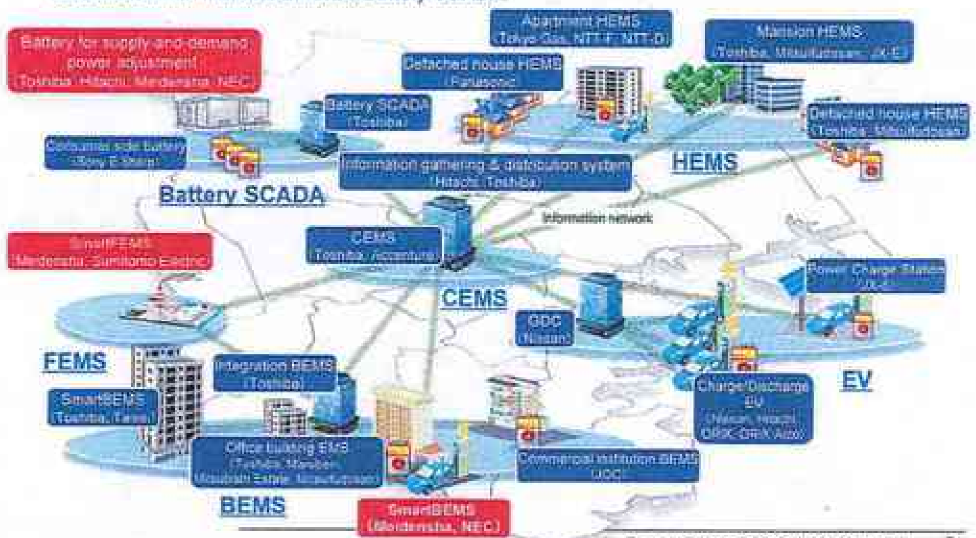
The change of the relationship between energy and the citizens by YSCP



↳ 日立 & NEC 共同管理. so does the ... case

Our Participation in Yokohama Smart City Project (YSCP)

"Development and realization of the energy management in large-scale city area by CEMS coordinated with HEMS/BEMS/EV/Battery SCADA."



Yokohama WORLD POTERS

◆ Commencement of operation: September, 1999 (210 stores, 8 cinema screens etc.)

◆Total floor area: approx.100,400m2 (6 floors 1 basement with 9 floors parking)

◆ Land area: approx.20,000m2

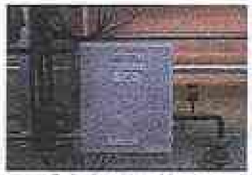
Equipment of YWP

MEIDEN 明电 & NEC 共同開発

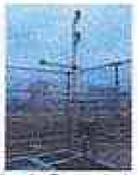
SmartBEMS ×2 sets

250kWh Li-Ion Battery System

Remote Stations ×27units
Elec. Power Sensor Panels ×27units

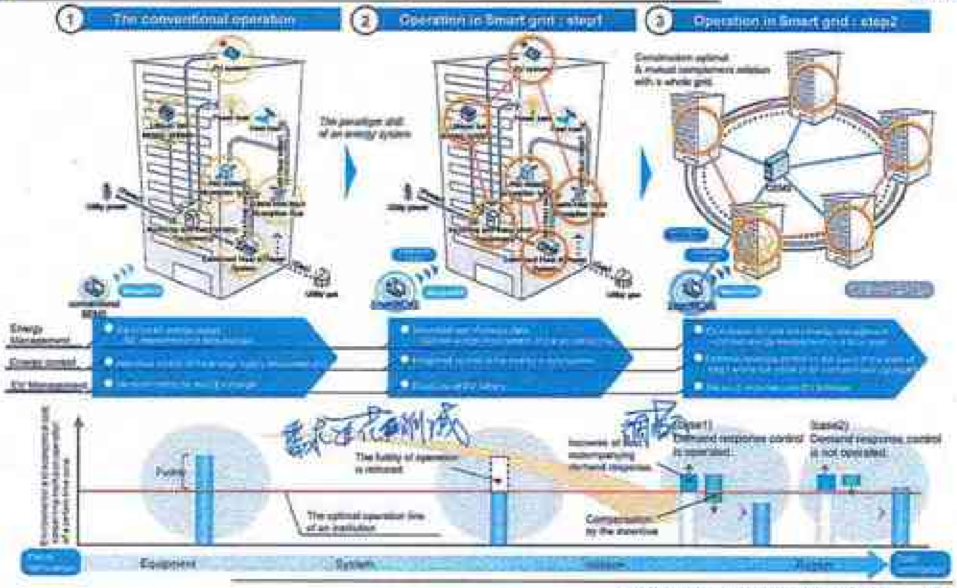


Calorimeter ×11sets

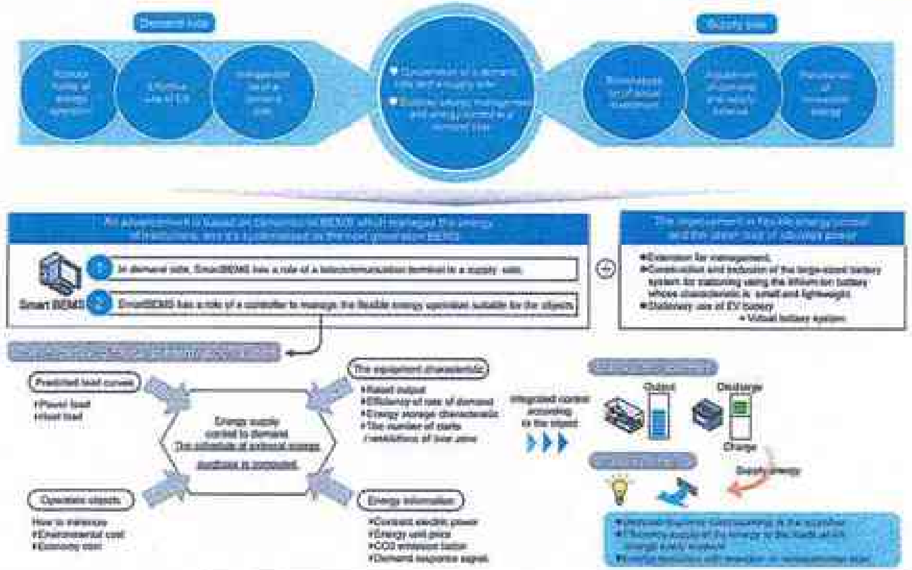


Climate Sensor ×1set

The Smartification of Existing Institution in an Operating Section



SmartBEMS : the core system for smartification



The Outline of SmartBEMS.

Development of SmartBEMS

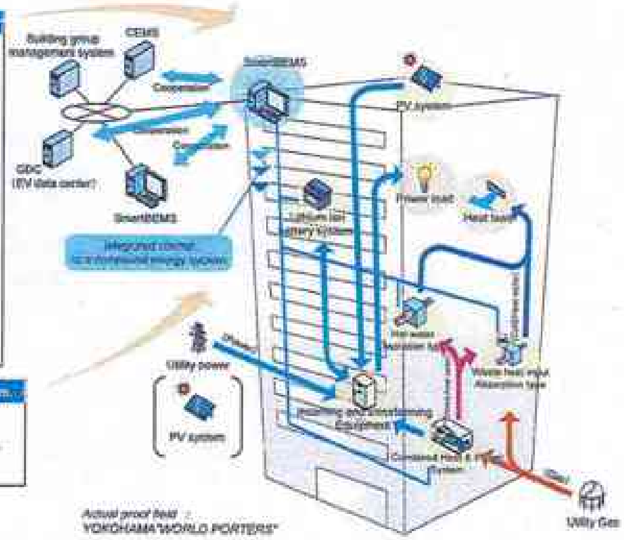
Demand response
- Load pattern prediction and reserved power management.
- Elastic operation of the energy according to the target.
- Automatic demand response corresponding to the incentives.

