出國報告（出國類別：開會）

第18屆IERE電力研討論壇會議

服務機關：台灣電力公司

姓名職稱：林哲毅　電機工程專員

派赴國家：日本

出國期間：107年05月20日至107年05月25日

出國報告審核表

出國報告名稱：		
出國人姓名 （2人以上，以1人為代表）	職稱	服務單位
林哲毅	電機工程專員	綜合研究所
出國類別	□ 考察 □進修 □研究 □實習 ■其他 開會 （例如國際會議、國際比賽、業務接洽等）	
出國期間：107年05月20日 至107年05月25日	報告繳交日期：107 年 07 月 20 日	

出國人員自我審核	計畫主辦機關審核	審 核 項 目
■	□	1.依限繳交出國報告
■	□	2.格式完整（本文必須具備「目地」、「過程」、「心得及建議事項」）
■	□	3.無抄襲相關資料
■	□	4.內容充實完備.
■	□	5..建議具參考價值
■	□	6.送本機關參考或研辦
□	□	7.送上級機關參考
□	□	8.退回補正，原因：
□	□	（1）不符原核定出國計畫
□	□	（2）以外文撰寫或僅以所蒐集外文資料為內容
□	□	（3）內容空洞簡略或未涵蓋規定要項
□	□	（4）抄襲相關資料之全部或部分內容
□	□	（5）引用相關資料未註明資料來源
□	□	（6）電子檔案未依格式辦理
□	□	9.本報告除上傳至出國報告資訊網外，將採行之公開發表：
□	□	（1）辦理本機關出國報告座談會（說明會），與同仁進行知識分享。
□	□	（2）於本機關業務會報提出報告
□	□	（3）其他 ______________
□	□	10.其他處理意見及方式：

報告人：綜合研究所（電） 107.7.20 林哲毅

單位主管：綜合研究所（電） 107.7.24 許炎豐代

主管處主管：綜合研究所副所長 107.7.25 范振理

總經理副總經理：綜合研究所所長 107.7.25 洪紹平

說明：

一、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

二、審核作業應儘速完成，以不影響出國人員上傳出國報告至「公務出國報告資訊網」為原則。

行政院及所屬各機關出國報告提要

出國報告名稱：第 18 屆 IERE 電力研討論壇會議

頁數__184__ 含附件：■是□否

出國計畫主辦機關/聯絡人/電話

台灣電力公司 人力資源處/陳德隆/02-23667685

出國人員姓名/服務機關/單位/職稱/電話

林哲毅/台灣電力公司 綜合研究所/七等電機工程師/02-80782263

出國類別：□1 考察□2 進修□3 研究□4 實習■5 其他

出國期間：107 年 05 月 20-25 日　　出國地區：日本

分類號/目

關鍵詞：智慧電網(Smart Grid)、先進讀表基礎建設(Advanced Metering Infrastructure, AMI)

內容摘要：

智慧電表為智慧電網架構下最重要的基礎建設之一。通過智慧電表，未來台電可不再派員抄表，並可自動化的收集民眾的每 15 分鐘用電資訊做為更精確的負載分析等用途；而對於民眾則可了解自家的即時用電量，且可選用時間電價，期許以多樣且實用之服務促使民眾改變用電行為，以達節能減碳的目標並減緩缺電的危機。

IERE 成立於 1968 年，為電力事業研究單位指標性的技術交流平台，每年固定於世界各地集結於電力事業領域的研究機構舉辦交流及研討論壇會。本次參加會議將發表有關本所研發之智慧電表的機構設計、通訊介面、金鑰管理系統、通訊評鑑流程制度、資通安全測試等相關議題。IERE 研討會廣邀學術界、產業界和電力公司專家進行交流，因應未來電網的應用不斷演變，本公司需將技術及設備不斷演進，以確保本公司在智慧電網的道路上能夠與世界先進各國接軌並藉由此機會與世界各國專家交流並尋求將本所研究成果推廣至國際的可能性。

IERE GWG/NWG 技術委員會會議

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壹、 出國緣由及目的

行政院 99 年 6 月 23 核定經濟部研擬之「智慧型電表基礎建設(AMI)推動方案」[1]，正式啟動我國 AMI 建置。我國已完成全國 2.4 萬戶高壓智慧型電表，並規劃於 113 年完成低壓 300 萬戶智慧型電表，目標掌握全國八成以上的詳細每日、分、時用電資訊，並配合住商多元時間電價方案之推動，達到抑低尖峰用電效果。

完整的 AMI 系統包含了智慧電表、電表至電業端之通訊模組(A Route)、電表至家庭端之通訊模組(B Route)及電表資料管理系統(Meter Data Management System, MDMS)，其中家戶電表負責量測即時用電資料，再透過通訊模組送至電業端使用 MDMS 進行資料之儲存、處理及應用，為使電力資料能發揮最大效益及加速 AMI 與家庭能源管理系統的連接，本計畫將開發多功能應用平台，使民眾可直接透過 APP 查詢電表端、家戶端的即時用電量、預估電費、並提供用電告警、用電分析等功能，以多樣且實用之服務促使民眾改變用電行為。

本次出國擬於第 18 屆 IERE 電力研討論壇會議[2]發表本所於 AMI 研發之成果，包含智慧電表的機構設計、通訊介面、金鑰管理系統、通訊評鑑流程制度、資通安全測試等相關議題，並了解世界各國智慧電網的發展情形進行交流。

貳、 出國行程

本出國計畫，自 106 年 05 月 20 日起，至 106 年 05 月 25 日止，前後 6 天，詳細行程如下表所示。

起始日	迄止日	實習機構	實習內容
1060520	1060520		去程(台北－京都)
1060520	1060523	IERE	參加今年 IERE 舉辦於日本京都的電力研討論壇會議，並於研討會中發表關於本所研究之智慧電表技術及發展概況，包含智慧電表的機構設計、通訊介面、金鑰管理系統、通訊評鑑流程制度、資通安全測試等。並藉由此機會與世界各國專家交流並尋求將本所研究成果推廣至國際的可能性，也可了解國外最新智慧電網發展趨勢並學習其優點
1060524	1050524	蹴上水力發電廠	參觀日本於 1891 年建置的第一間營業用水力發電廠及其所使用發電機的演進史。
1060525	1060525		返程(京都－台北)

參、 IERE 研討會

I. IERE 介紹

IERE (International Electric Research Exchange)成立於 1968 年，為一個以非營利為導向且自體經濟獨立的國際性機構，其成立的目的為評估創新及新興的電力事業技術與建置、協助在不斷變化的商業環境中樹立企業策略與研發、及促進發達經濟體將電力事業技術轉移至發展中經濟體[2]。

IERE 的成員包含了世界各國的電力公司、電力相關研究單位、設備製造商及大學院校等等，每年定期會在世界各地舉辦不同主題的研討會，像是 2006 年就曾經於台灣舉辦過主題為”R&D in Electricity: How is it Launched and How is it Evaluated?”的研討會。今年的 IERE 年會則是舉辦於日本，其主題為「下世代的電力輸配電系統(Power Transmission and Distribution Systems in the Next Generation)」，參加的機構包含美國電力研究機構(Electric Power Research Institute, EPRI)、加拿大電力技術實驗室(Powertech Labs)、法國配電公司(Enedis)、香港中華電力有限公司(CLP)、日本中部電力公司(Chubu EPCO)、關西電力公司(Kansai EPCO)、東京電力公司(TEPCO)、中央電力經濟研究院(CRIEPI)、韓國電力公司(KEPCO)、及台灣電力公司等等。

本次研討會共分為「輸配電系統的新潮流及需求(New Trends

and Requirements in the Field of Transmission and Distribution Systems」、「下世代的輸配電系統技術(Technology for Power Transmission and Distribution Systems in the Next Generation)」、「利用資通訊技術(含人工智慧及物聯網)及其在輸配電系統的效益(Use of ICT (including AI and IoT) and Its Impact on Power Transmission and Distribution Systems)」、及「進入下世代的輸配電系統(Toward the Transmission / Distribution System in the Nest Generation)」四項主題。而本所將受邀於上述第三個場次「利用資通訊技術(含人工智慧及物聯網)及其在輸配電系統的效益」發表本所於智慧電表的研究成果(圖 1)。

圖 1 本人於 IERE 研討會口頭發表研究成果

II. 研討會內容

本所今年在 IERE 所發表的題目為「台灣下世代的先進讀表基礎建設(Introduction of Next-gen AMI System in Taiwan)」。智慧電表為智慧電表架構中極為重要的一環。由行政院規劃的台灣智慧電網願景為建立高品質、高效率和環境友善的智慧化電力網，促進低碳社會及永續發展的實現；其目標包含了確保穩定供電、促進節能減碳、提高綠能使用、及引領低碳產業。其實程可分為以下三個階段：2011 年至 2015 年為前期布建、2016 年至 2020 年為推廣擴散、而 2021 年至 2030 年則為廣泛應用；包含了智慧發電與調度、智慧輸電、智慧配電、智慧用戶、智慧電網產業發展及智慧電網環境建構等六個構面；而智慧電表的建設主要屬於智慧配電及用戶的構面。

台電在民國 103 年已完成全數高壓用戶 24,000 具智慧電表的布建，其用電量約為總發電量的 60%。其架構如所示為將電子式電表的通訊埠連接到電表介面單元(Meter Interface Unit, MIU)，並通過加密後的專屬 4G 通道傳送到台電的後端電表資料管理系統。此方式的通訊可確保其穩定性，但因每一台電表皆須連結到一台(MIU)，且須向電信業者承租 4G 網路，因次此布建方式的成本較高，並不適用於低壓用戶。

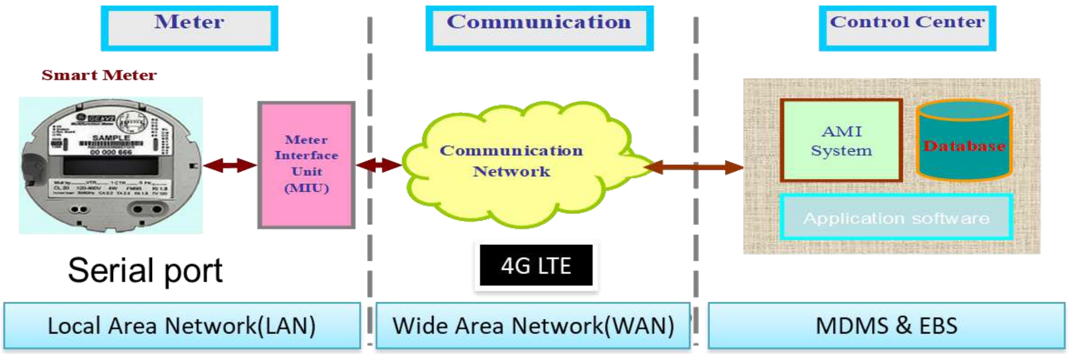


圖 2 高壓 AMI 系統規劃架構圖

在 103 年本公司執行了低壓 AMI 的初期 10,000 戶先導型建置案，當時的通訊模組內建於電表中，並使用了 ZigBee、電力線載波(PLC)、及電信網路等不同技術。由此建置案，我們學習到了以下幾點寶貴的經驗：

1. 在台灣的環境下，無法找到可適用於某地區內所有電表讀表的單一通訊技術。
2. 電表與通訊模組的生命週期並不一致。
3. 若通訊內建於電表中，當需更換通訊模組時則須破壞標檢局的封印鎖，當更換完成後須再請標檢局上鎖，此流程將增加成本。
4. 若全部由台電負責為運，當不同通訊技術皆使用時將增加倉管的困難。

因此，配合後續 AMI 系統建置及未來物聯網發展應用趨勢，本所研發了一套新的低壓 AMI 架構，其概念包含了以下幾點：

1. 參照 IEC 國際標準[3]及 CNS 國家標準[4]，制定符合台電公

司需求的標準介面以確保不同廠商設備間的互換性。

2. 為降低更換電表成本及對用戶造成的影響,將保留台灣既有圓表底座設計，未來換表作業每具僅需約 5 分鐘內即可完成。

3. 因通訊單元的可靠度及穩定度較計量單元(電表本體)低,因此通訊模組需可支援熱插拔以增加查修效率及成本,且可於不破壞標檢局封印下完成。

4. 須支援光讀頭的設定及資料讀取。

本公司規劃之低壓 AMI 系統採取電表模組化、通訊系統與計量分離、HAN/FAN/WAN 通訊技術 agnostic 等原則規劃，系統架構如圖 3 所示，共包含計量單元、AMI 通訊系統、HAN 通訊單元、手持裝置、本公司後端系統、用戶端系統、金鑰管理系統與 Agent 等 7 個組件與 5 個介面：

- **計量單元**：係指電表表體，負責計量、顯示、儲存與回報等功能，表體內須可收容 FAN 與 HAN 通訊單元(模組)等，計量單元可透過 FAN 通訊單元(模組)與頭端伺服器通訊；計量單元亦可透過 HAN 通訊單元(模組)將資訊推播到用戶端系統。
- **AMI 通訊系統**：連接本公司內部系統與電表計量單元之通訊系統，由 FAN 通訊單元(模組)、頭端伺服器與各種 FAN 或 WAN 通訊設備(例如: Repeater、Gateway、Concentrator 或 Base station 等)所組成。FAN 通訊單元(模組)扮演 P1、P2 介面與 AMI 通訊網路間閘道器的角色，而頭端伺服器則扮演 AMI 通訊網路與台電後端系統間電表資料閘道器的角色，也負責通訊系統中網路及設備的管理功能(包含: 金鑰管理與軟韌體管理等)，對於 FAN 通訊單元(模組)與頭端伺服器間的 AMI 通訊網路採用何種技術則非本文件範疇。
- **HAN 通訊單元(模組)**：電表與用戶端間的通訊介面。HAN 通訊單元(模組)扮演 P2 介面與 HAN 網路間閘道器的角色，

至於 HAN 採用何種通訊技術則非本文件範疇。

- **<u>手持裝置：</u>**執行本公司對於電表的近端操作需求，例如: 電表安裝、更換或 AMI 通訊網路失效必須近端存取或測試時，手持裝置可透過電表計量單元的光學埠對電表進行操作。亦可安裝電表得標廠商所提供之電表操作軟體，執行電表之金鑰初始化程序。
- **<u>台電後端系統</u>**：如: MDMS 等。具體包含哪些設備則非本文件範疇。
- **<u>用戶端系統</u>**：如: HEMS 等。HAN 通訊單元(模組)扮演 HAN 網路與用戶間閘道器的角色，至於 HAN 採用何種通訊技術則非本文件範疇。
- **<u>金鑰管理系統與 Agent</u>**：本公司後端管理系統的子系統之一，包含位於控制中心之金鑰管理系統(Key Management System；KMS)與位於各區處之 KMS Agent 所組成，負責產生、匯出及管理電表金鑰。其中金鑰之產生及管理方式則非本文件範疇。

電表 5 個介面包含 P1、P2、P5、P6 與 P7:

- P1：計量單元⇔AMI 通訊系統，其實體介面為 serial，使用 HDLC 進行資料交換。
- P2：AMI 通訊系統之 FAN 通訊單元(模組)⇔HAN 通訊單元(模組)，其實體介面為 serial，使用 HDLC 進行資料交換。
- P5：手持裝置⇔計量單元
- P6：AMI 通訊系統⇔台電後端系統
- P7：手持裝置⇔金鑰管理系統之 Agent

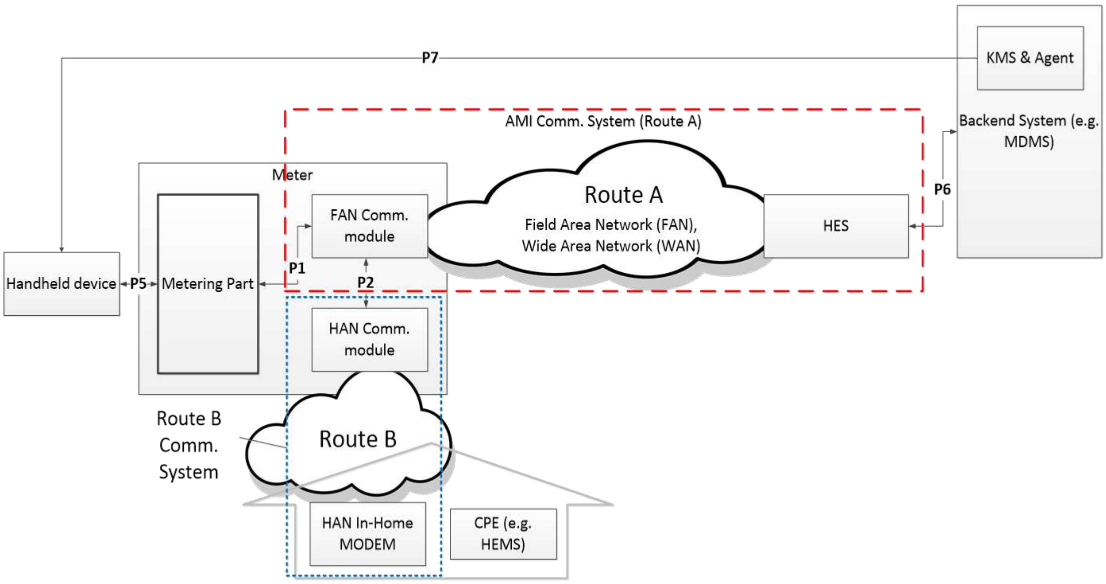


圖 3 低壓 AMI 系統規劃架構圖

圖 4 為 AMI 系統與通訊協定架構中計量單元採用 CNS 15593。表體內各模組的介接統一採用 serial UART 實體層與 HDLC based data link layer，應用層則由計量單元扮演 DLMS/COSEM Server 的角色，與 AMI 通訊系統、手持裝置與用戶端系統等不同的 DLMS/COSEM Clients 通訊，實現所需的 AMI 相關功能與服務。

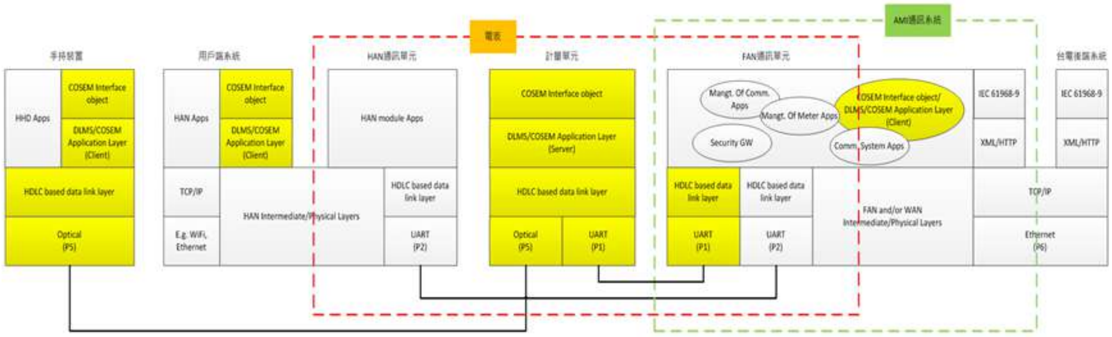


圖 4 AMI 系統通訊協架構

圖 5 為本公司所制定之低壓 AMI 通訊介面，其中電表對外包含 P1 及 P5 兩個介面。由電表計量單元做為伺服器(Server)端，而 FAN 通訊模組及手持式裝置則是客戶端(Client)，透過上述通訊介面標準與 Server 溝通，其實體層連接為 UART 介面，而資料連結層、網路層、應用層等則是依照 IEC 62056 DLMS/COSEM 制定開發。