Energy supply optimization
- Control based on the energy supply efficiency of the whole institution.
- Maximization of the supply efficiency by output control.
- The electricity demand shift by the fixed battery system.

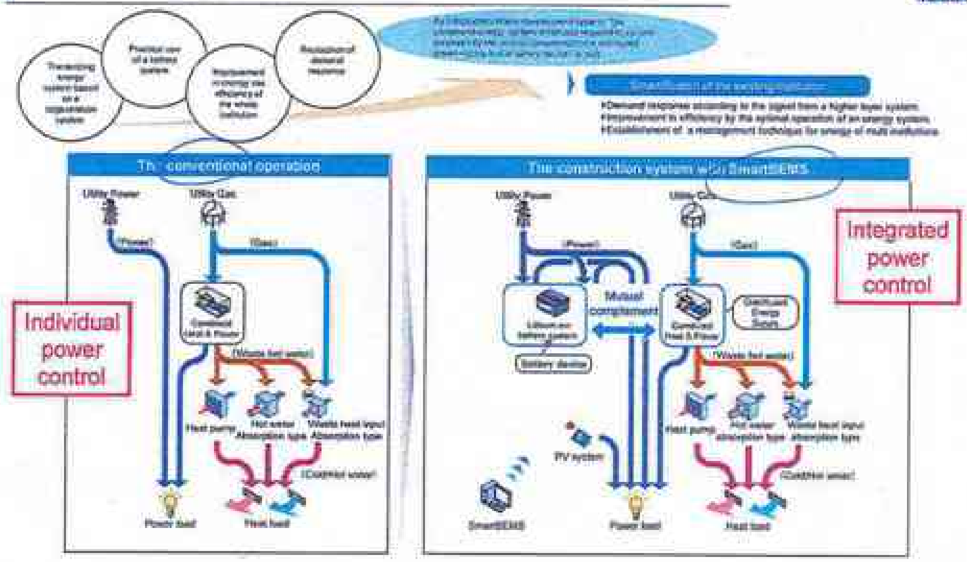
Cooperative building control
- Application in the demand where multi institutions which have individual management in the same site.

Common communication specification
- Standardization of a connection interface.

Development of the fixed large-scale battery system.
- Advancement in High-voltage and large-capacity of a lithium ion battery which is small and lightweight.
- The advancement of the control technology in a battery system.
- Improvement in flexibility of BEMS energy control.



Retrofitted System and The Contents of Demonstration



Typical Control of Demand Response

Tariff based Demand Response

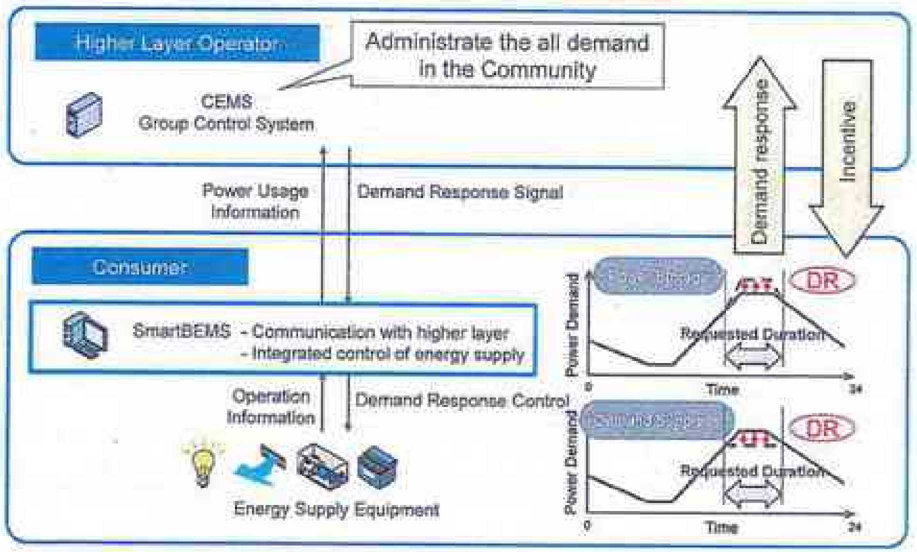
- **Time-of-Use(TOU)**
  Various tariffs are applied to peak time and off-peak time

- **Critical Peak Pricing(CPP)**
  Higher tariff is applied to the specific time on specific date

Incentive based Demand Response ← **Items of Demonstration in YSCP**

- **Peak Time Rebate(PTR)**
  Rebate is paid towards saved kWh during requested duration.
- **Capacity Commitment Program(CCP)**
  Rebate is paid towards the achievement of committed kWh saved during requested duration.

Operation of Incentive Based Demand Response



YSCP's Schedule

Step1 2011
Construction of Energy System

Introduce
- SmartBEMS
- Several Sensor
- Remodel Monitoring System
- Remodel CHP

Step2 2012
Demonstration for Energy System①
Optimal Energy Supply

Introduce
- Li-Ion Battery System

Step3 2013~14
Demonstration for Energy System②
Demonstration of Cooperative Control and LIB

Brush up
- Automatic Re-scheduling
- More Accurate Prediction
- Shorter Control Period
- More Effective CHP Control

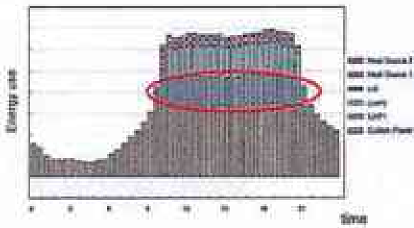
Result

	Heat Load	Electricity Price	Operation by BEMS	Reduction
Winter Weekday	Small	Middle	Control CHP operation when heat load is low. 2 CHP operation → 1 CHP operation	Energy Cost ▲about 4%
Winter Holiday	Small	Low	Control CHP operation when heat load is low. 2 CHP operation → 0 CHP operation	CO2 Emission ▲about 5%
Summer Weekday	Large	High	Operate more CHP when heat load is present.	
Summer Holiday	Large	Low	Control CHP operation when heat load is not present.	
Spring /Autumn Weekday	Middle	Middle	Operate more CHP when heat load is present, and Control CHP operation when heat load is not present.	
Spring /Autumn Holiday	Middle	Low	Control CHP operation when heat load is less or not present.	

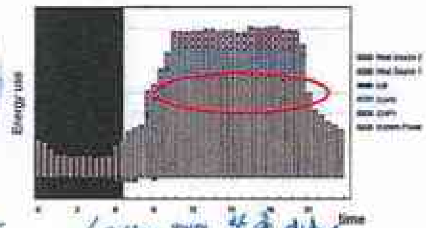
Result : Example of Each Season

Winter Weekday

Conventional Control ※ CHP operation



Control by SmartBEMS ※ CHP +LIB operation

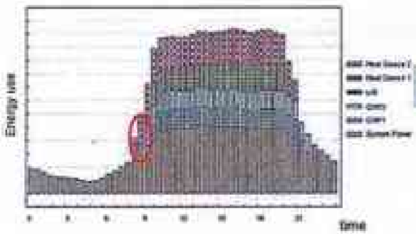


Conventional Control
✓ Overproduction of Energy was occurred when heat load was low.
↓
Control by SmartBEMS
✓ The number of active CHP is optimized by considering the electricity and heat load. (2 CHP → 1 CHP)

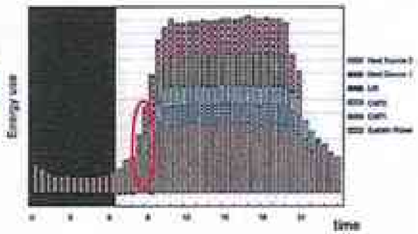
Result : Example of Each Season

Summer Weekday

Conventional Control ※ CHP operation



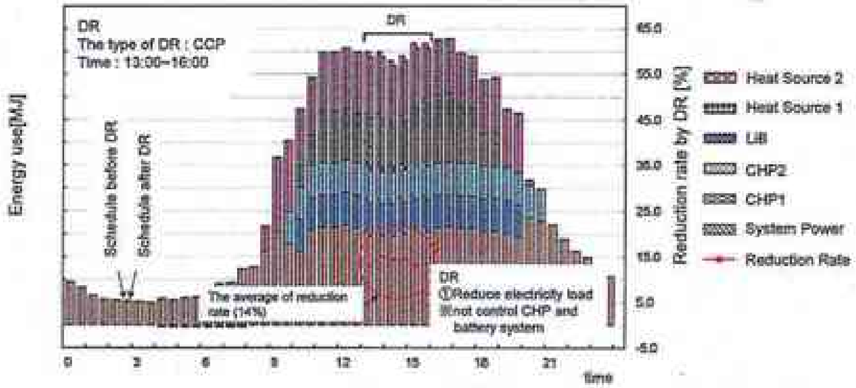
Control by SmartBEMS ※ CHP +LIB operation



Conventional Control
✓ Activation of CHP was late because electricity load was low when the heat load was present.
↓
Control by SmartBEMS
✓ Activate CHP as much as possible because the electricity price in summer is higher than the other seasons.

Result : EMS Control with DR

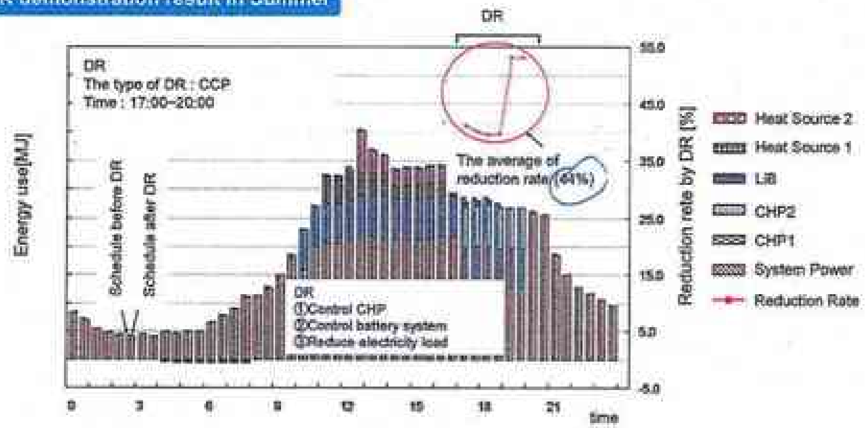
DR demonstration result in Winter



Comparison of effect by DR on a certain day in July 2014

Result : EMS Control with DR

DR demonstration result in Summer



Comparison of effect by DR on a certain day in January 2014

For The Customer Delight !

附錄三

NEC 相關資料

Orchestrating a brighter world NEC

NEC Renewable Energy Solutions

NEC Corporation

Agenda

- About NEC
- Renewable Energy for Islands
- NEC's Renewable Energy Solutions
  - ① PV Power Generation Prediction Services
  - ② PV/Wind Power Generation Control System
  - ③ Grid Storage System
  - ④ Power Plant Entrance Control
  - ⑤ SmartMaintenance
    - Plant Maintenance Support System -
  - ⑥ Power Demand Prediction Services
  - ⑦ Situational Analytics & Visualization (STI)
- Summary

About NEC

Orchestrating a brighter world NEC

About NEC: Corporate profile

公司名：NEC

（商號：日本電氣株式會社　英文公司名：NEC Corporation）

總公司：東京都港區芝五丁目7番1號

創立：1899年（明治32年）7月17日

代表取締役 執行役員社長：遠藤　信博

資本額：3,972億日圓（2015年3月底為止）

營業額：2014年度業績

連結 2兆　935億日圓

遠藤　信博

集團主要事業：PUBLIC、ENTERPRISE、TELECOM CARRIER、SYSTEM PLATFORM

員工數：<連結>　100,914名（2014年3月底為止）

公司數：<連結子公司>　258社（2014年3月底為止）

NEC Worldwide: "One NEC" formation in 5 regions

Business activities in over

168 Countries and territories

Our affiliates, offices and laboratories
North America : Canada-USA
Latin America : Argentina-Brazil-Chile-Colombia-Mexico-Venezuela
Europe / Middle East / Africa : Finland-France-Germany-Greece-Hungary-Italy-Netherlands-Nigeria-Portugal-Saudi Arabia-South Africa-Spain-Sweden-Switzerland-Turkey-United Kingdom
Asia Pacific : Australia-India-Indonesia-Malaysia-New Zealand-Philippines-Singapore-Thailand-Vietnam
Greater China : China-Hong Kong-Taiwan-Korea

2935.5 Billion Yen in FY2014 sales

事業領域與主要商品、服務

NEC提供的解決方案

提供「從海底到宇宙・Cyber空間」，廣泛的「社會解決方案」

Regional electricity business ★

Strategic collaboration partnership with SMUD

NEC, is poised to enter into strategic collaboration partnership with **SMUD, the sixth-largest public power utility in the United States**. Areas of focus include investigating the creation of technological architecture for a utility integrated grid management platform for distributed resources, including energy efficiency, demand response, non-carbon emission, energy storage and the internet of things

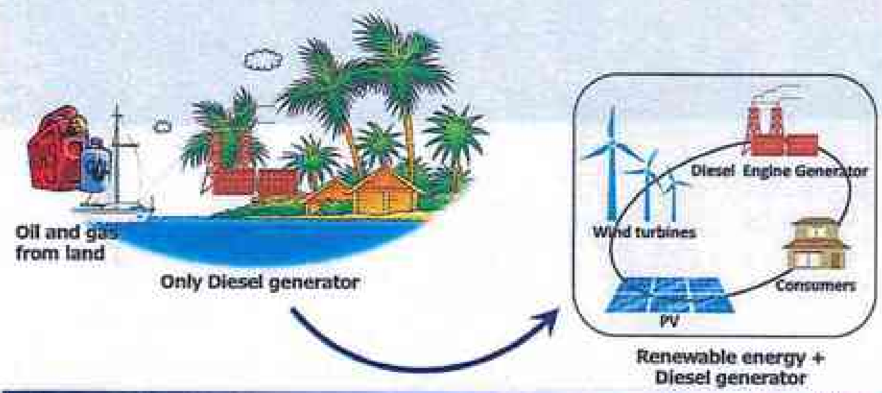
SMUD's smart grid – Smart Sacramento®

★Stable power supply using ICT	★ Low electric rates	★ High customer satisfaction
SMUD manages their operations using various ICT, while obtaining 50% of their power supply from non-carbon emitting sources, which have highly-variable outputs	SMUD's residential electric rates are among the lowest in California.	SMUD has ranked #1 in California for 14 consecutive years in J.D. Power's Electric Utility Customer Satisfaction Study.