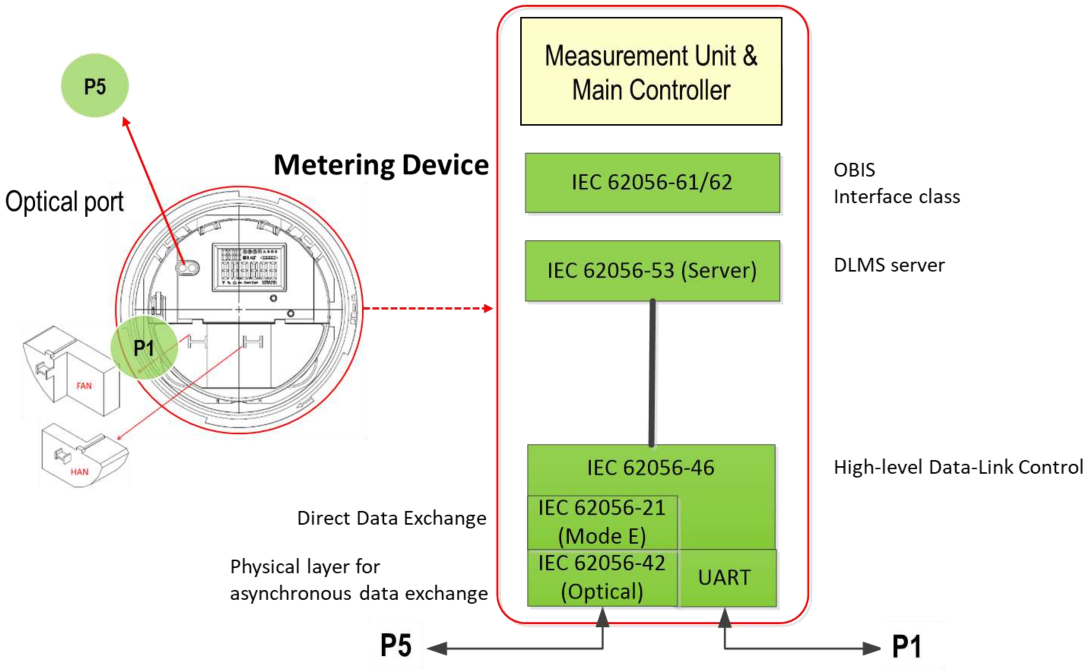


圖 5 電表表體與對外 P1、P5 通訊介面

如前述，本公司所設計之通訊單元可分為FAN通訊單元及HAN通訊單元；其中 HAN 的資料是透過 FAN 上的 UART PIN 腳，經由 P2 介面提供資料再通過 HAN 廠商自訂義之 P4 介面將電表資訊傳至各家戶中，如圖 6 所示。

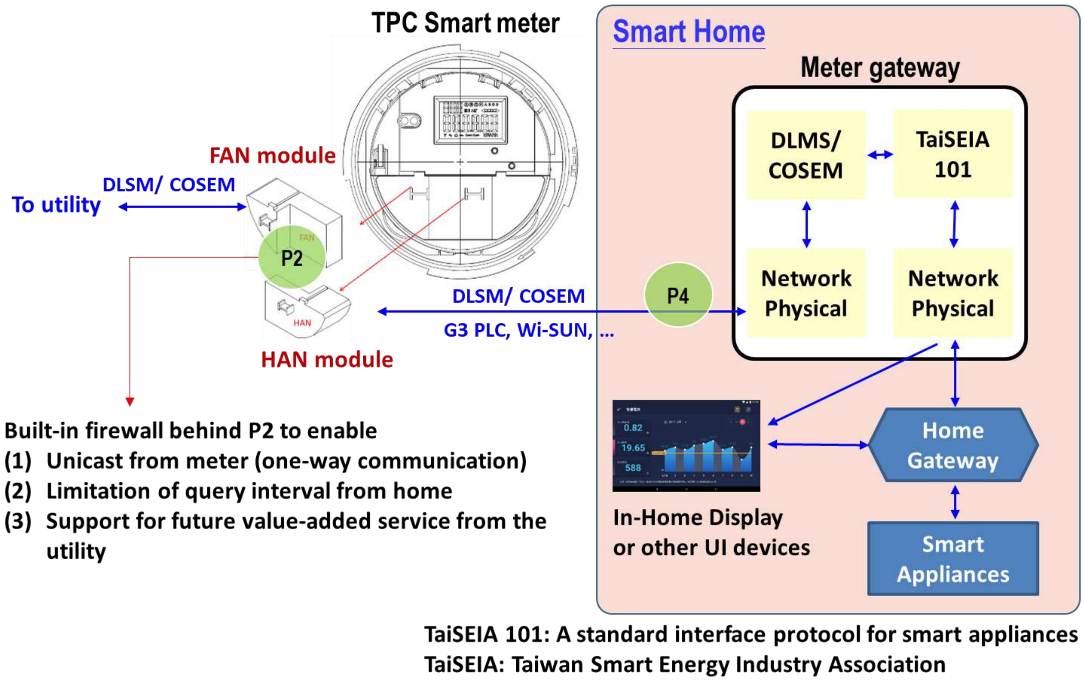


圖 6 HAN 模組通訊介面

因電表通訊為智慧電表布建計畫的主要功能之一，因此為了驗證廠商的通訊效能，本所以前述制定之通訊標準開發了一套電表模擬器用以產生符合標準之電表資料。此電表模擬器具備與未來模組化電表相同的介面、功能與行為。但計量部份使用模擬數據並進行加密，受測廠商讀表時所讀到的數據需經解密後才能得知實際的數值，以避免受測廠商偽造讀表數據。研究團隊依據台電 AMI 系統架構訂定兩個通訊介面：電表與 FAN 通訊單元通訊介面（P1）以及頭端伺服器與台電系統通訊介面（P6）。研究團隊針對 P1 與 P6 通訊介面開發相關測試工具，在實驗室測試場域及實際測試場域中對通訊系統進行相關端對端介面（end-to-end）測試，取得通訊系統的測試數據以作為未來評量的參考。其中頭端伺服器與台電系統通訊介面 P6 將會透過 Internet 進行通訊，此部份由受測廠商自行負責。研究團隊訂定頭端伺服器與台電系統間的 P6 通訊協定，並開發相關模擬系統以供 P6 通訊協定測試。電表與 FAN 通訊單元通訊介面 P1 則是透過 UART 介面進行溝通，研究團隊依照電表與 FAN 通訊模組間 P1 通訊協定，設計適合的軟硬體，在實地場域測試時使用。

電表模擬器核心為樹莓派（Raspberry Pi，RPi），是一款基於 Linux 的單晶片電腦，由英國的樹莓派基金會所開發，目的是以低價硬體及自由軟體促進學校的基本電腦科學教育。由於 RPi 具有完整的 GPIO（General-purpose Input/Output）介面可作為電表模擬器使用，且其作業系統為開源的 Linux 系統，各項資源豐富。研究團隊設計專供本計畫使用的擴充板，RPi 可透過 GPIO 與擴充板連接。擴充板具有外接電源，提供 RPi 及通訊模組使用，其規格如下表。RPi 可透過 GPIO 控制擴充板對通訊模組的電力供應，此項功能可模擬斷電後復電的功能，用來測試通訊模組在大規模停電復電後的連線能力。在實驗室測試中 讓 RPi 的 CPU 使用率達 100%，環境溫度 70°C 時可連續工作至少二週以上，代表在高溫環境下具有一定的穩定性，因此加上適當外殼及週邊連接器後作為本次測試的電表模擬器使用。

表 3.6-1 模擬電表擴充板規格

項目	規格
輸入電壓	AC 100V~240V

輸出電壓	5V(共二組)，由樹莓派 GPIO 控制開關 (一組為 pin 腳接頭，一組為 USB 接頭)
通訊介面	UART(一組) (由 jumper 決定連接通訊模組或 DB-9 接頭)
與樹梅派介面	40Pin
LED 燈號	4 個(由樹莓派 GPIO 控制)
按鈕	2 個(由樹莓派 GPIO 控制)
其它按鈕及燈號	電源開關、通訊模組 reset 按鈕、電源燈號、供電燈號、通訊模組燈號

由於測試場域中電表所在區域涵蓋室外及室內，在室內的部份有分佈在一樓、大樓各樓層及地下室，在室外的部份是放置在騎樓。在設計電表模擬器的外殼機構時需考量防水的部份，除避免室外的雨水影響外，還可以避免地下室濕氣過高影響電表模擬器的運作。除外殼機構設計需具防水功能外，與通訊盒的接頭及電源接頭亦需具防水功能，其設計圖如下。

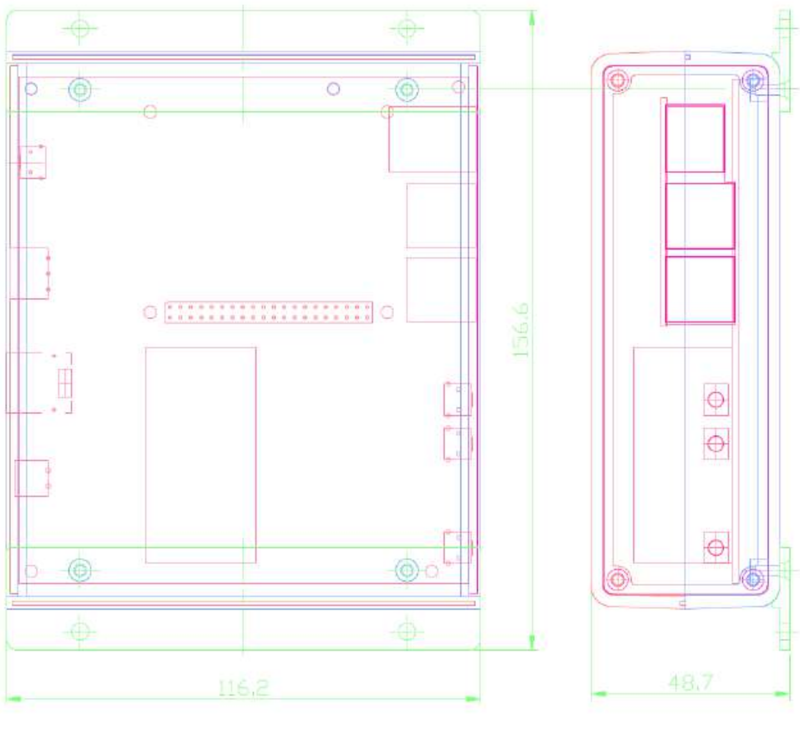


圖 3.6-16　電表模擬器外殼機構設計圖

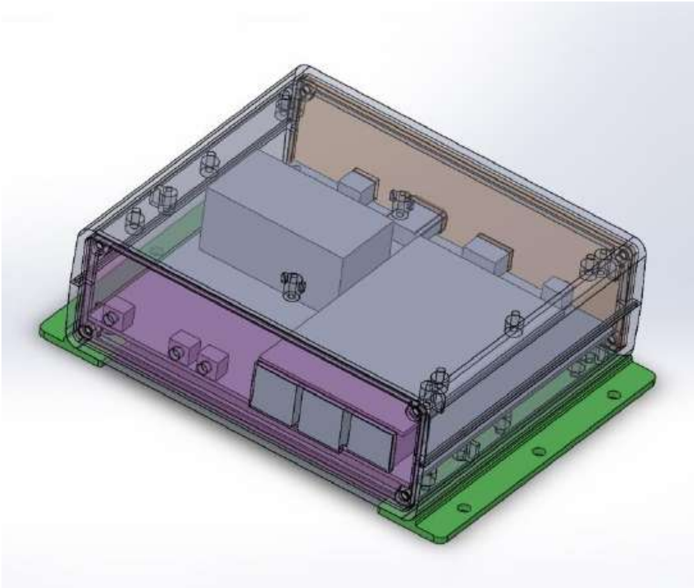


圖 3.6-17　電表模擬器 3D 透視圖

電表模擬器提供三個防水接頭，外觀說明及接法如下所示，說明如下：

1. 模擬器電源：2 pin 接頭，由電表中介引出電源至此接頭，使用 220V 交流電。此接頭為提供電表模擬器電源，一定要接上。
2. PLC 訊號耦合：2 pin 接頭，若通訊模組採用 PLC 通訊技術時，需透過這個接頭與通訊盒連接。當 FAN 通訊模組採用 PLC 通訊技術必需接此接頭,而採用 RF 通訊技術的 FAN 模組無需接此接頭。
3. 傳輸線 9 pin 接頭：此接頭內包含 FAN 通訊模組介面之 UART 腳位及其它 I/O 腳位。

Meter ID：每個模擬器的軟體中均有一個唯一的 Meter ID，代表模擬電表的虛擬電號，提供資料回傳時辨識用。外殼上也會標示此 Meter ID，以現場人員供辨識用。

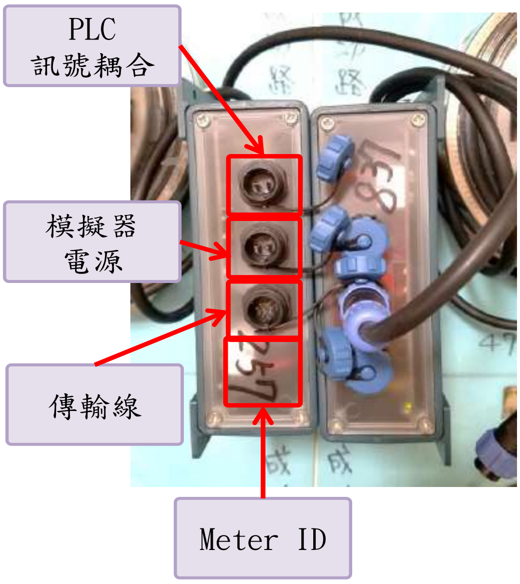


圖 3.6-18　電表模擬器接頭說明

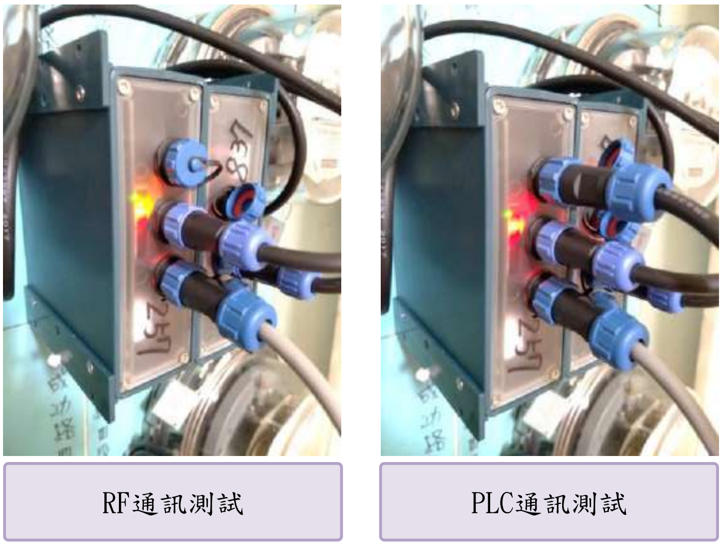


圖 3.6-19　通訊模組使用不同傳輸法式的接法

完整的 AMI 系統包含了智慧電表、電表至電業端之通訊模組(A Route)、電表至家庭端之通訊模組(B Route)及電表資料管理系統(Meter Data Management System, MDMS)，其中家戶電表負責量測即時用電資料，再透過通訊模組送至電業端使用 MDMS 進行資料之儲存、處理及應用，為使電力資料能發揮最大效益及加速 AMI 與家庭能源管理系統的連接，本計畫將開發多功能應用平台，使民眾可直接透過 APP 查詢電表端、家戶端的即時用電量、預估電費、並提供用電告警、用電分析等功能，以多樣且實用之服務促使民眾改變

用電行為。本公司配合能源局政策，於 106 年底完成了 1000 戶智慧電表與家庭端整合之示範計畫，其計畫架構如下：

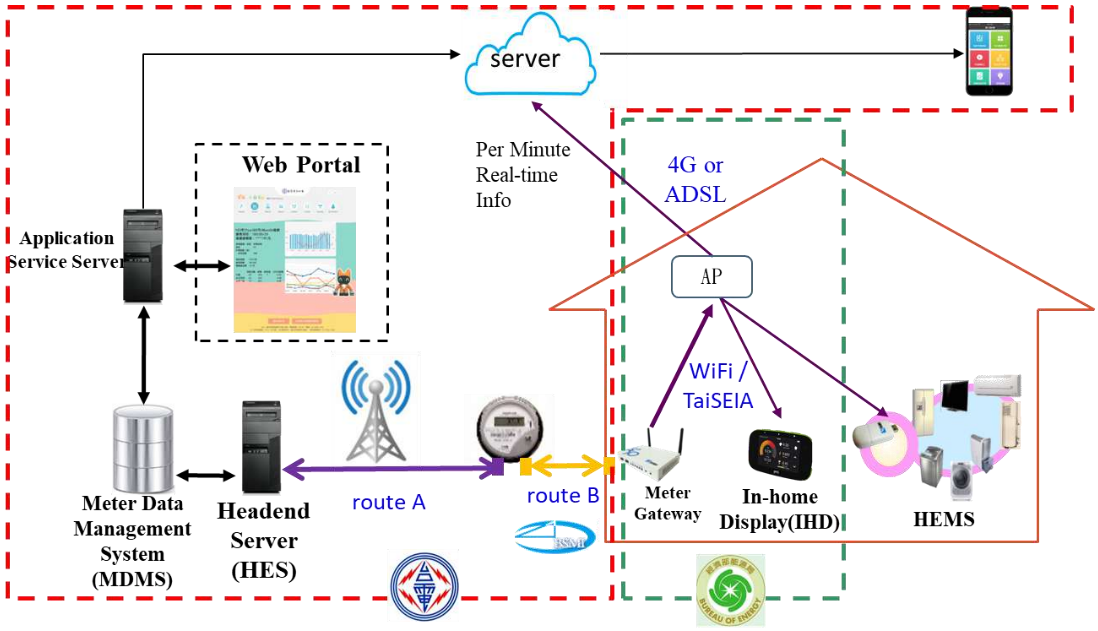


圖 7 1000 戶智慧電表與家庭端整合之示範計畫架構圖

圖 7 中紅色框的部分為台電所負責。主要包含安裝智慧型電表、透過 FAN 及 HAN 模組建置 Route A 及 Route B 通訊系統、開發電表資料管理系統、開發應用伺服器及用戶端 APP。而能源局部分則是做家庭能源管理及智慧家電連結等。