Renewable Energy for Islands

Renewable Energy: Trend for Islands

Most isolated islands are **facing the high cost of electricity** caused by expensive oil and gas and by transportation costs.
Renewable energy is a trend for islands as they need to reduce the generation cost and to assess their full potential for producing clean energy.



The Issues of Renewable Energy for Islands

Keep grid stability and high quality

- Integrate variable and intermittent renewable generation resources

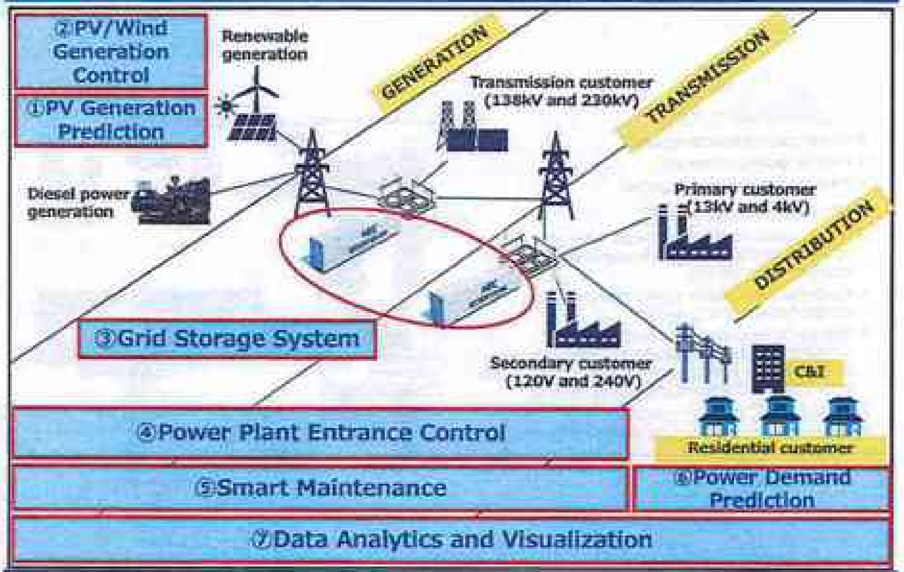
Demand-Supply balancing

- Increase the grid operational efficiency by maintaining supply-demand balance

Renewable energy facility security and maintenance

NEC's Renewable Energy Solutions

NEC Smart Energy Solutions



PV power generation prediction service

Recommended for

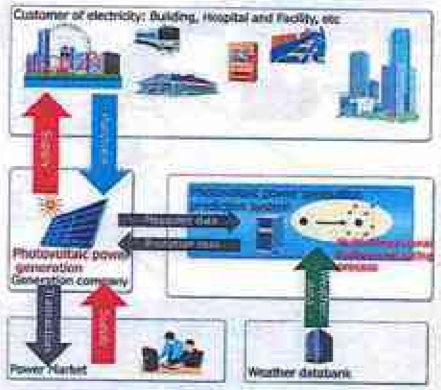
- Power generation company
- Electric power company
- Power producer and supplier

Features and Benefits

- We can predict PV power with high accuracy by using NEC's multi-dimensional feature extracting technique
- Multi-sites PV power prediction including averaging effect is possible
- This technique contributes to the most suitable bid to the business market, and the most suitable procurement in conjunction with an electricity-demand prediction system

Customer Value Proposition

- Effective application of PV power generation
- Reduction of the electricity procurement cost



①PV Power Generation Prediction Services

PV Generation Prediction

②PV/Wind Power Generation Control System

PV/Wind Generation Control

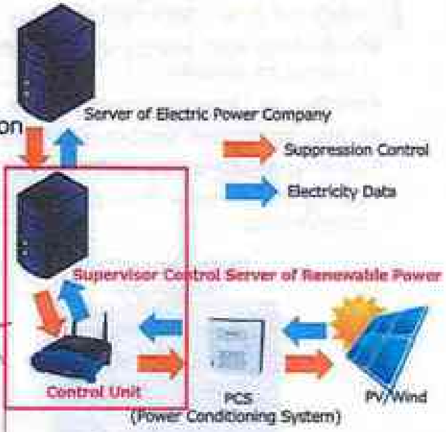
PV / Wind Power Generation Control System ★

- Problem
  Electric Power System Destabilization caused by Surplus electricity
- Solution
  Main function of the System
  ① Suppression Control
  Suppress the PV electricity generation

  ② Monitoring the electricity data
- Customer
  Tokyo Electric Power Co.,Inc.
  Tohoku Electric Power Co.,Inc.
  Hokuriku Electric Power Co.,Inc.

NEC developed
- Supervisory Control Server
- Control Unit
(which can speak many PCS protocols)

<System Architecture>



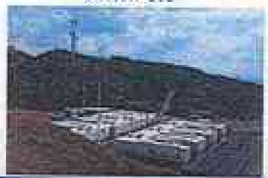
③Grid Storage System

GSS™

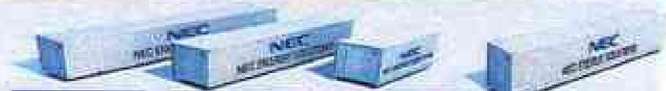
- The GSS™ is a fully integrated, turnkey energy storage plant ready to interconnect to the grid
- Designed and manufactured by NEC Energy Solutions, and includes
  - Rack-integrated energy storage with battery management system and controls hardware
  - Enclosures (standard containerized, but custom enclosures possible)
  - Power conversion hardware (inverters)
  - Command and control software suite
  - Configured to order from factory assembled & tested standard modular components

Building-based 8MW, 32MWh GSS

Containerized 32MW, 8MWh GSS



Grid Battery Systems Standard Containerized Unit Details



	GBS-C53-LD40	GBS-C40-LD28	GBS-C20-LD12	[illegible]
Energy storage (nominal)	4 MWh	2.8 MWh	1.2 MWh	575 kWh
Power Rating	4 MW	2.8 MW	1.2 MW	2 MW
Dimensions (LxWxH)	16.2 x 2.5 x 2.9 (m)	12.2 x 2.5 x 2.9 (m)	6.1 x 2.5 x 2.9 (m)	16.2 x 2.5 x 2.9 (m)
Mass	63,600 kg	45,500 kg	21,400 kg	29,100 kg
DC Efficiency*	97% (C/2 rate)			96% (1C rate)
DC Voltage	944V Nominal (750V-1050V DC operating range)			960V nominal (750V-1050V DC operating range)
Ambient Operating Temperature Range	-30°C to +50°C			
Enclosure details	Containerized, ISO 1496-1 certified, IMO CSC compliant, designed to IP56 per IEC 60529			

*DC Efficiency – inclusive of battery management electronics, excluding auxiliary power consumption by thermal management systems. Long Duration GBS efficiency measured at full depth of discharge. High Rate GBS efficiency measured at partial depth of discharge near mid state of charge

HR GBS™

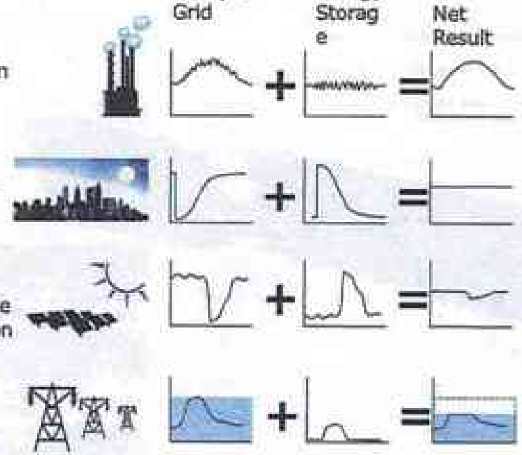
Standard containerized battery packages

GBS HR
- High Rate (HR) design, up to 2MW/575kWh in a single container
- Designed for 15 minutes of energy storage at high power output
- Number of energy storage racks is customizable (up to 20 racks)
- Utilizes Nanophosphate® lithium ion cells

GBS-C53-HR20*	
Power rating	2.0 MW
Energy rating	575*kWh
Container size	53' x 8.5' x 9.5' 16.2m x 2.6m x 2.9m
Rack qty	Up to 20 HR Racks*
Integrated Fire Suppression	Included

*Containerized systems shown populated w/ 18 racks. Other rack quantities available. Capacity directly correlates with rack content. Power capability may be limited below 16 racks

NEC's Four Target Applications



Regulation: Increase efficiency; Reduce CO_2 emission

Reserves: Faster and more reliable reserve power

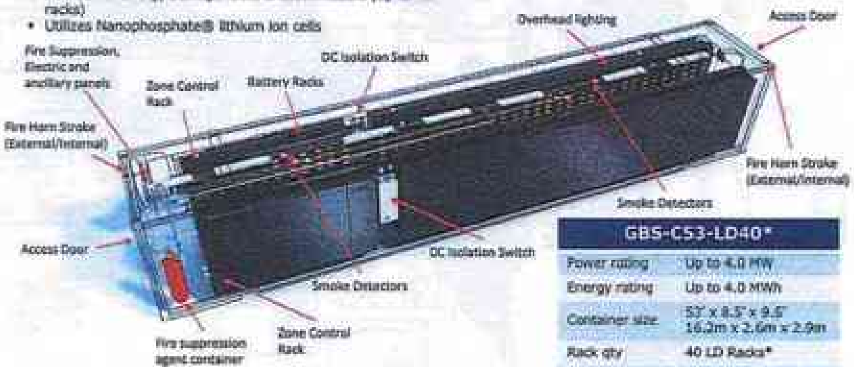
Renewable Integration: Firm renewable power; Enable greater penetration

T&D Support: Reinforce the grid; Frees capacity for future growth

LD GBS™

GBS-C53-LD40

GBS LD
- Long Duration (LD) energy storage, up to 4MW/4MWh in a single container
- Designed for 1hr of energy storage or more (at reduced power output)
- Number of energy storage racks is customizable (up to 40 racks)
- Utilizes Nanophosphate® lithium ion cells



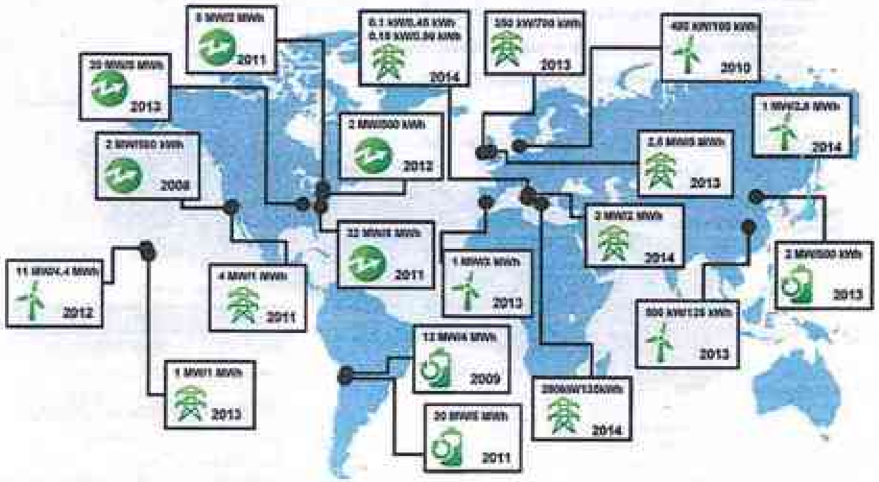
GBS-C53-LD40*	
Power rating	Up to 4.0 MW
Energy rating	Up to 4.0 MWh
Container size	53' x 8.5' x 9.5' 16.2m x 2.6m x 2.9m
Rack qty	40 LD Racks*
Integrated Fire Suppression	Included

*Containerized systems shown fully populated w/ racks. Partially populated systems available.

GSS™ global deployments

Primary Reserve · Frequency Regulation · T&D Support · Renewable Integration

Over 110 MW[1] deployed in more than 20 Grid Storage Installations around the world in 5 years



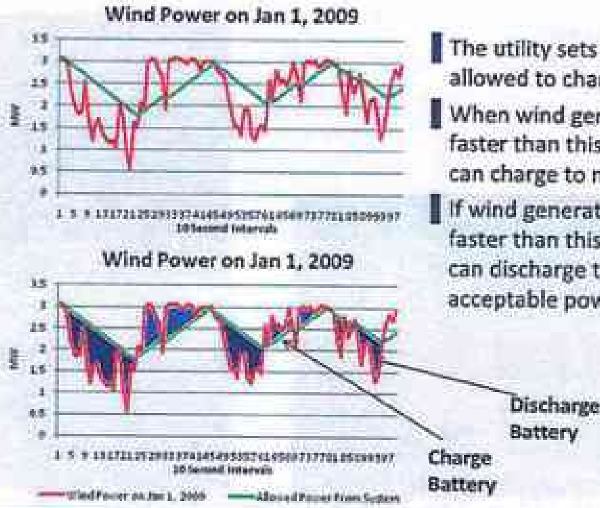
Note: [1]Last update: April 2014

CASE STUDY: Island Wind Ramp Mitigation

Auwahi Wind Farm

- 24 MW wind farm in Hawaii
- 11 MW Energy Storage System
- 7 Mvar shunt capacitors
- Completed December 2012

Exemplary Wind Profile



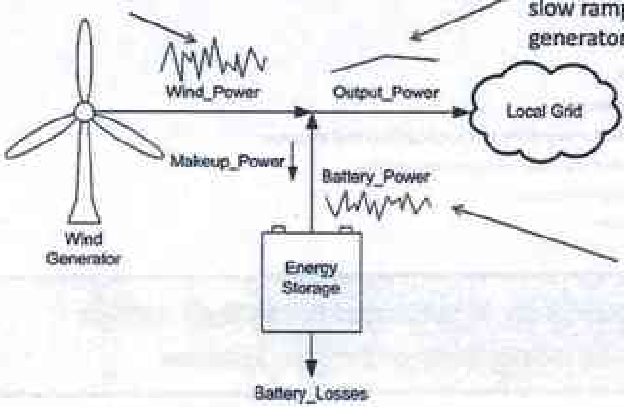
- The utility sets a rate at which power is allowed to change in MW per minute
- When wind generation is increasing faster than this rate energy storage can charge to mitigate
- If wind generation suddenly drops faster than this rate energy storage can discharge to maintain an acceptable power output

Wind Ramp Management Power Flow

1. Wind generators create power with fast ramps up and down

2. Local utilities require predictable slow ramps from generators

3. A storage system smoothes the output power by absorbing the wind generator's volatile output



Why NEC

- Lithium Ion Energy Storage provides effective ancillary services.