在這 1000 戶的示範案中，我們於 Route A 及 Route B 皆嘗試使用不同的通訊技術以驗證其可行性。Route A 部分使用了 802.15.4g RF 及 LTE 兩種通訊技術；而 Route B 則是使用了 HomePlug PLC 及 WiSun 兩種技術。

AMI 通訊系統包含 FAN 通訊模組、DCU 及 HES 三個部分，分別由 FAN 與 HES 與電表端及後端系統的 MDMS 連接。因所使用 FAN 通訊技術包含了 RF mesh 及 LTE 兩種，是故因採用技術不

同，需不需要使用 DCU 來匯集現場電表資料再後傳也因此而有所區別。

FAN 通訊的部分，RF mesh 是以 840-847MHz 頻段的通訊技術為主，每個 channel 頻寬為 200KHz，可以軟體指定不同 channel 使用。傳輸功率最大為 26dBm(0.4W)，接收訊號靈敏度為-105dBm。採用的 Routing 技術為可支援 IPv6 的 RPL(IETF Routing Protocol for Low Power and Lossy Networks)技術，可允許資料採 multi-hop 方式進行傳輸。以 RF module 本身的傳輸能力，在無遮避狀況下即可達 1.2Km 的點對點傳輸距離，再加上使用 multi-hop 技術將可使整個網路覆蓋範圍達 1Km 方圓以上(因在有遮避環境點對點傳輸距離會縮短到數百公尺或甚至 100 公尺以內)。當使用 RF mesh 技術於表端時，現場需搭配使用資料集中器(DCU)以將現場讀表資料進行匯整後再送往後端系統。DCU 為具備 840MHz RF mesh 通訊能力與 WAN LTE/3G 通訊能力的嵌入式系統，其上有 ARM-based CPU 與記憶體使其具有運算及儲存資料的能力。搭配 IP66 的外殼，可直接裝設在戶外環境使用。LTE 模組為本系統另一應用於表端的通訊技術，同時可支援 LTE Cat. 1 通訊並向下相容 3G 通訊能力。支援 LTE 頻段包含 Band 28 (700)、Band8 (900)及 Band 3(1800)，與 3G UMTS/HSPA+ 的 Band 1(2100)。LTE 模組的使用，可使 HES 直接透過電信網路進行讀表工作。

以上兩種通訊技術的搭配，預計可涵蓋所有不同住宅環境的需求，以期達到 100%讀表涵蓋的目標。在場域中無論是透過 RF mesh

到 DCU，抑或是直接透過 LTE 模組，在連接到 MDMS 之前都會先經過 HES 系統。HES 即是控管現場電表與 DCU 的後端系統軟體，提供電表資料抓取，控制命令下達以及網路節點管理的功能。HES 是由基本通訊平台、資料收集服務、資料庫以及 MDMS 介面等幾部分組成。

電表資料管理平台開發包含 MDMS(Meter Data Management System)的核心功能以及與 A Route 的 HES 通訊功能等，整個系統的軟體架構如圖 8，MDMS 包含 P6 介面的介接功能、資料處理、VEE 資料驗證、儲存及應用，資料在儲存時使小量資料使用 Maria 方式儲存，而巨量資料使用 HBase 進行接收及處理，確保了資料可以長期儲存，而後端預留了未來在處理如 OMS、WMS 或是 CIS 等系統的介接空間，可以使用 P6 介面或是 restful 來介接都是可行的方式，而目前內部介面 MDMS 及內部 Web 之間即是採用 restful 方式來進行呼叫。

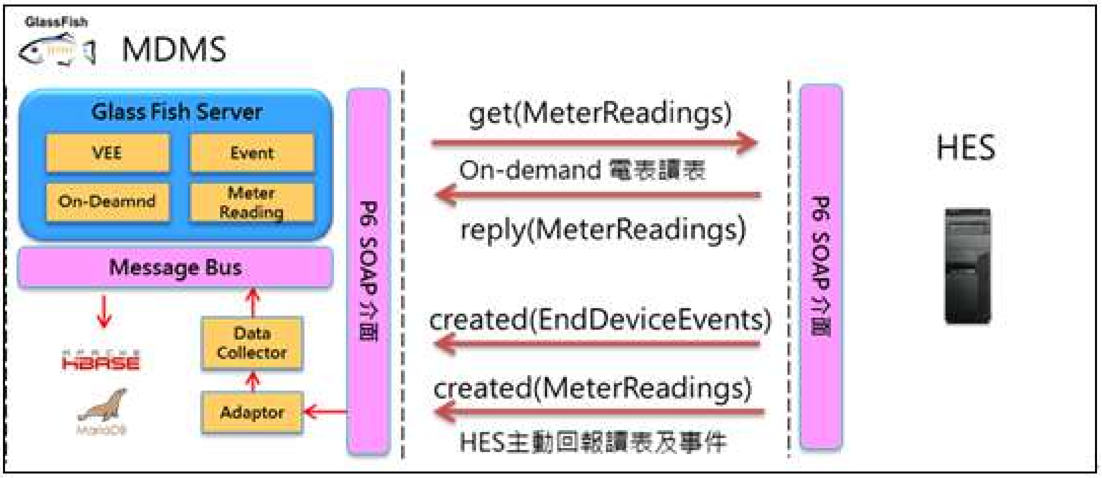


圖 8 MDMS 整合功能

MDMS 由於要負擔管理功能，網頁的 UI 介面不可或缺，本計

畫提供後台介面供操作人員使用，可以讀取存在傳統資料庫或是存在於 Hbase 內的電表資料，已實作之介面請見以下說明。

一、　電表清單

電表清單的資料是儲存於 Maria 資料庫中，在網頁端可以直接顯示及呈現相關的清單，點入後可以觀看到電表的基本資訊如表號、型號廠牌等，以及電表的讀表資料，如圖 9。

圖 9 管理介面電表清單

二、　用戶清單

用戶清單的資料是儲存於 Maria 資料庫中，在網頁端可以直接顯示用戶的電號、地址等，對於管理的查詢相當方便，點入後可以連結到對應電表的讀表資料，如圖 10。

圖 10 管理介面用戶清單

用戶清單點入後可以對應到相對應的電表號，在這裡可以和電表清單點入的畫面相同，此功能可以快速查閱用戶的用電情形，如圖 11。

圖 11 管理介面用戶電表資料

三、 電表讀表數據

由於 HES 端定期會不斷拋上電表的每 15 分鐘 Load Profile 資料，而這些用電資料在系統中已經可以做呈現，如實際場域已經建置秀朗公宅的電表，相關資料可每日匯入系統中，如圖 12 顯示的即是 5/12~5/16 的每 15 分鐘用電資訊，由於目前電表端 P1 規範所定義的 Load Profile 是指當下的總用電度數，圖面會做成將所有數值採每 15 分鐘進行相減而得到真實每 15 分鐘的用電度數，可以更完整呈現相關的用電情形。

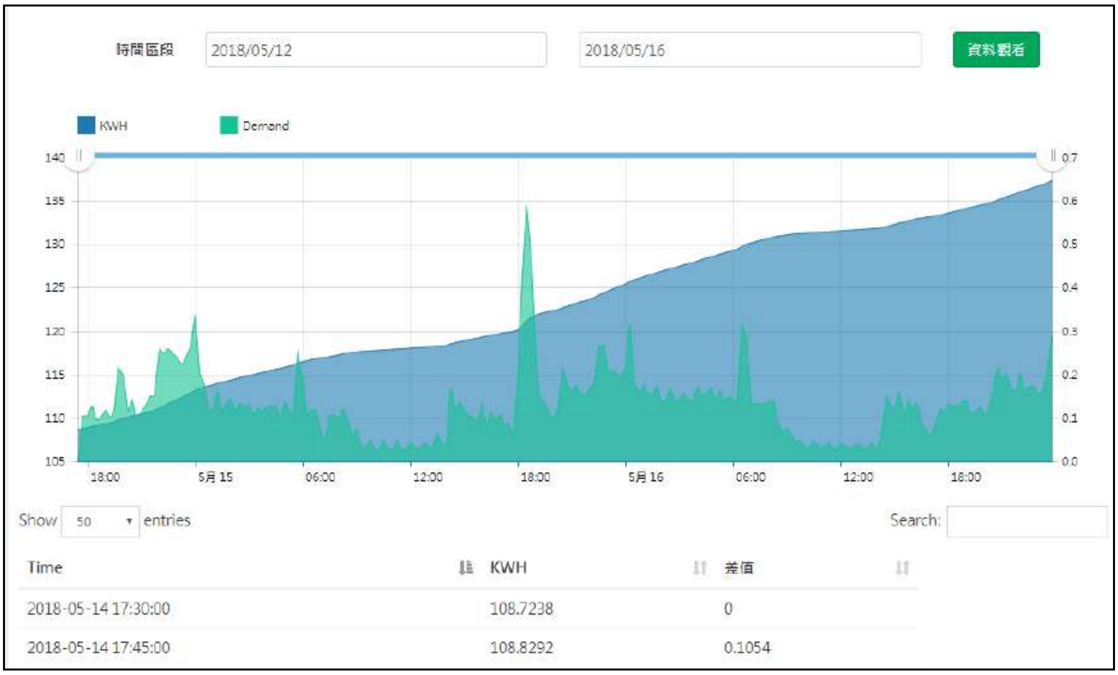


圖 12 管理介面電表用電顯示

四、 電表事件資料

MDMS 在接收到 HES 端所上傳的事件之後都會存在於資料庫內，相關的事件會顯示於網頁上供管理員觀看，以圖 13 為例，可

以看到此電表在 2018/01/01~2018/04/22 的資料範圍中，曾在 2018/3/9 曾有過一個事件的紀錄，就可以從網頁上觀看到。

圖 13 管理介面電表事件及數值顯示

五、 On-deamnd

電表清單任意點選電表之後就可以連結到電表內，管理者可以任意對電表進行讀表操作，如圖 14，此範例是選定 kwh(Register) 來讀取數值，HES 端並在 30 秒內即回應。

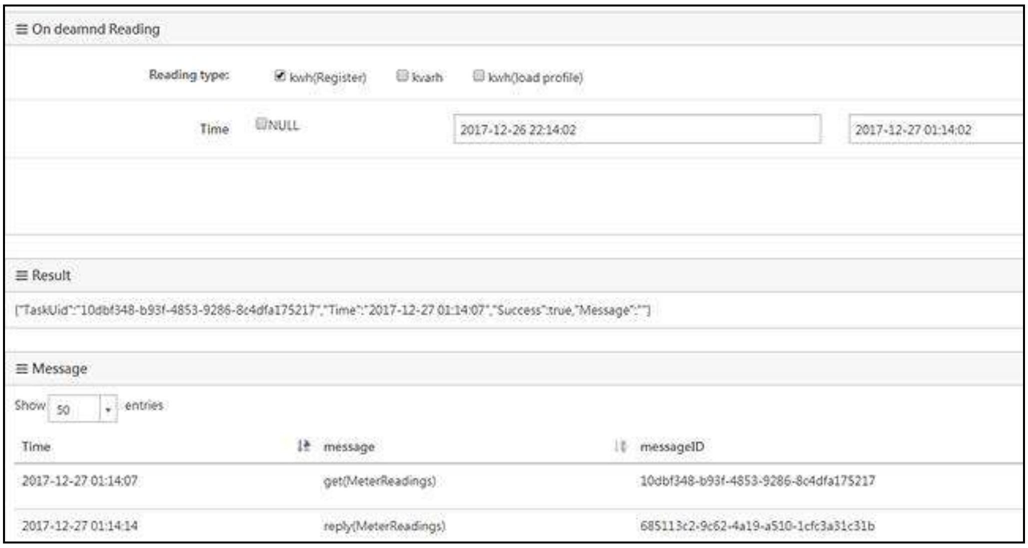


圖 14 on-demand 介面

六、 電表操作

電表操作功能整合了 on-demand 讀表、取得事件、送訊息以及設定的功能，都是由 MDMS 主動發送的，在這裡若是 on-demand 可以選擇各種 ReadingType 來做讀取，如圖 15，若是送出 control 訊息則可以選擇不同的 code type 來做發送，如圖 16，另外若是要發送 Terminal Message 訊息到表的話，甚至可以輸入相關的訊息文字由 A Route 端來發送，如圖 17，此功能提供了管理人員非常完整的操作工具來對於電表進行操作。

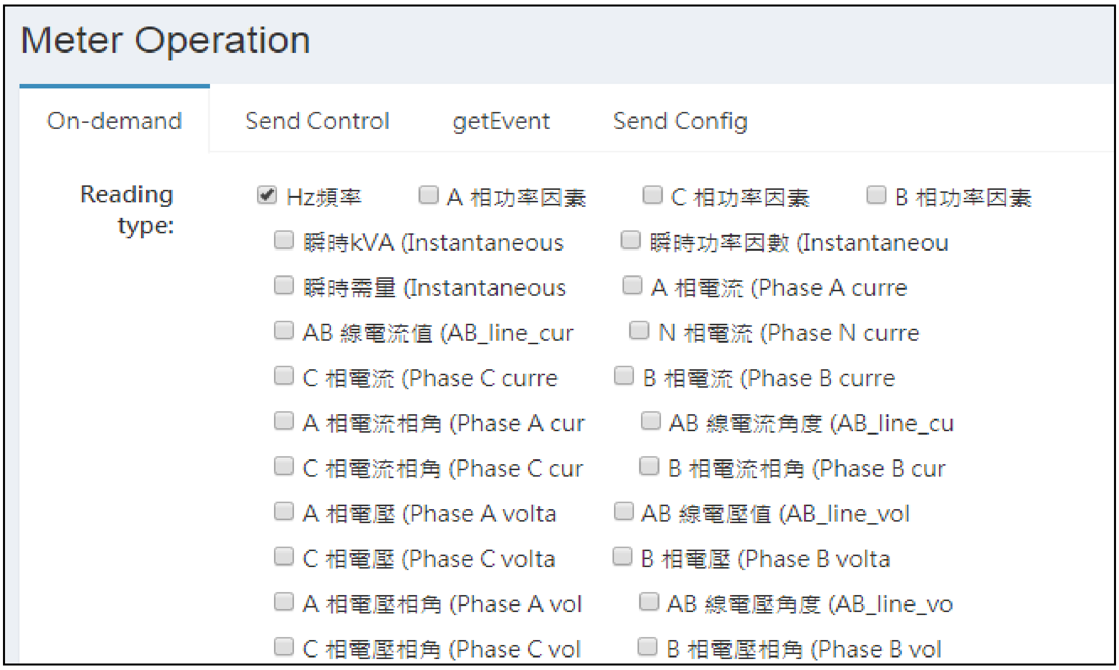


圖 15 電表 on-demand 功能頁面

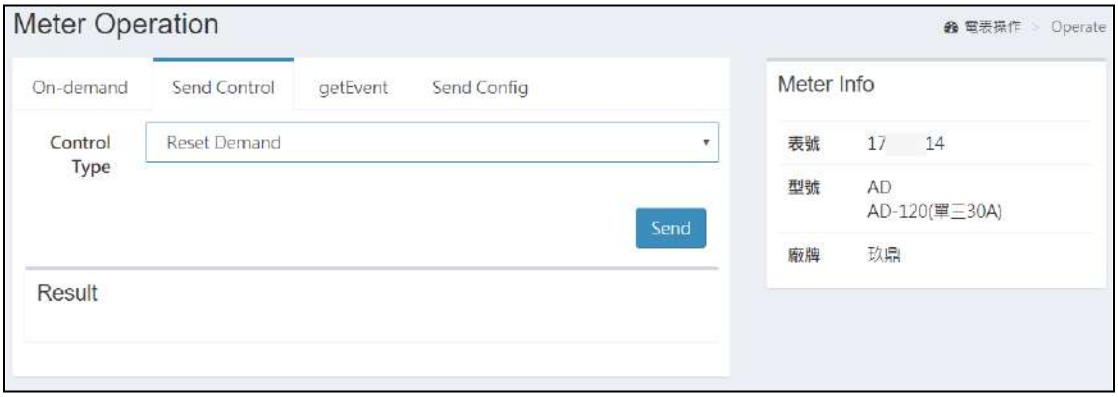


圖 16 電表 send control 功能頁面

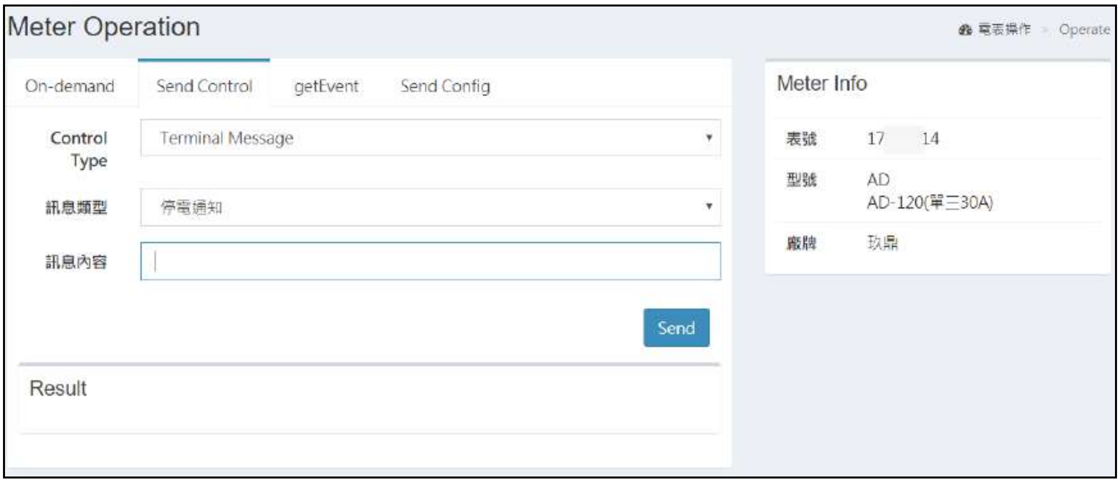


圖 17 電表發送 Terminal Message 功能頁面

七、 系統 Log

MDMS 與 HES 會定期進行通訊，無論是 HES 上傳的或是 MDMS 主動發出的，系統的 Log 對於觀察系統的狀態以及 debug 相當有幫助，如圖 18；點入詳細資料後還可以觀看此訊息的實際 log，如圖 19。