- NEC's world wide experiences have already validated the performance and effectiveness of storage including:
  - Faster response
  - Higher Efficiency
  - No fuel consumption
  - Low Total Cost of Ownership
  - Versatile – can perform many different applications and locations
  - Flexible – can be scaled from kW to hundreds of MW
  - Compact - can fit in tight locations
  - Easy to site and permit

NEC is a uniquely experienced technology partner in advanced battery storage systems

④Power Plant Entrance Control

Generation ⟷ Transmission ⟷ Distribution

Power Plant Entrance Control

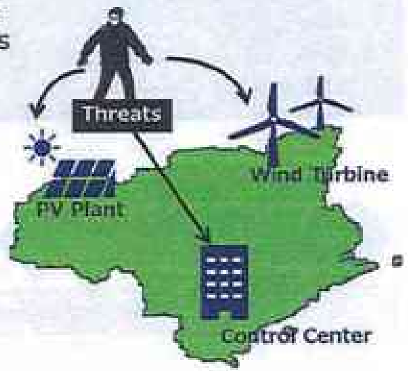
Orchestrating a brighter world NEC

Needs for Critical Infrastructure Management

Energy industry facilities such as power generation plants and the control center are **critical elements** of an island's infrastructure.

Disruptions to these installations pose **a massive impact** on society, which is why it is important to ensure that these places are well protected.

NEC offers a **reliable and easy-to-use entrance control system** using its face recognition technology.



System Overview

When employees or visitors reach the entrance:

- A face can be recognized in 0.5 second.
- Real time grasp of those who stay in the facility

Already in operation at one power generation plant in Japan

⑤SmartMaintenance
- Plant Maintenance Support System -

Generation ⟷ Transmission ⟷ Distribution

Smart Maintenance

Orchestrating a brighter world NEC

System Overview

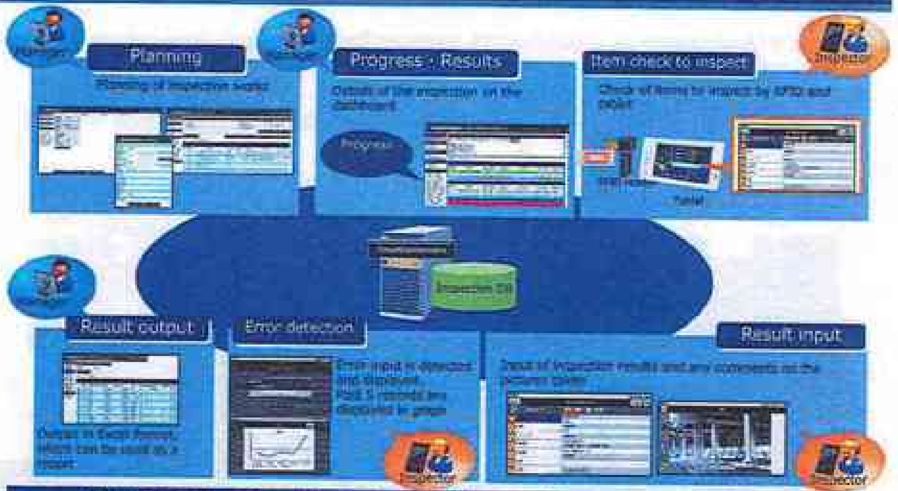
SmartMaintenance is a solution to support field work by using tablet terminal and RFID.

It enables efficient and accurate inspection works and equalization of work level.

Effect of SmartMaintenance

It enables quality up and efficient maintenance works through tablet, RFID and GIS. Tablet uses the same inspection template as the existing paper one.

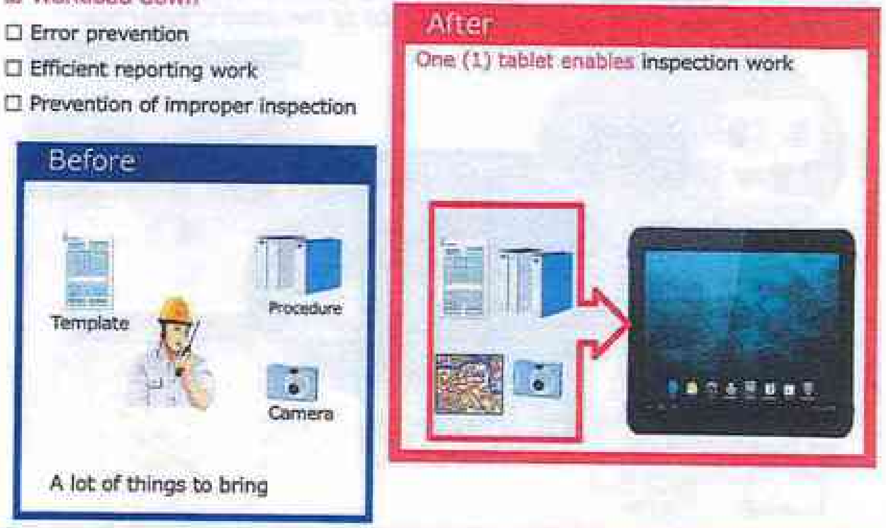
Outline of Functions



All required functions for field workers and managers are contained in One package

Value for Field Worker (1/2)

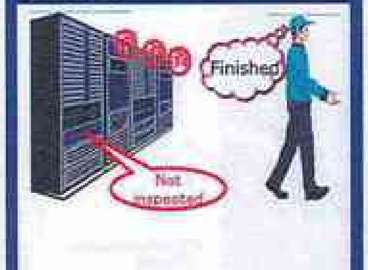
☑ Workload down
☐ Error prevention
☐ Efficient reporting work
☐ Prevention of improper inspection



Value for Field Worker (2/2)

☑ Workload down
☑ Error prevention
☐ Efficient reporting work
☐ Prevention of improper inspection

Before



A lot of similar products

After

By RF tag, products to inspect are correctly found. Inspection items are displayed on the tablet.

Un-inspected items are easily searched.

Value for Manager (1/2)

☑ Workload down
☑ Error prevention
☑ Efficient reporting work
☐ Prevention of improper inspection

Before

Much time for making a report

After

After the inspection, just upload!

No need to change paper reports into electrical data.

Value for Manager (2/2)

☑ Workload down
☑ Error prevention
☑ Efficient reporting work
☑ Prevention of improper inspection

Before

A report submission without any inspection

After

Registration of location data for the inspection by GPS.

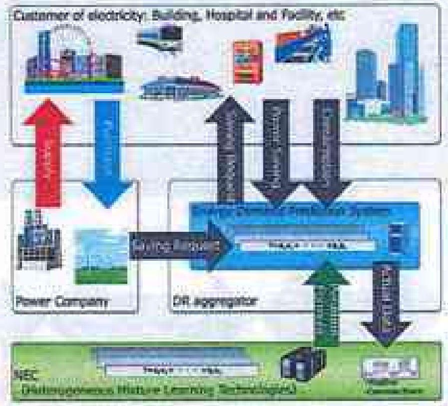
⑥Power Demand Prediction Services

Power demand prediction services

Recommended for
- Customer of electricity, electric power company and DR aggregator

Features and Benefits
- Automatically learns past trend of electricity demand of buildings, hospitals, railway companies and facilities by utilizing NEC original machines learning technology.
- Predicts future energy demand with high accuracy, and reduces cost of power generation and purchasing electricity for power companies, and provide power savings and advanced DR for customers.

Customer Value Proposition
- Reduce power supply cost and manpower for demand prediction for power companies, and save electricity expenses for customers.