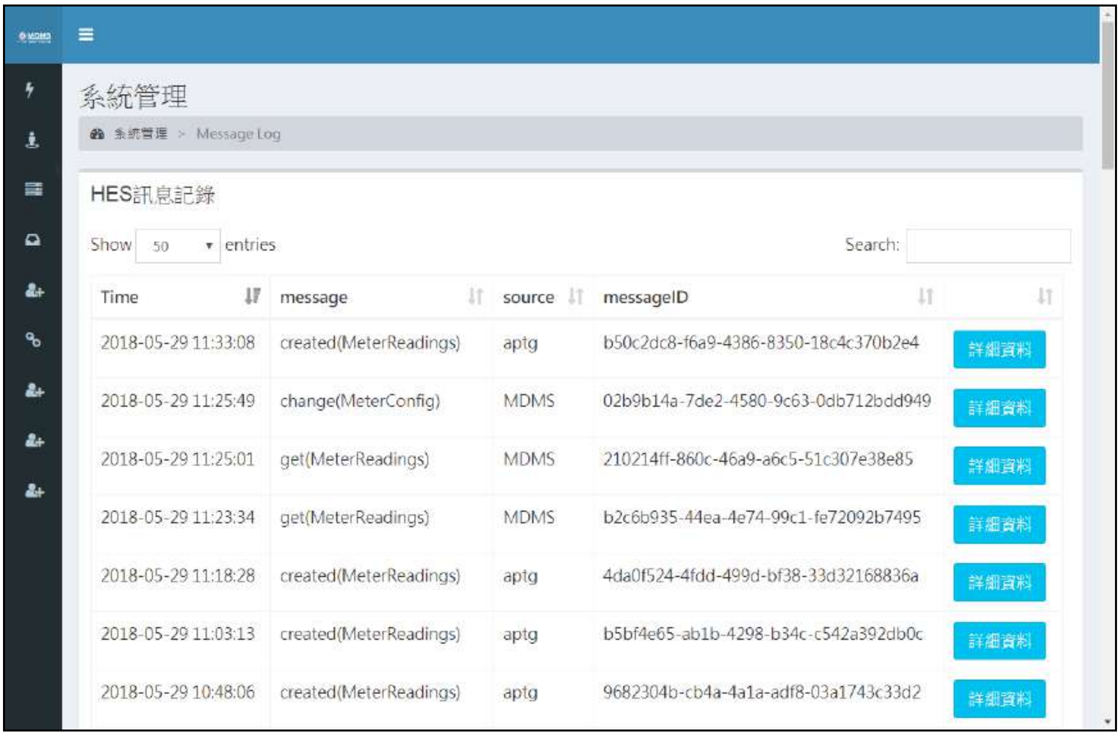


圖 18 管理介面訊息 Log

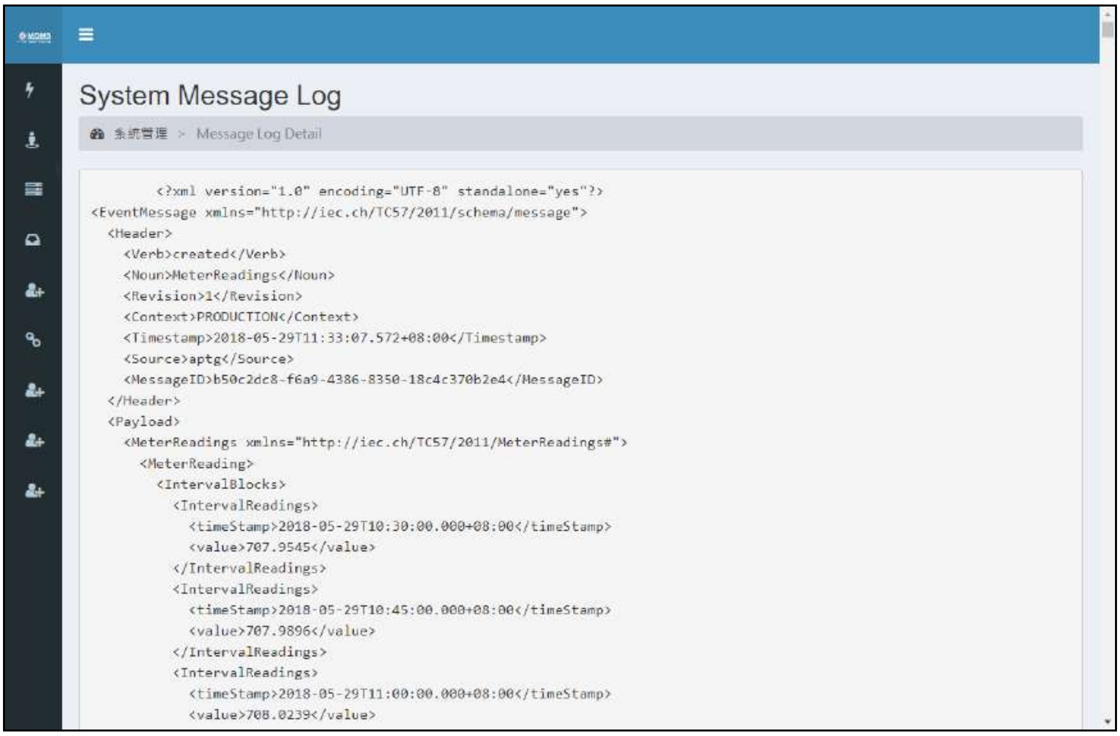


圖 19 管理介面訊息 Log 詳細資料

除了一般的功能之外，此網頁還提供 on-demand 的訊息功能，

專門為 on-demand 的訊息提提供 log，可以看出特定的 on-demand 流程，如圖 20，其中的兩個訊息是配對的，Get 及 Reply 為同一組訊息，方便查閱。

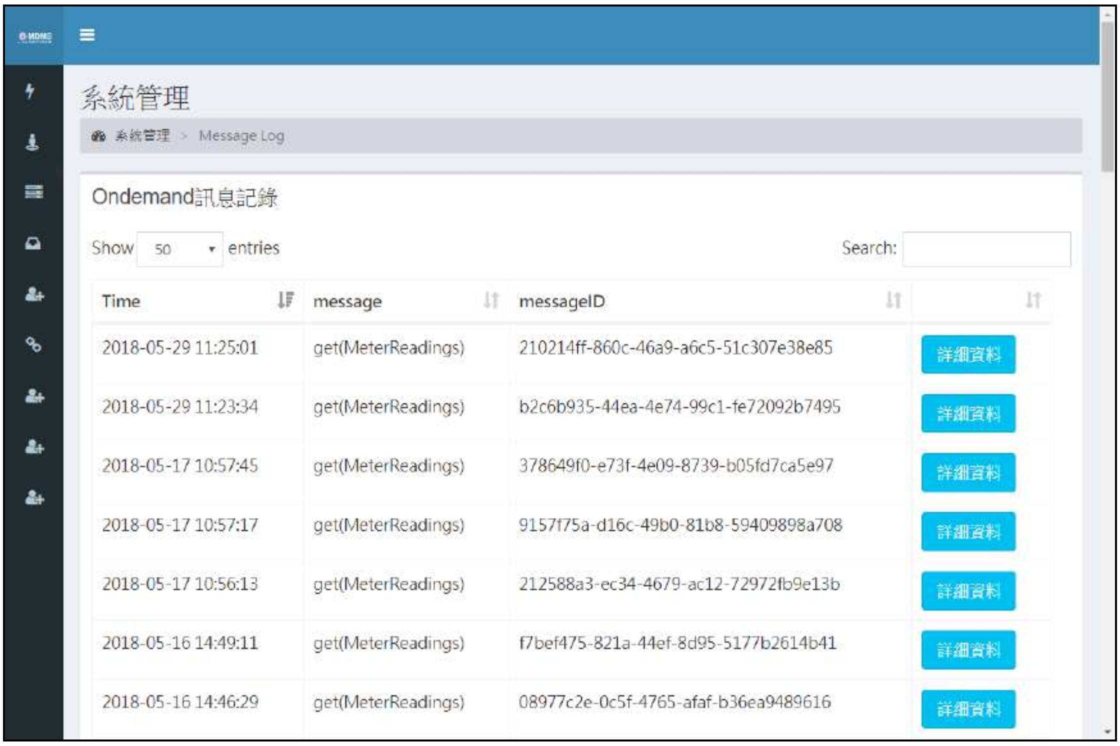


圖 20 on-demand Log

本 1000 戶示範計畫義開發了 Android 及 iOS 的 APP，目的為讓更多民眾了解智慧電表帶來效益，故本公司在設計 APP 架構時，分為兩部分，第一部分為開放性資料之功能(如：最新消息、節能資訊、今日電力資訊及台電服務所等)，第二部份為電表用戶資料(如：用電查詢、電費方案試算、用戶訊息與設定等)，智慧電表 APP 功能架構圖，如圖 21。

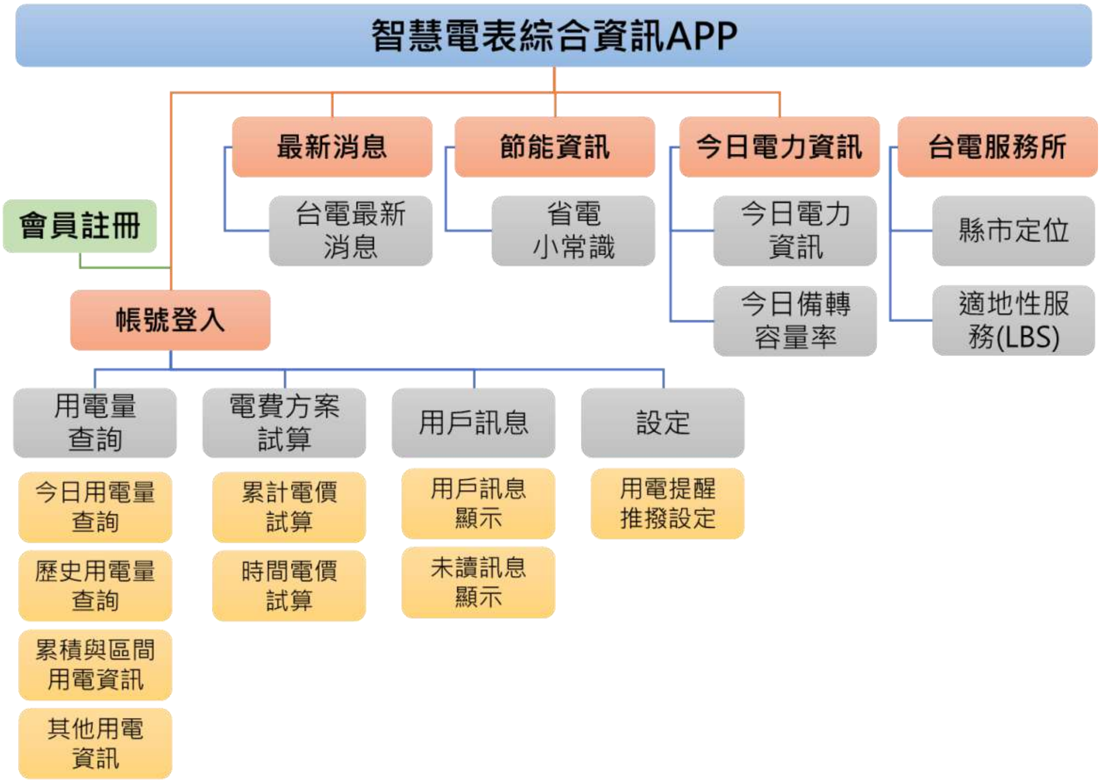


圖 21 智慧電表 APP 功能架構圖

會員登入後即可在首頁獲得目前的預估帳單費用及用電度數，此外，並提供用電提醒功能，若目前用電度數接近或已超過使用者自己設定的用電度數，首頁最上方將會出現紅色或黃色之訊息，警示民眾需要節約用電之訊息，如圖 22。

圖 22 登入後首頁畫面

登入後民眾可查詢當期預估電度與電費，並提供當日與其他歷史區間(指定區間、上期、最近一星期、最近一個月)查詢功能，所有查詢皆提供對應累計用電與區間用電資訊，為了使民眾更清楚觀看用電量，故採用圖表方式呈現，讓民眾可一目瞭然。

針對當日之用電情形為介接 B Route 資料提供每分鐘資訊；其他查詢區間則採用 A Route 資料提供每 15 分鐘資訊。並依據查詢結果提供自家總用電、附近住戶平均總用電、平均用電量、電費級距與碳排放量等其他用電資訊，如圖 23。

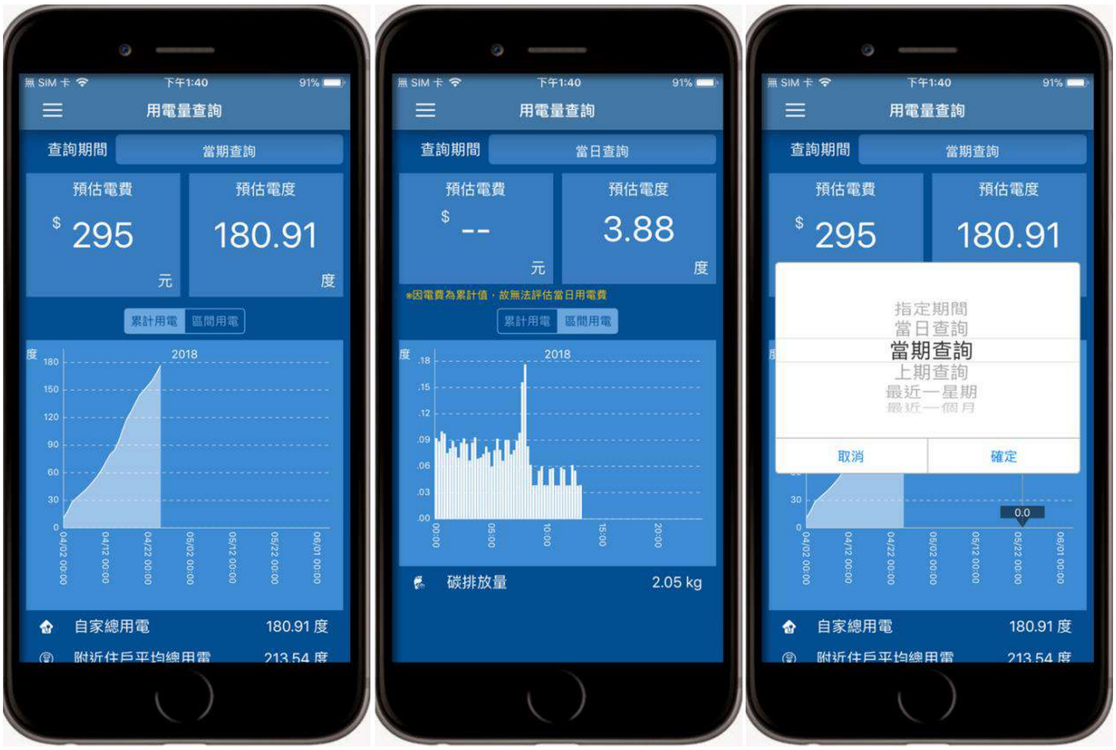


圖 23 用電量查詢功能畫面

由於在現實生活中，許多商品會因時段不同造成需求量之差異，對電力的需求也是如此，在某些時段的需求特別多，某些時段的需求則較少，故台電公司對於一般住商用戶提供有累進電價、二段式時間電價與三段式時間電價等 3 種收費方式，本計畫之示範用戶為公宅住戶，為讓使用者了解自家的用電習慣在不同收費模式下的差異，本計畫也提供了上述三種電費方案試算查詢。而為使台電公司後續可依據本計畫示範用戶之用電情形進行分析與研究，本團隊在計畫執行期尾聲也配合台電公司對於公宅住戶推廣時間電價之政策，於管理後台提供實際計費模式設定功能，結合 APP 前端即時呈現最正確之預估資訊，如圖 24。

而由於台電公司之政策為每半年皆會檢視目前電價方案，並依據檢視結果決定是否調整電價方案，故本計畫所開發之 APP，在執

行與保固期間也會依據公告之電價方案調整相關費用試算依據。

圖 24 電費方案試算功能畫面

本次參加研討會之目的除了發表本所之研究成果外，也學習到了國際上各電力公司或能源產業最新及最先進的研究成果。IERE 官方列出了電力事業在 2020 年將面臨的新科技，稱之為 Technology Foresight 2020。其中包含了五個重點技術、15 個緊急技術及 5 個邊緣技術，經過所有會員及董事會票選後，今年將針對人工智慧(Artificial Intelligence, AI)進行探討。今年帶領的小組長為東京工業大學[5]的 Terano 教授，其小組成員包含了本公司、德國 Innogy SE[6]、日本 CRIEPI[7]、法國 Enedis[8]、香港 CLP[9]、及韓國 KEPCO[10]。

在會議中提到，AI 的主要功能為預測(Prediction)及分類(Classification)兩種，且針對電力系統的發電、輸電、配電、及販售皆可有相對應的應用(圖 25)。

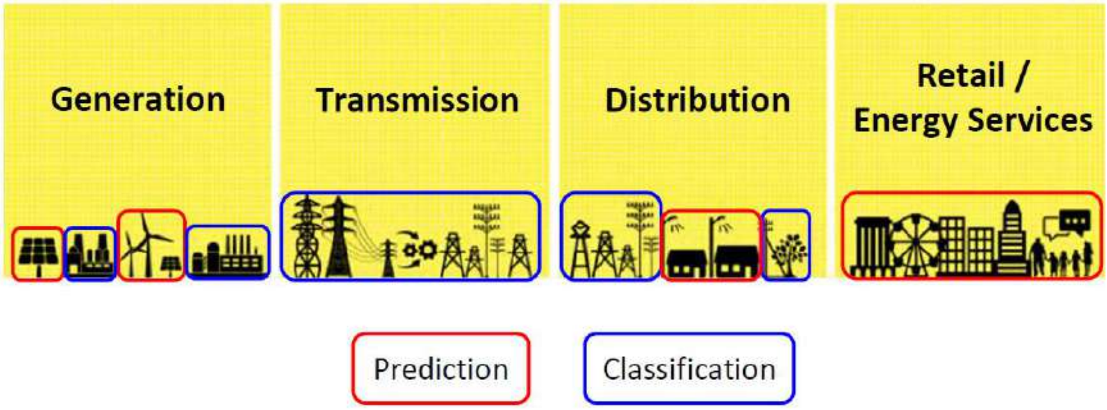


圖 25 AI 於電力事業的應用

發展再生能源為目前國際間的趨勢，但是因為再生能源發電量的不穩定性可能會針對電力系統造成不小的衝擊。人工智慧即可應用於再生能源的發電量預測(圖 26)，若預測模型建構的準確，其系統可靠度及經濟運轉調度最佳化如備轉容量及儲能系統調節可大幅提升。

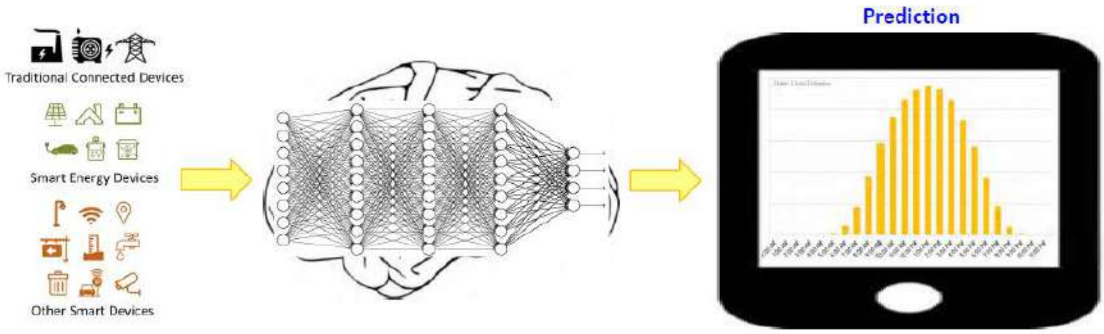


圖 26 應用人工智慧於再生能源發電量預測

另一個電力事業的應用為資產管理。當一個設備如變壓器在運轉時的聲音、震動、油的化學組成等即時量測數據資料可利用分類的方法進入大數據資料庫，經過機器學習後可自動判斷變壓器該維修的時程。此方法可大幅的優化維修效率，且可避免重大設備損害所造成之影響。

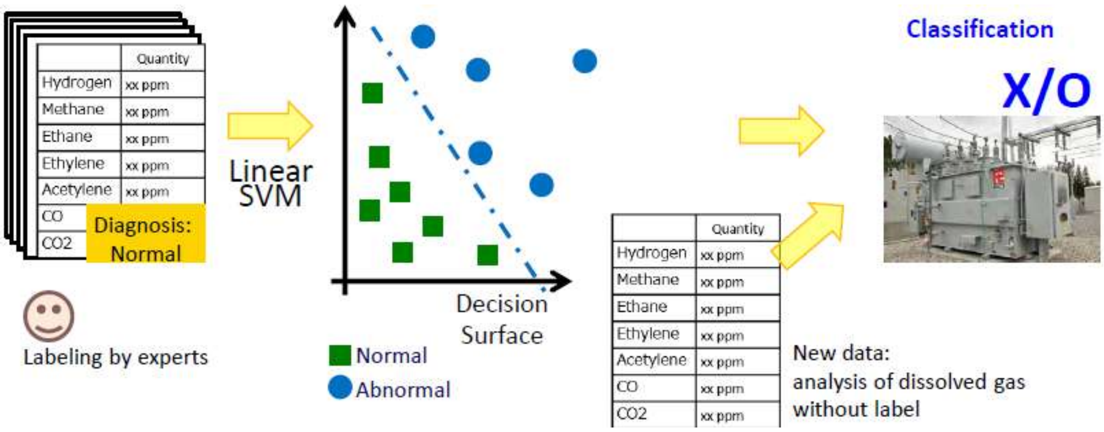


圖 27 應用人工智慧於設備資產管理

AI 人工智慧亦可應用於減少電力公司的人事成本。電力公司每日接到數以百計民眾諮詢電話，其絕大部分的問題及回答皆為類似，因此，可利用人工智慧開發一個聊天機器人自動學習問答題庫，網後民眾來問相關類似問題時即可讓機器人自動回答，此舉可降低人力成本及降低給民眾錯誤訊息的機率。

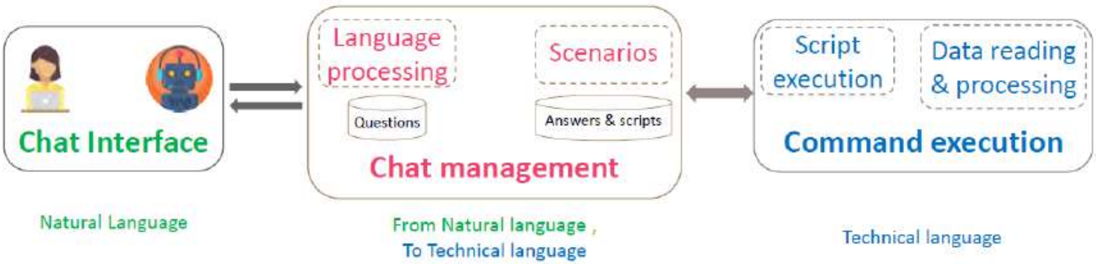


圖 28 應用人工智慧於聊天機器人

III. 心得與建議

本次於 IERE 電力研討論壇會議發表了台灣 AMI 發展的近況，包含機構的設計、通訊介面的制定、功能面規劃、未來布建藍圖等。因對於不同地點所適合使用的 AMI 通訊技術皆為相異，且新的通訊技術不斷的推陳出新，本公司所設計的模組化電表可提供最大的安裝彈性以因應上述之情形。於發表完成後，世界各國如美國、菲律賓、日本、中國等的研究學者皆對我們所設計的新一代電表感到非常的有興趣。

本公司預計於 107 年底完成 20 萬具電表安裝，明年底前完成累計 100 萬具，在安裝完成其確定本所制定之標準可行性後，可將本所之研究成果更進一步的發表到世界各地。

本次的研討會亦有與會學者談到 AI 人工智慧、虛擬電廠、雷擊預測、孤島運轉新判斷方法、再生能源面臨的挑戰等等議題，本人也獲益良多並私下與這些學者進行交流。

參考資料

[1] 行政院，低壓智慧型電表推動規劃 ，https://www.ey.gov.tw/Page/448DE008087A1971/da819b00-0c0b-491b-9bae-4086bf6860cf

[2] IERE Electric Power Technology Platform，https://www.iere.jp/index.html

[3] IEC 62056 Electricity metering data exchange - The DLMS/COSEM suite，https://webstore.iec.ch/publication/6397

[4] CNS 15593 電力計量－讀表、計費及負載控制之資料交換，http://www.gbstandards.org/CNS/CNS_standard_chinese.asp?word=CNS%2015593-21

[5] 東京工業大學，https://www.titech.ac.jp/

[6] Innogy SE公司，https://www.innogy.com/web/cms/en/3087918/for-your-home/

[7] CRIEPI，https://criepi.denken.or.jp/en/

[8] Enedis公司，https://www.enedis.fr/

[9] CLP公司，https://www.clp.com.hk/zh

[10] KEPCO公司，http://home.kepco.co.kr/kepco/EN/main.do

附件

Integration of renewables using smart and hybrid solutions›

EnBW Energie Baden-Württemberg AG
Research and Development
Prof. Dr. Wolfram Münch, CSO
Kyoto, 22 May 2018

EnBW

EnBW

Profile
EnBW Energie Baden-Württemberg AG

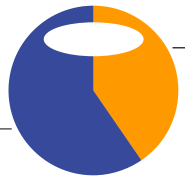
- One of the largest energy supply companies in Germany and Europe
- Business segments:
  Sales, Grids, Renewable Energies, Generation and Trading
- Sales of electricity, gas, energy solutions and energy industry services
- Customers: around 5.5 million
- Annual revenue in 2017: more than 21 billion euros
- Employees: around 21,000

Sales segment in 2017

EnBW

Sales segment

Sales in 2017



Key figures in 2017

3,331 employees (as of 31/12/2017)

€330.0 million adjusted EBITDA in 2017

€110.6 million investment in 2017

15.6 % share of adjusted EBITDA in 2017

Number of B2C and B2B customers

Around **5.5** million

Key figures in 2017

Current value

Target value

Grids segment in 2017

EnBW

Grids

Grid lengths in 2017

151,000 km
Electricity transmission and distribution grid

28,000 km
Gas transmission and distribution grid

Key figures in 2017

8,858 employees (as of 31/12/2017)

€1,045.9 million adjusted EBITDA 2017

€787.5 million investment in 2017

49.5 % share of adjusted EBITDA in 2017

Transmission volume in 2017

64.4 billion kWh
Electricity

33.1 billion kWh
Gas

Development of adjusted EBITDA (in € billion)

Current value

Target value

Renewable Energies segment in 2017

Renewable Energies

Generation portfolio in 2017[1]

7,088 GWh
generation

1,734 MW
installed output

Key figures in 2017

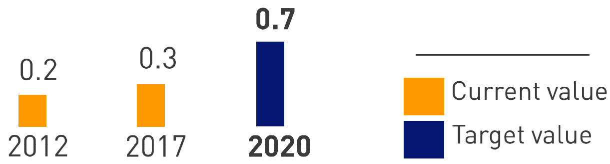
1,050
employees (as of 31/12/2017)

€331.7 million
adjusted EBITDA 2017

€706.4 million
investment in 2017

15.7 %
share of adjusted EBITDA in 2017

Development of adjusted EBITDA (in € billion)



1 The sums stated for the generation and installed output in the Renewable Energies and Generation and Trading segments are not identical to the totals for the EnBW Group. Some of the generation plants are assigned to other segments. The total generation of the EnBW Group is 50.194 GWh, of which 8,290 GWh or 16.5% is -generated from renewable energy sources. The total installed output of the EnBW Group is 13,154 MW, of which 3,381 MW or 25.9% is from renewable energy power plants.

Generation and Trading segment in 2017

Generation and Trading

Generation portfolio in 2017[1]

42,827
GWh
generation

11,234 MW
installed output

Key figures in 2017

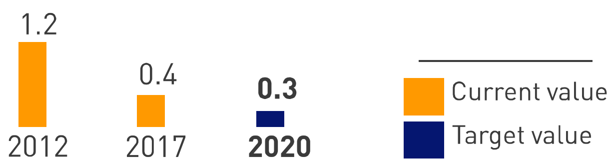
5,457
employees
(as of 31/12/2017)

€ 377.1 million
adjusted EBITDA 2017

€140.2 million
investment in 2017

17.8 %
share of adjusted EBITDA in 2017

Development of adjusted EBITDA (in € billion)



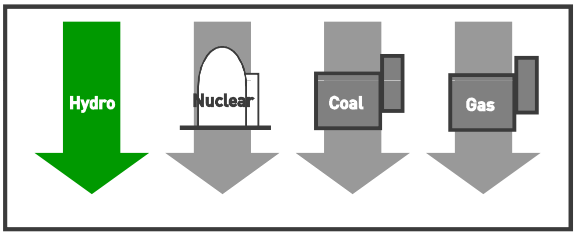
1 The sums stated for the generation and installed output in the Renewable Energies and Generation and Trading segments are not identical to the totals for the EnBW Group. Some of the generation plants are assigned to other segments. The total generation of the EnBW Group is 50.194 GWh, of which 8,290 GWh or 16.5% is -generated from renewable energy sources. The total installed output of the EnBW Group is 13,154 MW, of which 3,381 MW or 25.9% is from renewable energy power plants.

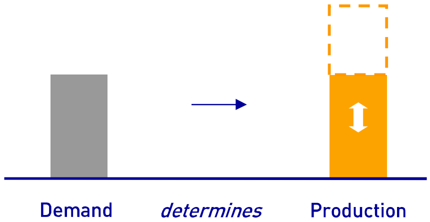
IoT- technologies to increase elasticity in demand: smart energy

EnBW

Yesterday

- Production follows demand
- Manage production in few large plants

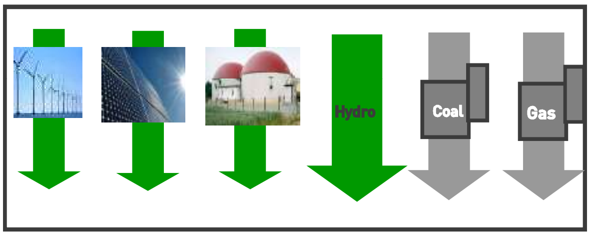


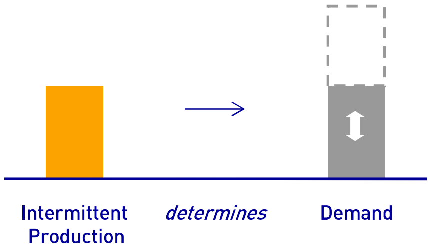


Balancing by few power plants and storage facilities

Tomorrow

- Intermittent renewable production stimulates demand
- Manage production in many plants/ storage devices
- Mobilize elasticity in electricity demand

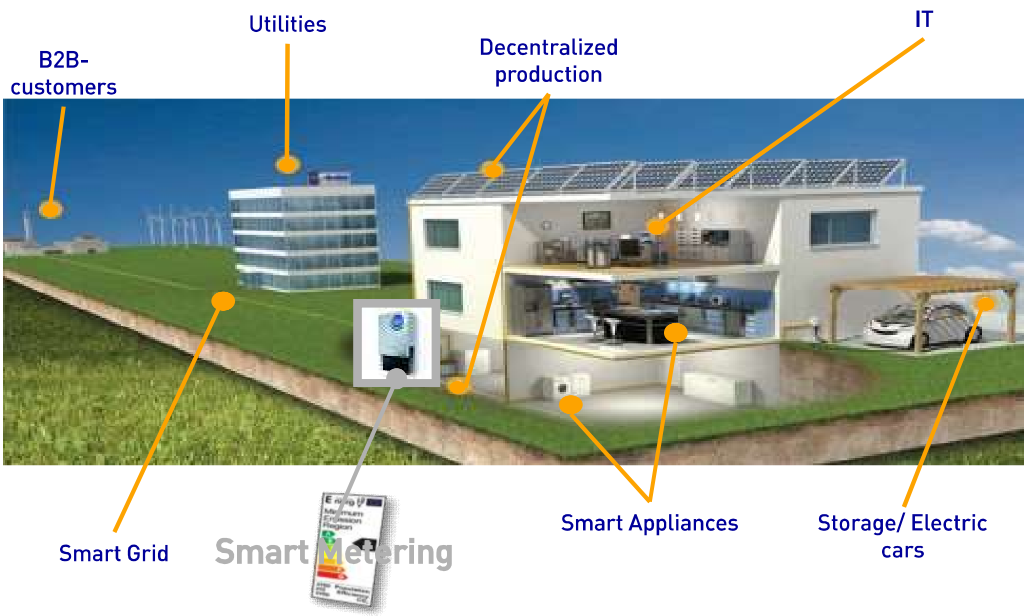




Balancing by smart solutions (DSM, batteries)

Smart energy technologies are ready to use!

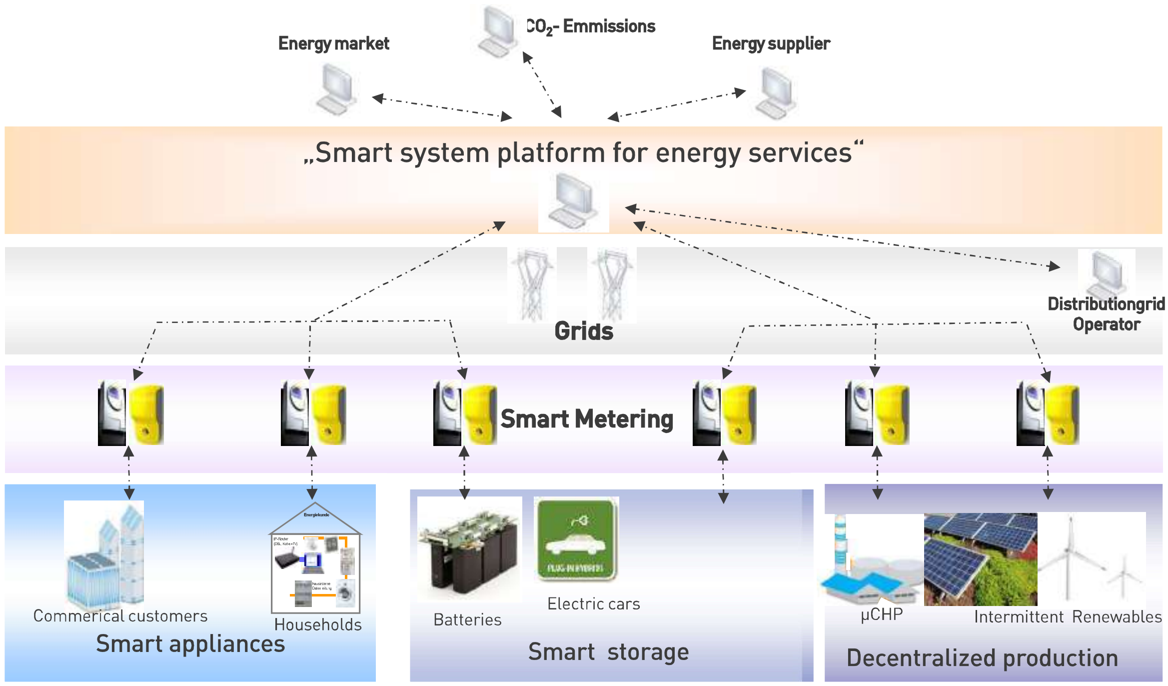
EnBW



MeRegio Certificate for emmission reduction

Price signals may manage supply and demand

EnBW



Even by manual control: variable prices have an impact on electricity demand for private customers

EnBW

- 7x24h impact on demand: 7 – 15 %

  - 500 W average demand per houshold -> 35 - 75 W controllable demand for grid- or energy services available
  - Scale-up for all German households: 50% of the current balancing power market

- By higher awareness and efficiency energy usage additionally drops by 1%, i.e., for 1000 customers 43 t CO_2 less per year