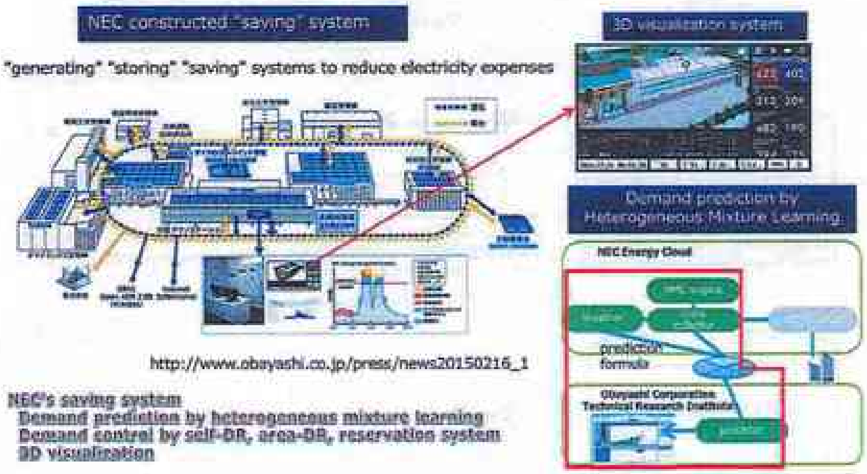
⑦Situational Analytics & Visualization (STI)

Power demand prediction for buildings (in service!) ★

Smart Energy System at Obayashi Corporation Technical Research Institute

NEC constructed "saving" system

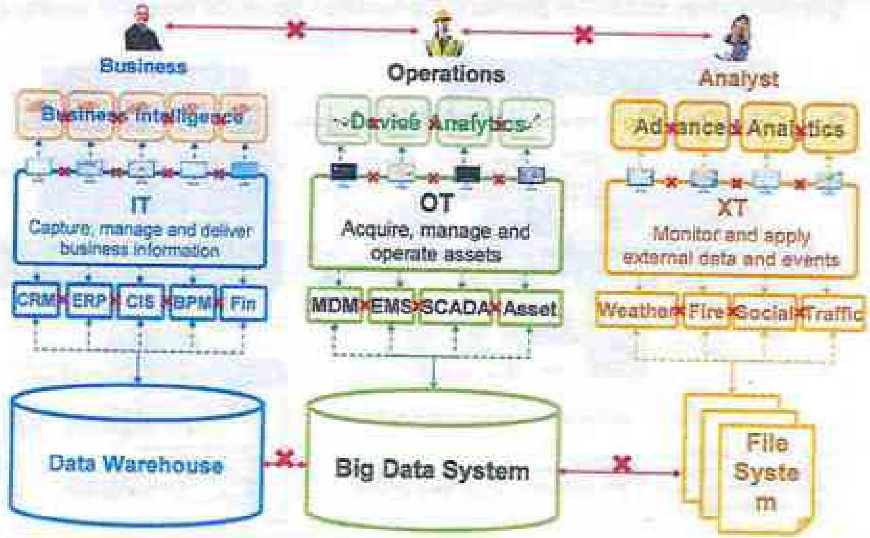
"generating" "storing" "saving" systems to reduce electricity expenses



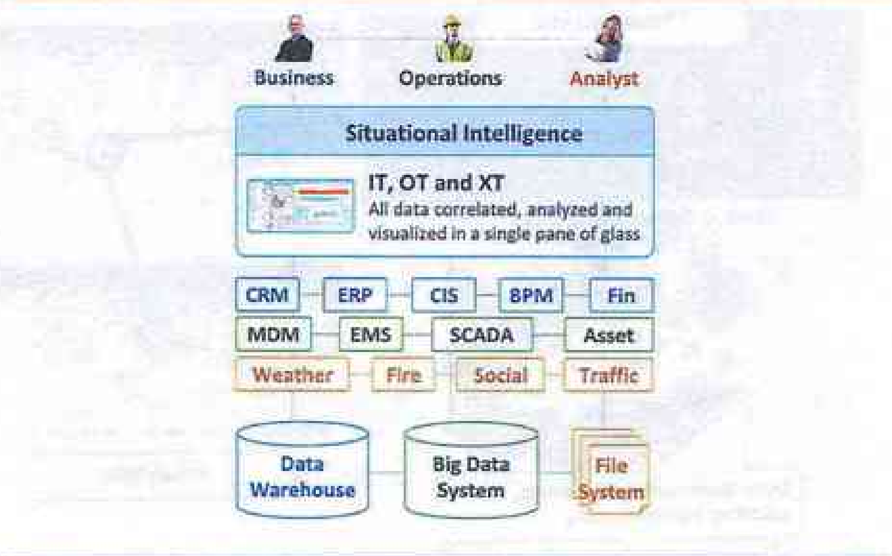
http://www.obayashi.co.jp/press/news20150216_1

NEC's saving system
Demand prediction by heterogeneous mixture learning
Demand control by self-DR, area-DR, reservation system
3D visualization