MeRegio

Supported by BMWi

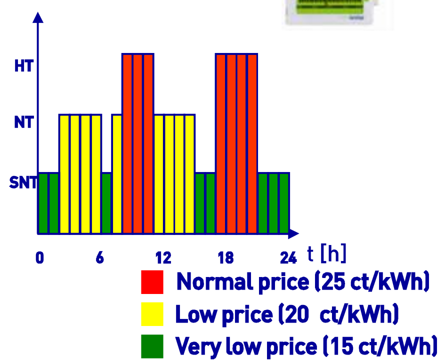
IBM

EENERGY

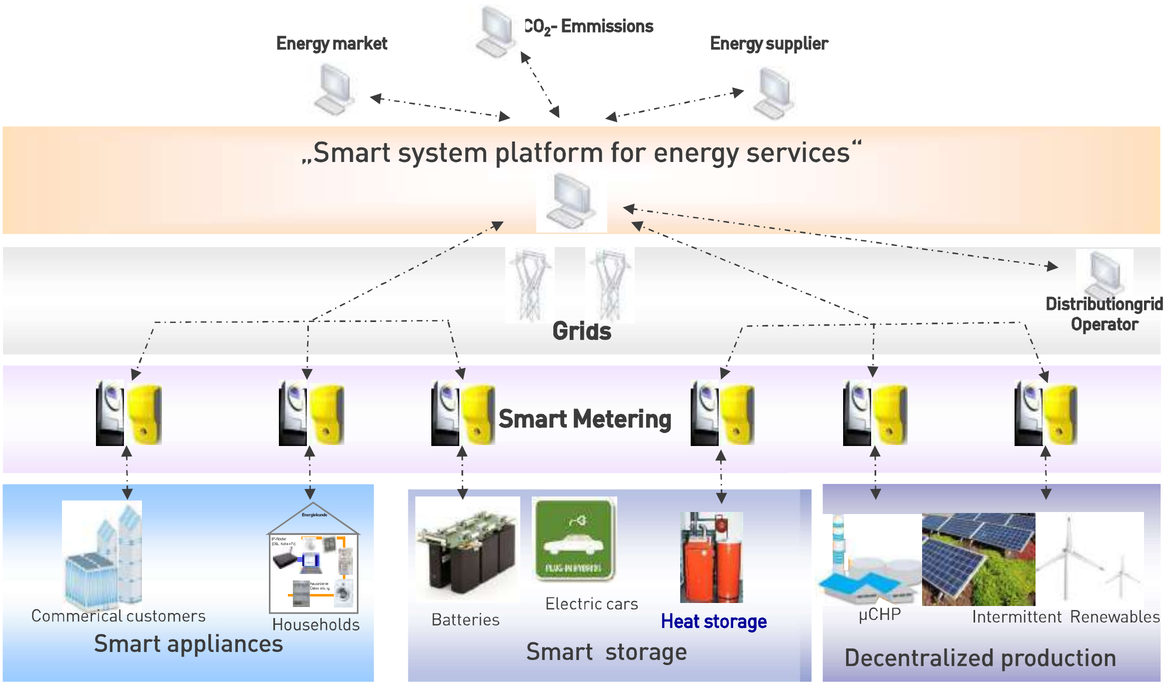
systemplan

ABB

KIT

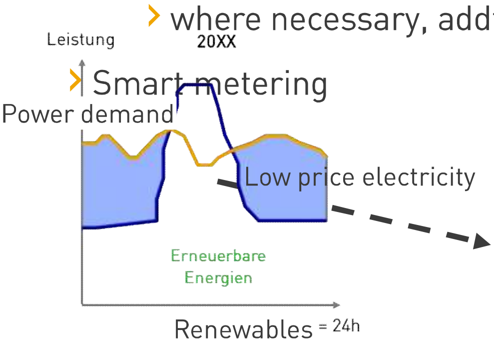


Price signals may manage supply and demand: need for hybrid technologies



Using heat storage for electricity? Hybridizing heat supply

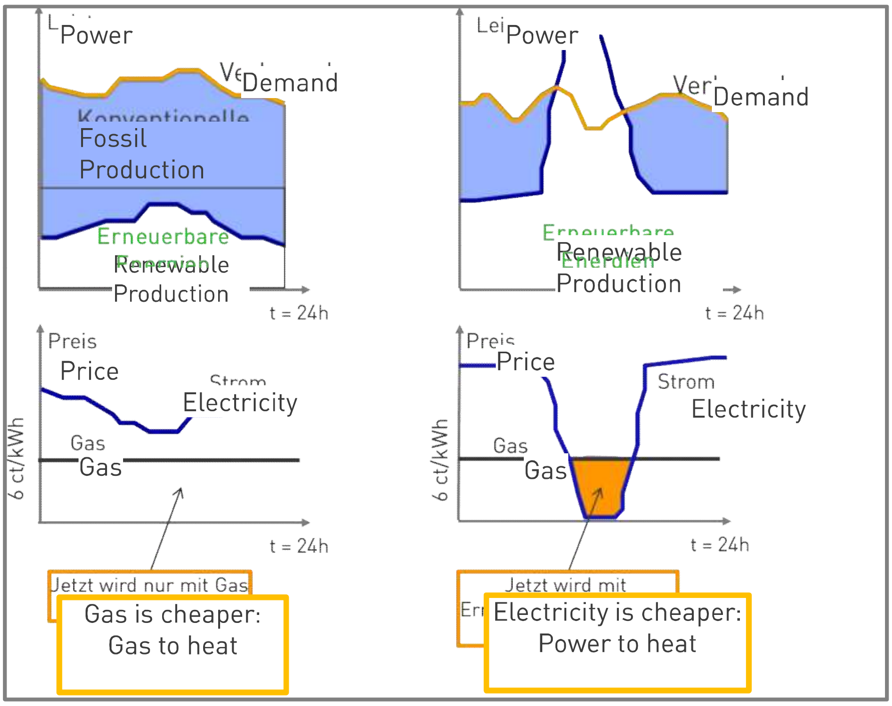
- Hybrid heating device
  - Uses different energy carriers depending on supply
    - If there is an over-supply of renewable electricity heat is produced from electricity
  - Uses available heat storage (optimizing burner, solar thermal)
  - where necessary, addtional heating rod needs to be installed
- Smart metering



Quelle: heizung-solar24.de

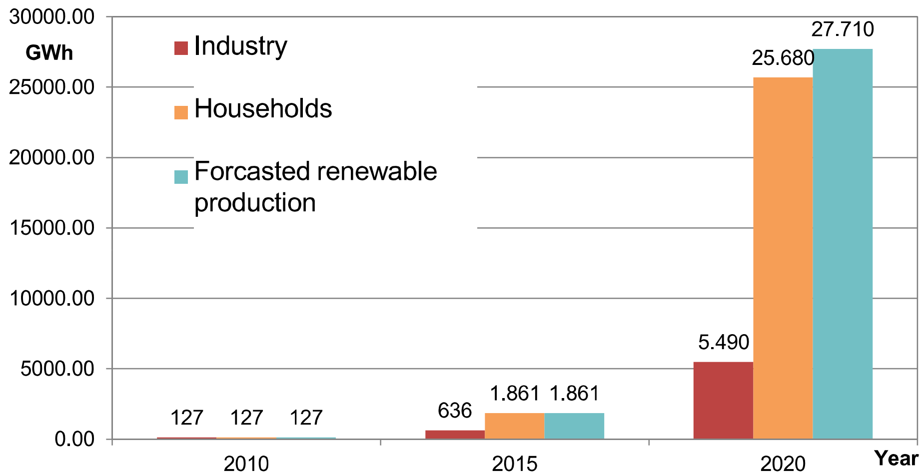
A hybrid heating device to facilitate sector coupling

EnBW



Forecasted renewable production at low electricity demand can be fully integrated

EnBW



Ref: et 5, 44 (2012)

In industry and households all the intermittent renewable production at low prices (energy, power) of the year 2020 can be used to substitute natural gas

What could be a market model?

Hybridizing heat supply increases renewable share in primary energy demand substantially

- Renewable electricity for heating?
  - 50% of German household use gas: 390 TWh/a
  - 5 TWh/month- heat demand during the summer
  - 160 – 400 TWh could be substituted by wind energy: more than 100.000 MW Wind on-shore may be installed
- Feed- in tariffs for wind are in the range of 50 – 70 $/bbl
- Evolutionary decarbonisation of the heating sector by renewable electricity!

New regulations are needed to achieve meaningful price signals

Electricity costs

Source: BDEW 2013

Distribution grid: 20%

Taxes, fees, allocations: 50%

Production, marketing: 30%

Today: marginal energy prices are dominated by fixed costs (70%)

Private customer (3500 kWh): 29 €ct/kWh -> 1008 €/a (84 €/Month)

New price model

Aim:

No additional/new subsidies necessary

Marginal energy prices are dominated by marginal production prices

Sketch of a price modell with high elasticity

New price model

No additional/new subsidies necessary

Private customer (3500 kWh): 29 €ct/kWh → 1008 €/a (84 €/Month)

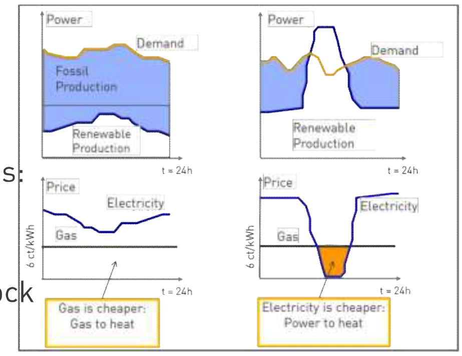
New Price model → 1008 €/a

Marginal energy prices are dominated by marginal production prices

Fixed monthly rate („Grid fee“): 59 €/Month

- Includes all fix costs: taxes, fees, allocations
- Independent of actual usage

- Variable prices depending on actual energy needs: 8,6 €ct/kWh (avg.)
  - Costs for production and marketing only
- Price depends on actual electricity price at the stock exchange
- For comparison: natural gas price (private customer): 6 €ct/kWh



„Grid fee“ enables competition between electricity- and gas supply at the final customer site

Actual rate of the grid fee may depend on ...

- Technical efficiency: peak power demand, ...
- Environmental aspects: energy demand of the building, age of the heating device, total energy demand, ...Social aspects
- Ability for self- supply, renewable capacity installed ...

Competition between electricity- and natural gas usage is easy to manage by politics

- Independent of the financial support system for renewables

Sector coupling by market coupling between electricity and gas spot prices

„Grid fee“ may have many advantages ...

- addtional degree of freedom to politically control energy demand
- Promotes renewables without interfering with renewable support schemes

Conclusion

EnBW

- Smart and hybrid solutions are ideal for the integration of wind and solar energies
  - Large shares of intermittent renewables can be integrated while fossil fuels are cut
  - Big opportunities for hybrid heating devices
    - Important link between electricity and gas markets
- Integration of intermittent renewables is not just a technical - but also a regulatory issue!
  - New regulations and market rules are needed
- For the future renewable energy system to work
  - Smart regulations and rules are more important than subsidies!

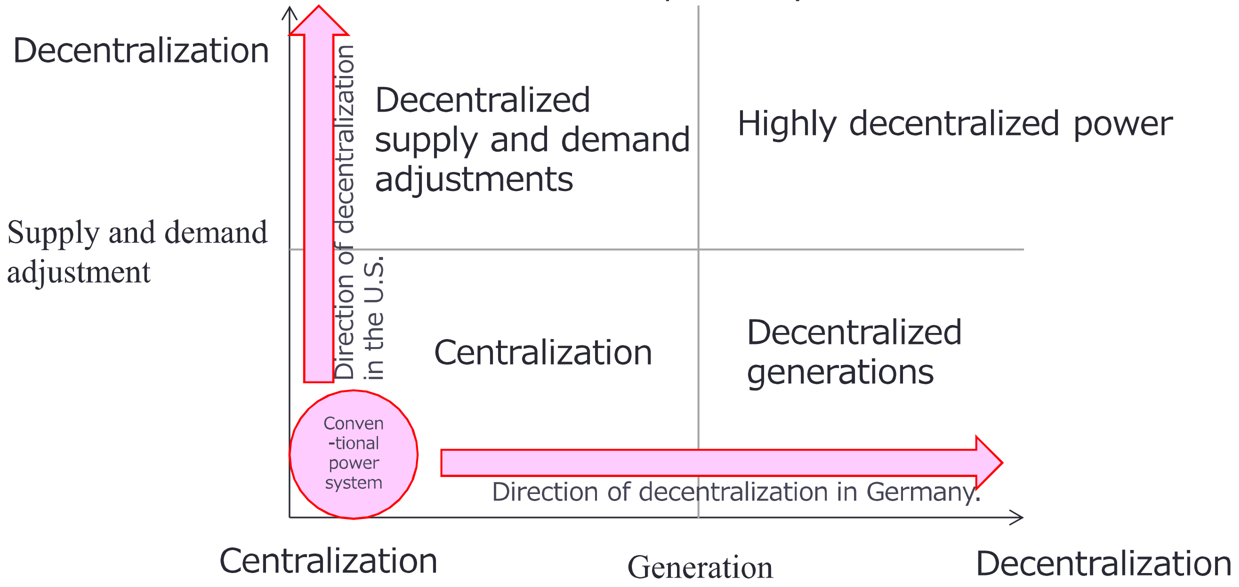
Recent examples of efforts by advanced aggregators to expand their renewable energy growth rates

May,22 2018

Japan Electric Power Information Center (JEPIC)
Joji Kawano

Introduction

- Direction of decentralization of electric power systems



Each country has its own direction of different power system decentralization.

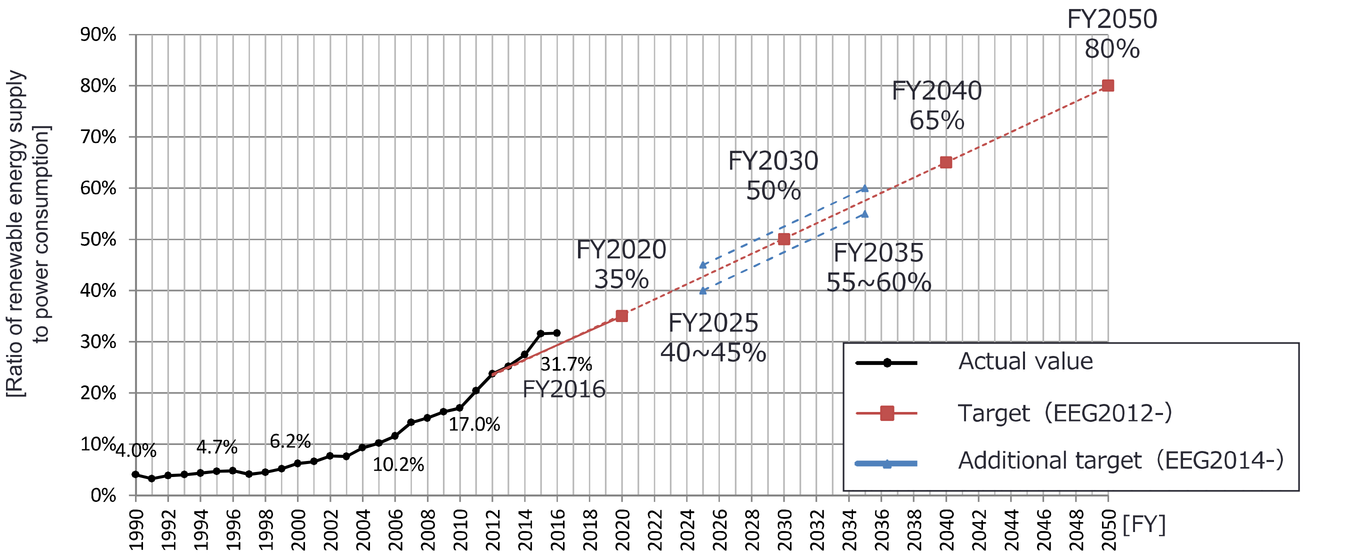
✓ Germany prefers to decentralized power generations.
⇒Decentralized generation.

✓ The US prefers to decentralized supply and demand adjustments.
⇒Decentralized supply and demand adjustments.

⇒The focus of this presentation will be Germany's decentralized generation system.

Source: Thomas Rowlands-Rees (Smart energy Week 2018)

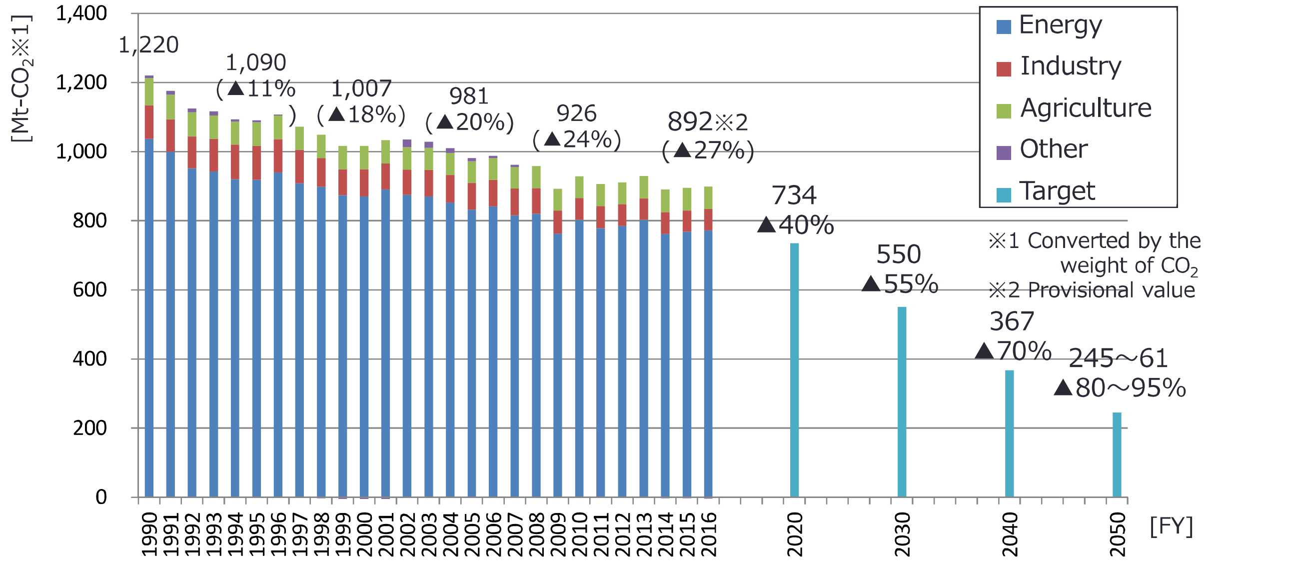
Trend of renewable energy growth rate in Germany



Source: BMWi (Energiedaten 2017)

- Energywende（Energy transition）
  - Germany will promote the transition of energy towards the expansion of renewable energies and the phasing out of nuclear power.
  - As for the energy consumption (kWh), the renewable energy ratio already exceeds 30% as of 2016, and the target for 2020 is expected to be achieved.
  - Following the Japanese Great Earthquake of 2011, nuclear power plants are scheduled to be shut down by 2022.