Organizational Challenge - Siloed Data, Systems and Decisions

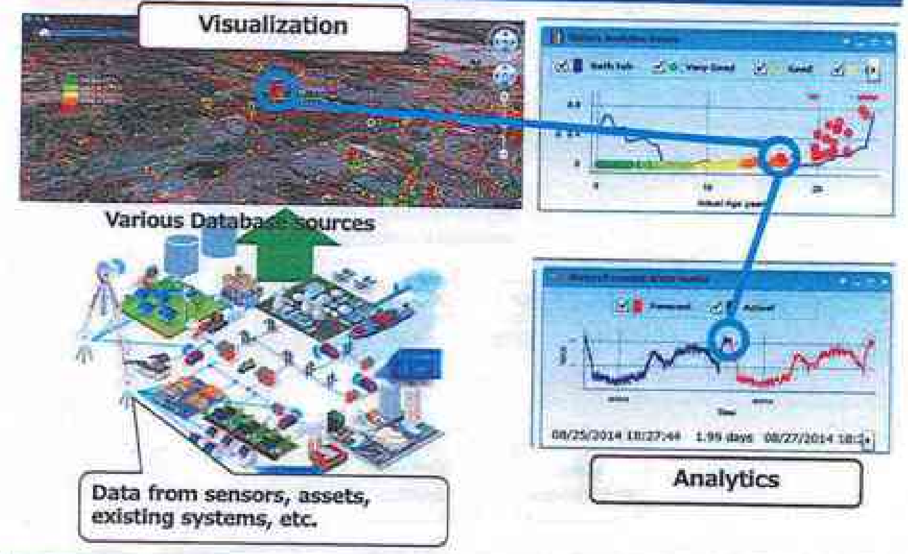


Situational Intelligence - Faster, More Informed Decisions

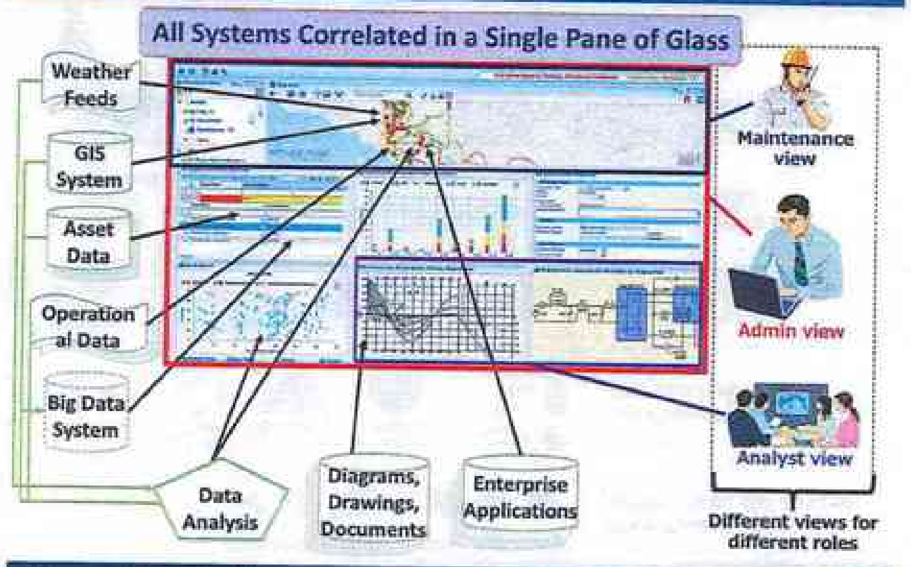


Energy Analytics and Situational Intelligence

Energy Analytics and Situational Intelligence



Situational Intelligence: A typical implementation

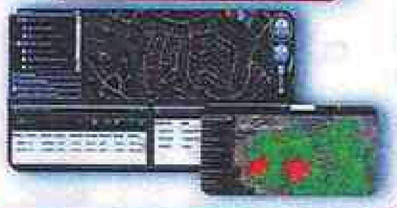


Situational Intelligence Applications

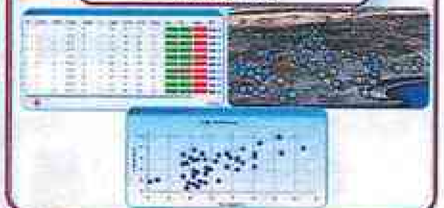
Asset Intelligence

Demand Response Intelligence

Advance Metering Infrastructure Intelligence



Small Grid Intelligence



Situational Intelligence Applications

Asset Intelligence

- Analyze asset health, life expectance and consequence…
- Assess impact of asset risk on real-time operations
- Justify, plan and allocate capital costs

Demand Response Intelligence

- Lower System Peak Demand
- Reduce Feeder Stress
- Improve ROI of Battery Fleet

Advance Metering Infrastructure Intelligence

- Detect and Respond to Smart Meter Anomalies
- Optimize Smart Meter Communications
- Optimize Smart Meter Replacement

Small Grid Intelligence

- Forecast PV generation
- Forecast wind generation
- Optimize grid storage

Situational Intelligence Customers

Wholesale Markets and Trading Intelligence

California ISO
MISO
cepr

Transmission and Distribution Intelligence

EDISON
SDG&E
Entergy
CenterPoint Energy
FPL

Smart Meter and Demand Intelligence

SMUD
SDG&E
FPL
Los Angeles Department of Water & Power
BC hydro

Asset Intelligence

PG&E
NextEra Energy
SDG&E
CLP 中電
hydro one

Other Industries

FedEx
United Nations World Food Programme
Chevron

Summary

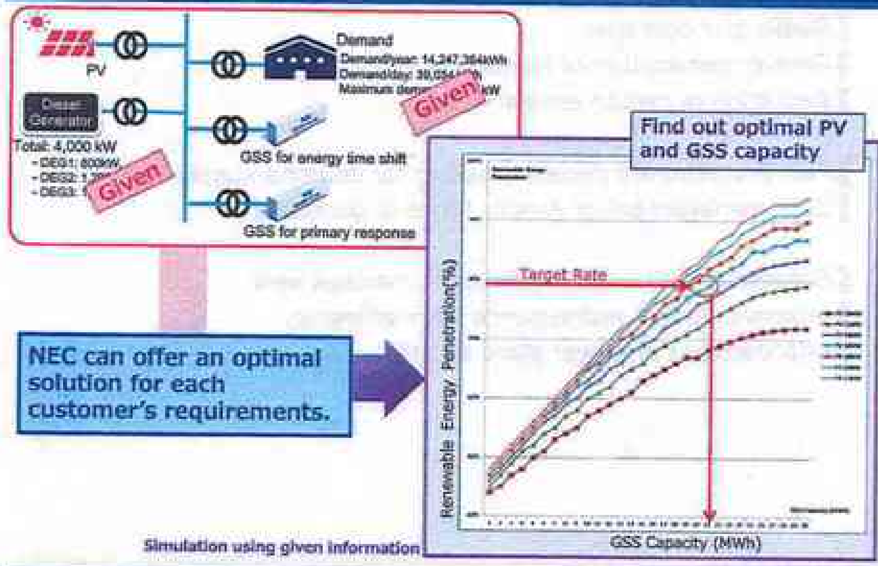
Values NEC can Provide

- Stable grid operation
- Greater penetration of Renewable energy
- Reduction of carbon emission

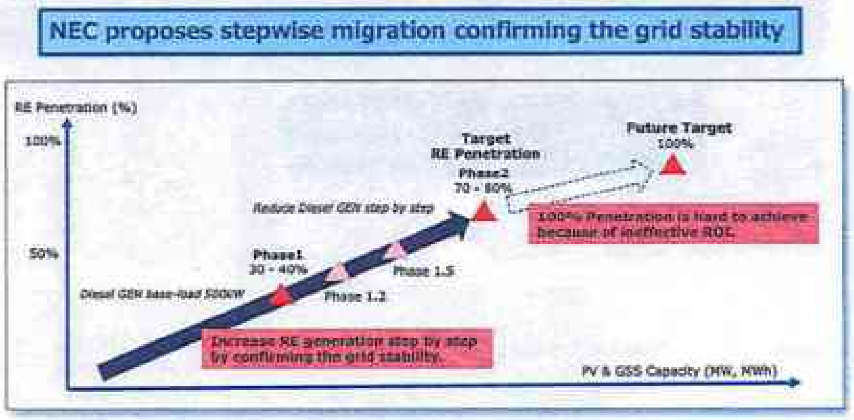
- Fast and accurate decision making for demand-supply balancing
- Easy management of various types of generators

- Suitable decision making for asset management
- Improvement of maintenance work efficiency
- Improvement of power plant security

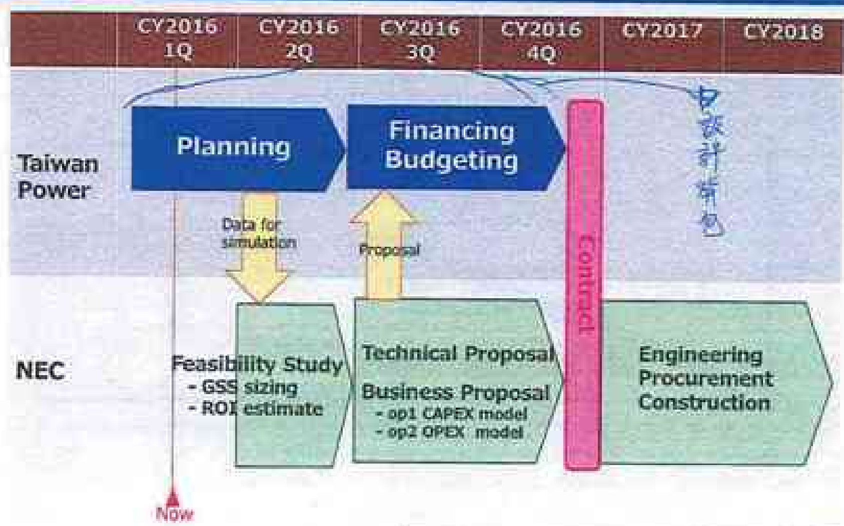
Offering an Optimal Solutions



Proposal for Migration towards High RE Penetration



Next Steps



The process of Taiwan Power is assumed by NEC.

Orchestrating a brighter world

NEC