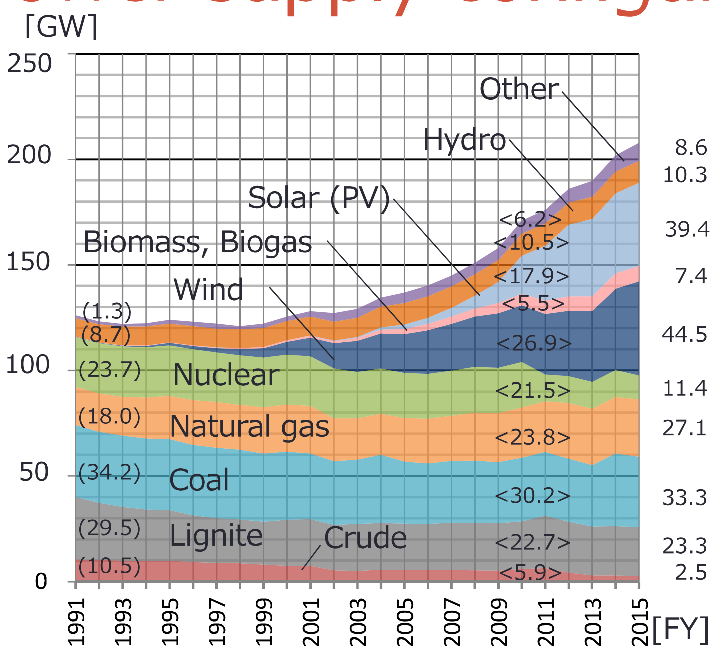
Greenhouse gas (GHG) emissions rate in Germany



Source: BMWi (Energiedaten 2017)

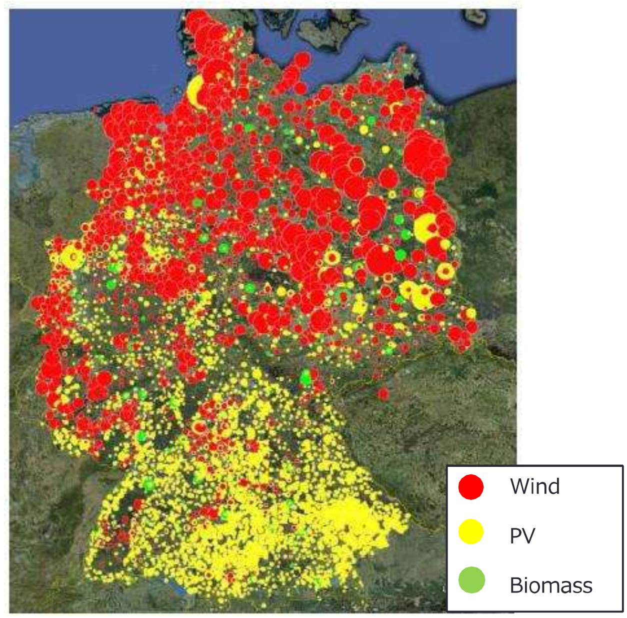
- GHG emissions control target was set in the Energy Concept program established in 2010.
- GHG emissions target for 2020 was a 40% reduction from the 1990 level, but the target is actually expected to be a 33% reduction.
- Based on the climate change action plan agreed to in 2016, Germany plans to suppress emission of GHG gas in the energy field.
  ⇒In order to achieve the 2050 target, it is necessary to close all existing coal-fired plants.

Power supply configuration in Germany



The number indicates output of each generator in FY2014.
※( ) As of FY1992, < > As of FY2009.
※Geothermal is included in Other

Source: BMWi (Energiedaten 2017)

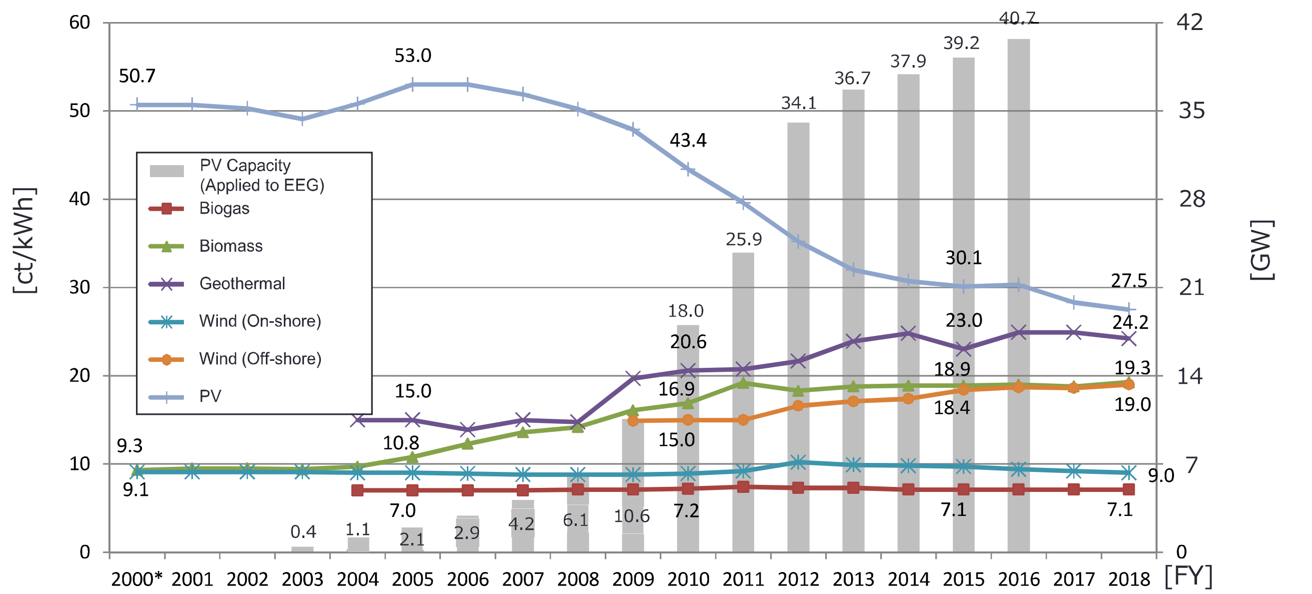


※ The area of the circle is proportional to each generation capacity.

Source: 50Hertz, TenneT, Amprion, TransnetBW internal data

- Distribution and growth of renewable generation
  - The total capacity of the power generation facilities is 200 GW.
  - Approximately half of the total capacity consist of renewable generation.
  - In the last 5 years, PV has doubled, and biomass and wind has increased 1.5 times.
  - Nuclear has been reduced by 50% after 2011.

Trend of renewable energy prices and total PV capacity



* Price in FY2017 and FY2018 are estimated by TSO.

Source: BMWi(EEG-umlage 2000 bis 2018)
(EEG in Zahlen 2017)

- Purchasing electricity from renewable sources became obligatory in Jan. 1991.
- Purchasing renewable electricity at a fixed price for 20 years became obligatory in Apr. 2000.
- Since around 2009, the EEG* has been revised for the purpose of reducing levy cost burden and reducing output suppression.

*EEG: Erneubare Energien Gesetz (Renewable Energy Law)

Measures against increasing VRE

Policy	Contents	Effect
Revision of EEG (Renewable energy law)	Preferential treatment of adjustable power supply and highly efficient power supply.	+
	Review purchase price appropriately	-
	Initiation of FIP and competitive bidding system.	
	Setting the upper limit of subsidies	
Deregulation of the electricity market	Participation of players such as aggregators for supply-demand adjustments.	+

- ✓ There are 2 policies against increasing VRE in Germany.
- ✓ Results obtained by the measures can be organized into two categories.
  - ➢ The installation amount of VRE (such as PV, and WF) is limited.
  - ➢ The installation of adjustable power supplies is supported.

- ✓ In this presentation, I will report on the efforts of advanced aggregators in Germany to enable the installation of renewable energies.

Classification of aggregators in each country

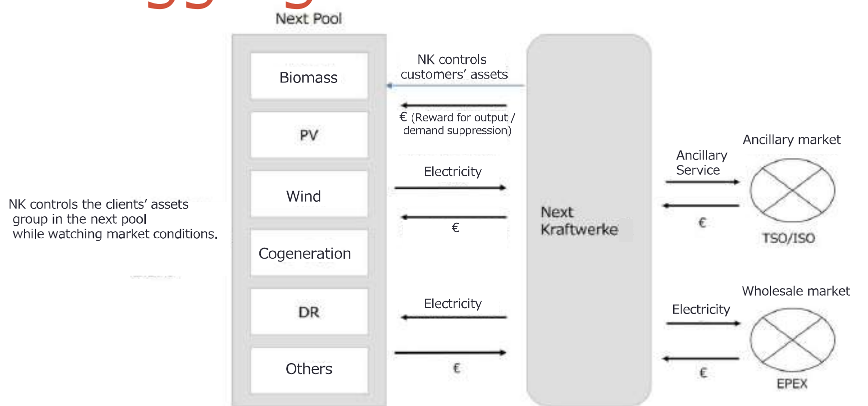
	DE: Next Kraftwerke, e2m IT: Centrali Next SK: VPP	DE: Sonnen CA: Enbala Power Networks US: Sunverge, Tesla, Green Charge Networks, Solar City	GB: Flexitricity, Open energi FR: Actility, Energy pool US: EnerNOC, Stem, Comverge, Building IQ
Adoption of renewable energies	√	√	×
Contribution to supply-demand adjustment	Large	Small	Large
Roles as a business operator	Supply-demand adjustor	Total demand minimizer	—

- In this presentation, aggregators are categorized based on whether they adopt renewable energies and contribute to supply and demand adjustments.

→Next Kraftwerke and e2m can be classified as aggregators that provide capabilities from renewable energies to the power grid.

※Aggregators such as Sonnen or Sunverge, which make relatively more use of storage batteries are not subject to this presentation.

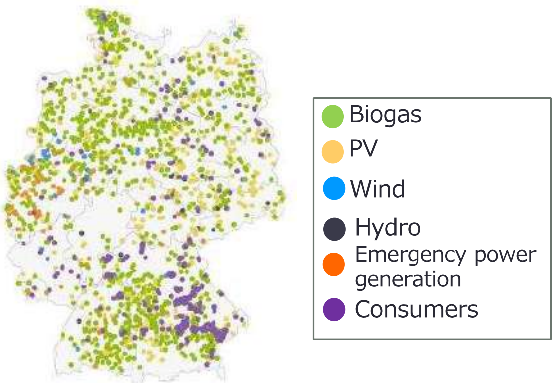
Advanced aggregator #1 Next Kraftwerke



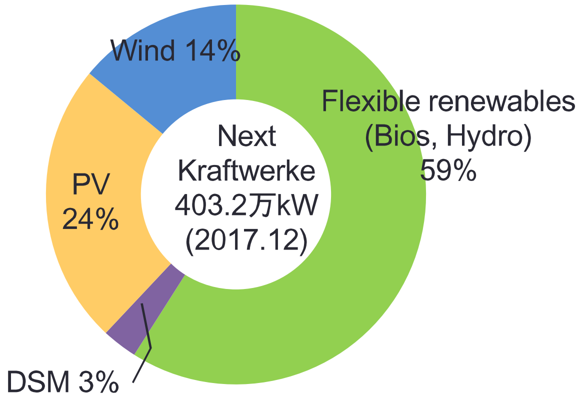
Source: METI

- Company information
  - Established: FY2009
  - Location: Köln, Nordrhein-Westfalen, Deutschland
  - Business scale: Employees: 140, Customers (Generation): 5,000 (3,800MW), Sales: € 273M (FY2015)
  - Shareholders: High-Tech Gruenderfonds, etc.
  - Business objectives, characteristics
    - Next Kraftwerke (NK) is a platform operator, which interconnects power generators, consumers, system operators, and markets.
    - NK has built a network consisting of bioenergy, PV, wind, etc., and small and medium-sized power producers.
      (NK does not have its own power generation facilities)
    - Based on the request from the system operator (TSO), NK provides flexibility enabled by the network managed by NK.

Advanced aggregator #1 Next Kraftwerke



Assets in Germany



Total portfolio

Source: Next Kraftwerke

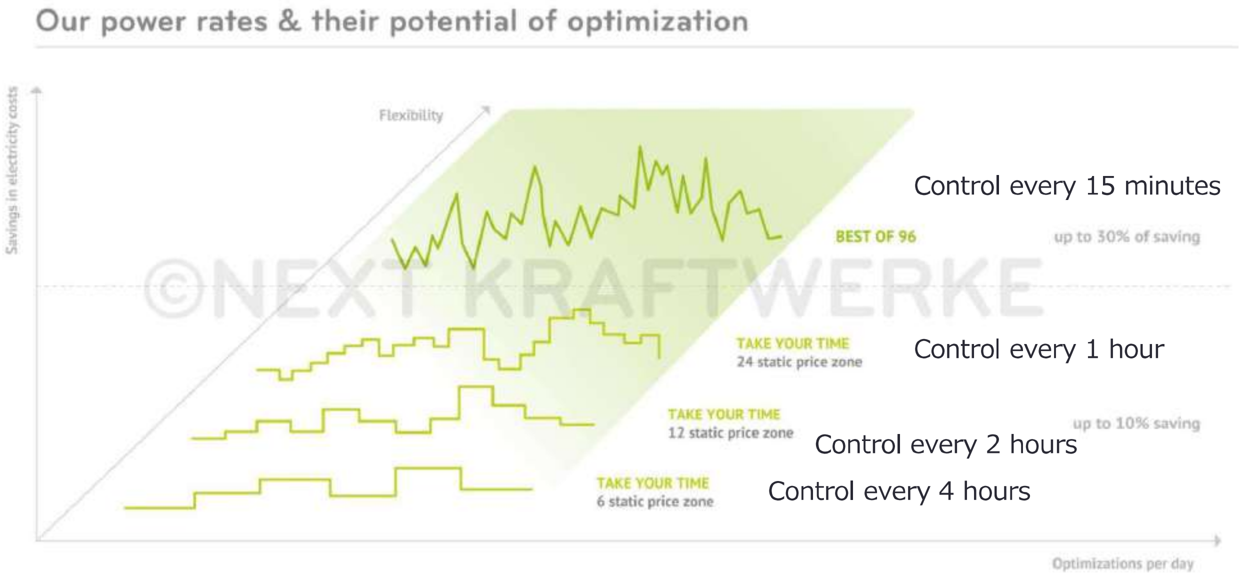
- Concept of NK's assets portfolio
  - Assets configuration
    - NK does not specify the required amount of equipment for each power supply.
    - NK sets the purchase price relatively lower for VRE, such as PV, wind, etc., where it is difficult to adjust capacity.
    - The value of adjustable power sources such as biogas is high because trading at high prices can be expected in the spot market.
    - For wind and DSM, since the advantage of trading is small, they have not actively increased in value.
  - Measures against fluctuation of Valuable Renewable Energy (VRE) output
    - NK combines an exclusive weather forecaster with IT to carry out meteorological forecasting across a wide area, mainly in Germany.

Advanced aggregator #1 Next Kraftwerke

Source: Next Kraftwerke

- Operations of clients assets
  - Supply and demand orders to the clients (power producers) are implemented via NEXT BOX.
    - ➢ NK is certified as an important infrastructure operator by Federal Office for Information Security (BSI).
      - ✓ NK is certified as an information security management system.
      - ✓ In addition, NK is also satisfied with certification regarding important infrastructure operators targeted by businesses with power generation facilities with capacity of 430 MW or more. (ISO/IEC-27001, ISO/ICE TR27019)
    - ➢ NK installed control communication equipment called NEXT BOX on clients.
    - ➢ By using NB, it is possible to measure the amount of power generation and control power generation output. (Interactive communications)
    - ➢ NEXT BOX is developed by NK, has high scalability, and can be used for P2G purpose, can control air conditioning facilities.
    - ➢ The time required to control 10,000 NEXT BOX is about 2 seconds.
    - ➢ From the specification decision, installation time is less than a month.

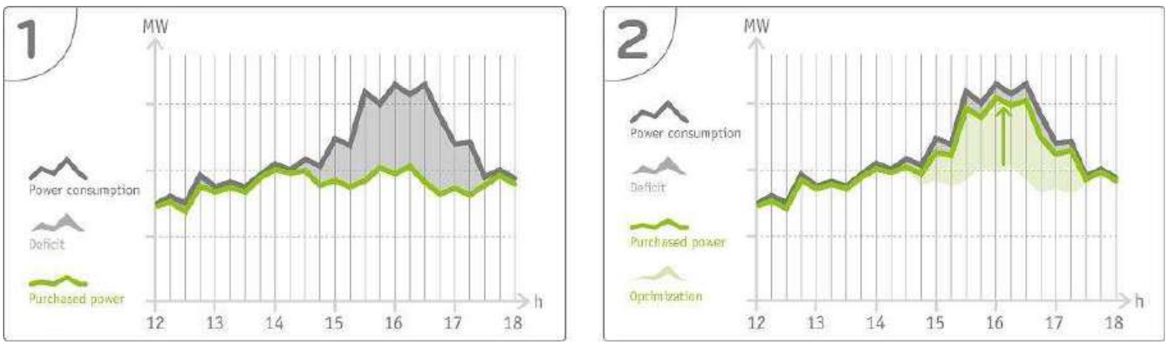
Advanced aggregator #1 Next Kraftwerke



Source: Next Kraftwerke

- Characteristics of control logic
  - ➢ The client is involved in output control up to 96 times a day.
  - ➢ Similar menus are also prepared on the consumers side, so the contract changes with the number of times that can be adjusted one day.
    - ✓ As the adjustable number of times increases, the electricity charge can be reduced up to 30%.

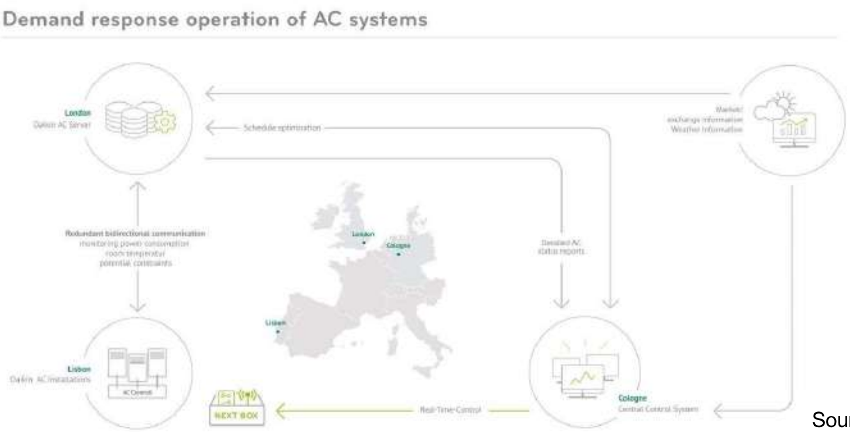
Advanced aggregator #1 Next Kraftwerke



Source: Next Kraftwerke

- ■ Operation plan
  - Supply and demand adjustment
    - ➢ A penalty is imposed strictly in Germany when imbalance occurs. Therefore, NK is not to generate imbalance as much as possible.
  - The advantage of NK can be summarized as follow:
    - ➢ The strengths is high precision weather forecasting technology.
    - ➢ The ability to control adjustable power generation equipment at high speed.
- ■ Others (Supplementary information)
  - NK considers that there is no benefit from the installation of storage batteries or the implementation of DR under current German domestic rules. Therefore, they do not consider these aggressive installations.
  - NK considers that it is possible to respond quickly even if there are changes in rules, such as preferential treatment for the installation of storage batteries.

Advanced aggregator #1 Next Kraftwerke



Source: Next Kraftwerke

- ■ R&D
- As of Nov. 2017, eight projects are in progress by NK. Representative ones are as follow:
  - ➢ Hydrogen storages (P2G)
    - ✓ The purpose is to utilize surplus PV output.
    - ✓ Aim for hydrogen contamination in natural gas network.
    - ✓ The goal is to improve accuracy when calculating the amount of Hydrogen produced.
  - ➢ Joint project with NEDO in Portugal
    - ✓ The goal is to reduce operating costs of air conditioners with electricity charges and set temperature as parameters.
    - ✓ Validation of economics combining PV and Next Box.
    - ✓ The project period is the end of Dec. 2019.

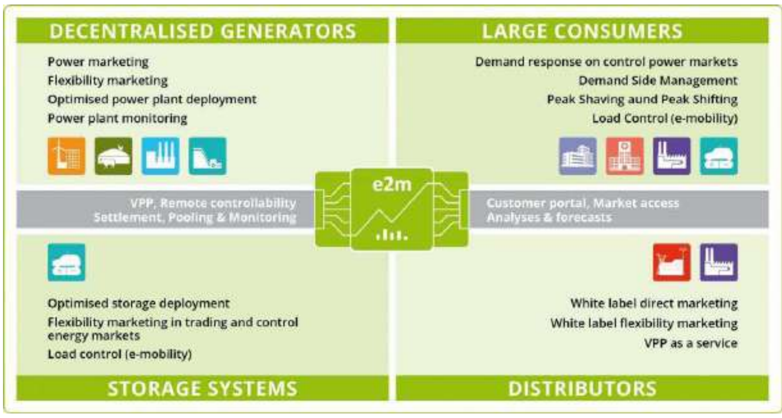
Advanced aggregator #1 Next Kraftwerke

- ■ Summary
  - – The advantages of NK can be categorized as follow:
    - Provision of aggregate adjustment power to the market in a short time.
    - Immediate analysis of live data.
  - – At present, NK does not actively use EV, storage batteries, etc.
    - Because NK believes that there are few advantages to adopt under German domestic rules.
    - Along with future rules changes, they will revise priorities as appropriate.

⬇

  - – NK can respond promptly to changes, and can be organized with the aim of to maximizing client profits.

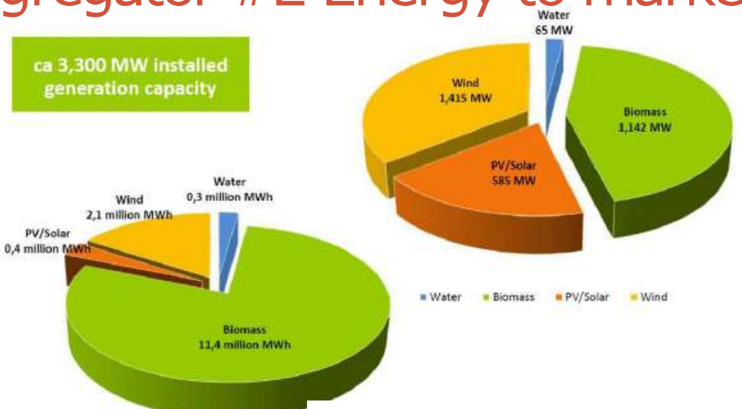
Advanced aggregator #2 Energy to market (e2m)



Source: e2m

- Company information
  - Established: FY2009
  - Location: Leipzig, Freistaat Sachsen, Deutschland
  - Business scale: Employees: 100, Customers (Generations): 5,000 (3,200MW), Sales: € 251M (FY2016)
  - Business objectives, characteristics
    - Energy to market (e2m) is a platform operator, which interconnects power generators, consumers (include Stadtwerke), system operators, and markets.
    - e2m has built a network consisting of bioenergy, PV, wind, etc., and small and medium-sized power producers.
      (e2m does not have its own power generation facilities)
    - Based on the request from the system operator (TSO), e2m provides flexibility enebled by the network managed by e2m.

Advanced aggregator #2 Energy to market (e2m)



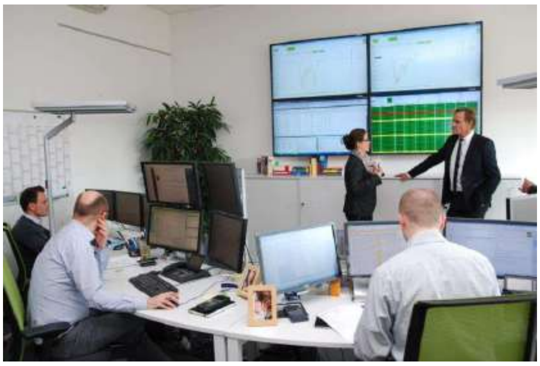
Total portfolio

Source: e2m

- Concept of e2m's assets portfolio
  - Assets configuration
    - Similarly to NK, e2m emphasizes adjustable power sources, and the ratio of biomass power generation reaches approximately 80% based on generated electricity.
    - E2m considers power generators with co-generation assets as adjustable power producers, and uses them for optimization of their power generation.
    - Also, e2m does not specify the required amount of equipment for each power supply.
    - E2m has 50 MW of energy storage batteries. (Germany's first attempt at the time of installation.)
  - Measures against fluctuations in Variable Renewable Energy (VRE) output
    - E2m also recognizes that VRE is difficult to handle.
    - E2m predicts weather based on information from external organizations.

Advanced aggregator #2 Energy to market (e2m)

e2m BOX



central control room

Source: e2m

- Operations of clients assets
  - Supply and demand orders to the clients (power producers) are implemented via e2m BOX.
    - ➢ e2m is certified as an important infrastructure operator by Federal Office for Information Security (BSI).
      - ✓ e2m is certified as an information security management system.
      - ✓ In addition, e2m is also satisfies technical requirements for quality management system and risk management system. (ISO-9001, ISO/IEC-27001, ISO-31001)
    - ➢ e2m develops e2m BOX. In addition, the manufacture of e2m BOX is carried out outsourcing. Installation was carried out by e2m and a lease contract was implemented.
    - ➢ By using e2m BOX, e2m can instantly provide power generation status to the central control system in the head office (Leipzig). And also, e2m can control the power generation output of each power generation facilities.
    - ➢ From the specification decision, installation time is around 6 weeks.

Advanced aggregator #2 Energy to market (e2m)

Source: e2m

- Others #1
  - Installation of batteries in Switzerland
    - ➢ Ampard, a Swiss EMS company, is a sub aggregator that bundles 3,000 homes with home PV and storage batteries, and e2m aggregates Ampard as one of its clients.
    - ➢ E2m considers that it can create new value by connecting batteries with VPP.
    - ➢ The storage battery used by e2m in Switzerland already meets the specifications in Germany, and e2m considers that its storage batteries meet the specifications required by the EU.
    - ➢ Compared with the UK, which recognizes batteries as reserve power, e2m considers that Germany is not very active in installing storage batteries in the current situations.

Advanced aggregator #2 Energy to market (e2m)

- Others #2
  - Demand response by e2m
    - ➢ E2m will adjust supply and demand for companies (factories).
    - ➢ Main services are as follows:
      - ✓ Output control of blower in car factories and in supermarkets.
      - ✓ Output control of freezer in Scandinavian countries.
    - ➢ The scale of output control is 10 to 20 MW as a whole.
    - ➢ e2m provides flexibility obtained by DR as secondary and tertiary reserve to the market.
    - ➢ The Order of DR is mainly "Nega-Watt" but "Posi-Watt" is also possible.

- R&D
  - Electrification of transport (energy to mobility)
    - ➢ Participated in demonstration project on street scooter developed by DHL group.
    - ➢ E2m participates in a demonstration test on EV charging in Berlin, Leipzig.
    - ➢ In the demonstration test, the smart grid is connected to the power grid.

Source: e2m

Advanced aggregator #2 Energy to market (e2m)

- Summary
  - – E2m has a business form similar to NK. They also utilize biomass that can be adjusted as a power source for renewable energies.
    - The recognition of the problem of VRE is similar to NK.
  - – One of the differences from NK is the type of customers.
    - E2m appeals to customers are large such as Stadtwerke and car companies.
    - E2m introduces customer interaction as publicity activity, such as opening visitor records from overseas on their website.
  - – There is also a difference in the utilization of external organizations / institutions.
    - E2m effectively uses external organizations such as weather forecasters and equipment manufacturers.

  - – E2m is a rational aggregator, and they outsource a part of their business.

Conclusion

- We conducted an interview with advanced aggregators that use renewable energies as a power source and reached the following conclusions.
  - Germany has developed relevant laws to expand their renewable energy growth rate. Moreover, since 2000, they have developed laws concerning the promotion of the development of adjustable power sources such as biogas generation.
  - In Germany, advanced aggregators are emerging that combine VRE, such as PV, wind, with power generation technology that has adjustable power such as biogas.
    - Utilizing high-speed ICT and IoT technologies, they realized the power of market trading through renewable energies such as adjustable biogas.
    - Advanced aggregators that promptly respond to changes and seek to maximize profits are expected to emerge in the future.
    - Compared with adjustable biogas, the value of VRE such as PV and wind power is low.
  - In this survey, storage batteries were expected to be power generation assets due to their adjustability, but it was determined that their mass introduction at the present time was premature.
    - Supply and demand can be adjusted with the existing facilities controlled by the advanced aggregators, so it was determined that batteries are not essential.
    - Although there was no negative opinion on the installation of the storage batteries itself, there was one opinion that it is necessary to lower the cost and increase the subsidy.
    - There are already aggregators who intensively install storage batteries such as Sonnen (Germany).

技研
R&D Center

Demonstration Project of KANSAI EPCO's Virtual Power Plant

22nd May 2018

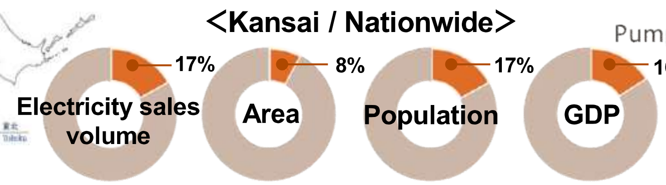
IERE Japan Forum

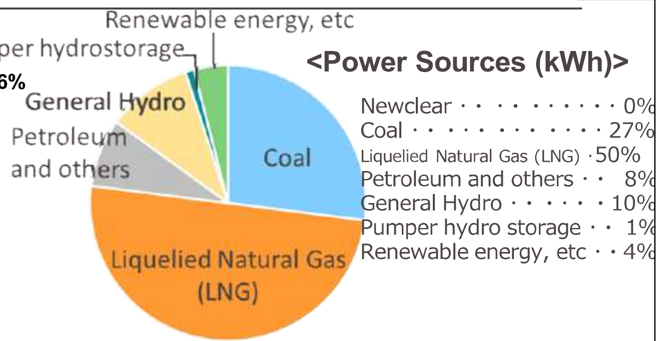
Kansai Electric Power
power with heart

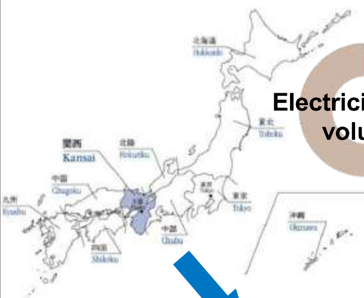
Advanced Technology Laboratory
R&D Center,
THE KANSAI ELECTRIC POWER Co., INC., Japan

Contents

KANSAI at a Glance







Transmission Line 18,742km
Distribution Line 131,758km
(as of March 31,2017, route length)

Company Data (FY2016)

Establishment	May 1,1951	
Moody's Rating	A3	
Paid-in capital	JPY 489 billion	
Total assets	JPY 6,853 billion (Consolidated)	
Generation facilities	Thermal	19,408 GW
	Nuclear	8,928 GW
	Hydro	8.226 GW
	Renewable energy	0,011 GW
	Total	**36,57GW**
Total electricity sales	**121.5 billion kWh**	
Operating revenues	**JPY 3,011 billion** (Consolidated)	
Ordinary income	**JPY 196 billion** (Consolidated)	
Net income	JPY 141 billion (Consolidated)	
Employees	32,666 (Consolidated)	

KUROBE No.4 Hydropower Station

"Dum Curry Rice"

"KUROBE No 4
Hydro Power Station"

Sources)
https://www.elinn-kyoto.com/news/?id=82

"KUROBE mineral water"

Sources)
http://www.kanden-rd.co.jp/others/water/index.php

from Osaka/Kansai to the world

OSAKA-KANSAI
JAPAN
EXPO 2025

World Expo 2025
Candidate

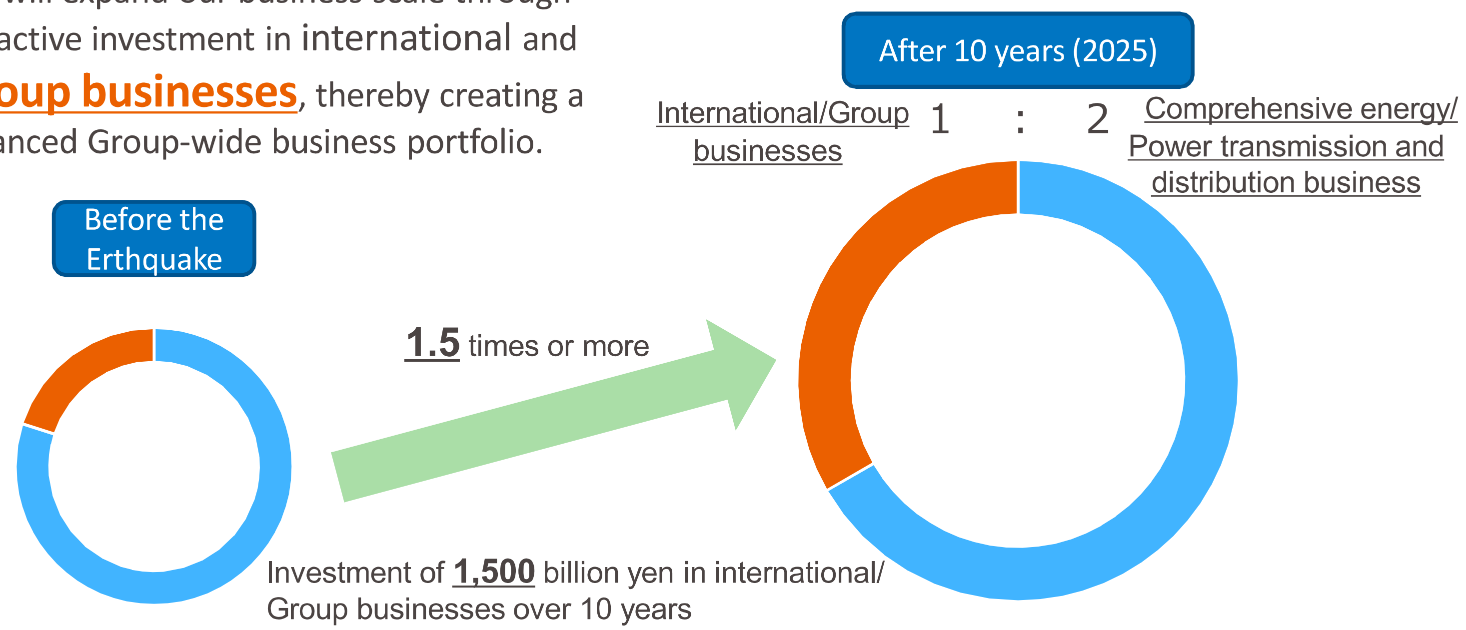
Theme "Designing Future Society for Our Lives"
EXPO concept "People's Living Lab"

Will be voted on at the 164th General Assembly in November 2018

Business Portfolio after 10 Years

We will achieve a Group-wide profit which exceeds the pre-Earthquake (1.5 times or more)

We will expand our business scale through proactive investment in international and **Group businesses**, thereby creating a balanced Group-wide business portfolio.



"VPP" is one of the candidate to create new Group Business by Innovation

Energy Mixture ～ Power supply configuration in 2030～

○ Based on the Basic Energy Plan, the government formulated a balanced energy mixture in July 2015 from the perspectives of "S + 3 E" as a forecast for long-term energy supply and demand.

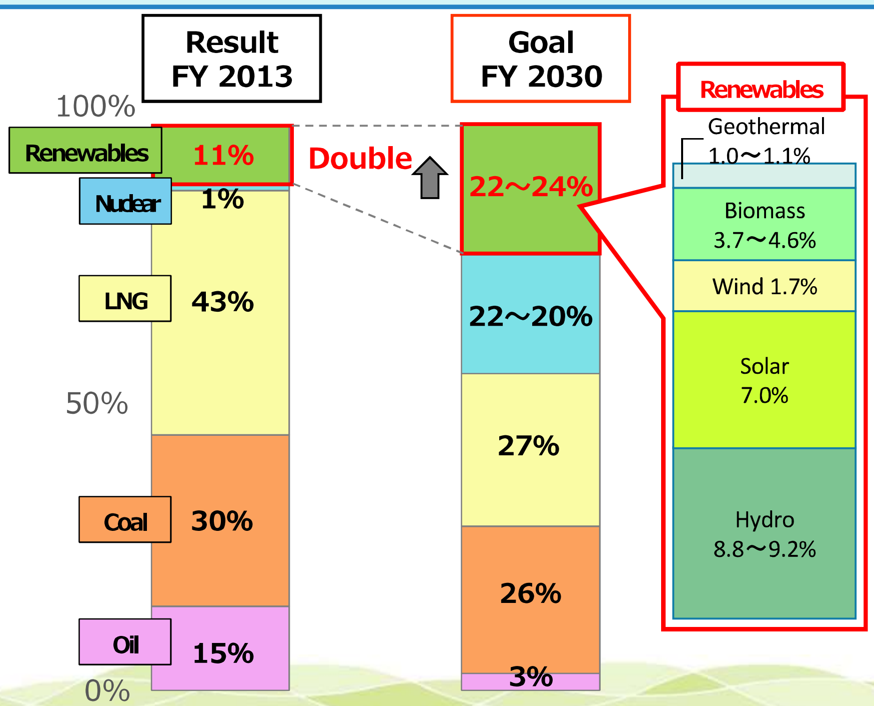
○ The government has set an ambitious goal of share for renewable energy in the power supply composition of 2030 from 22 to 24% as doubling from 11% actual result of 2013.

<FY 2013>

Self-sufficiency rate
About 6%

Electricity Tariff
Rise highly
(Industry : 30% up
Household : 20% up)

Greenhouse gas
CO2 emissions from energy source were the worst ever



<FY 2030>

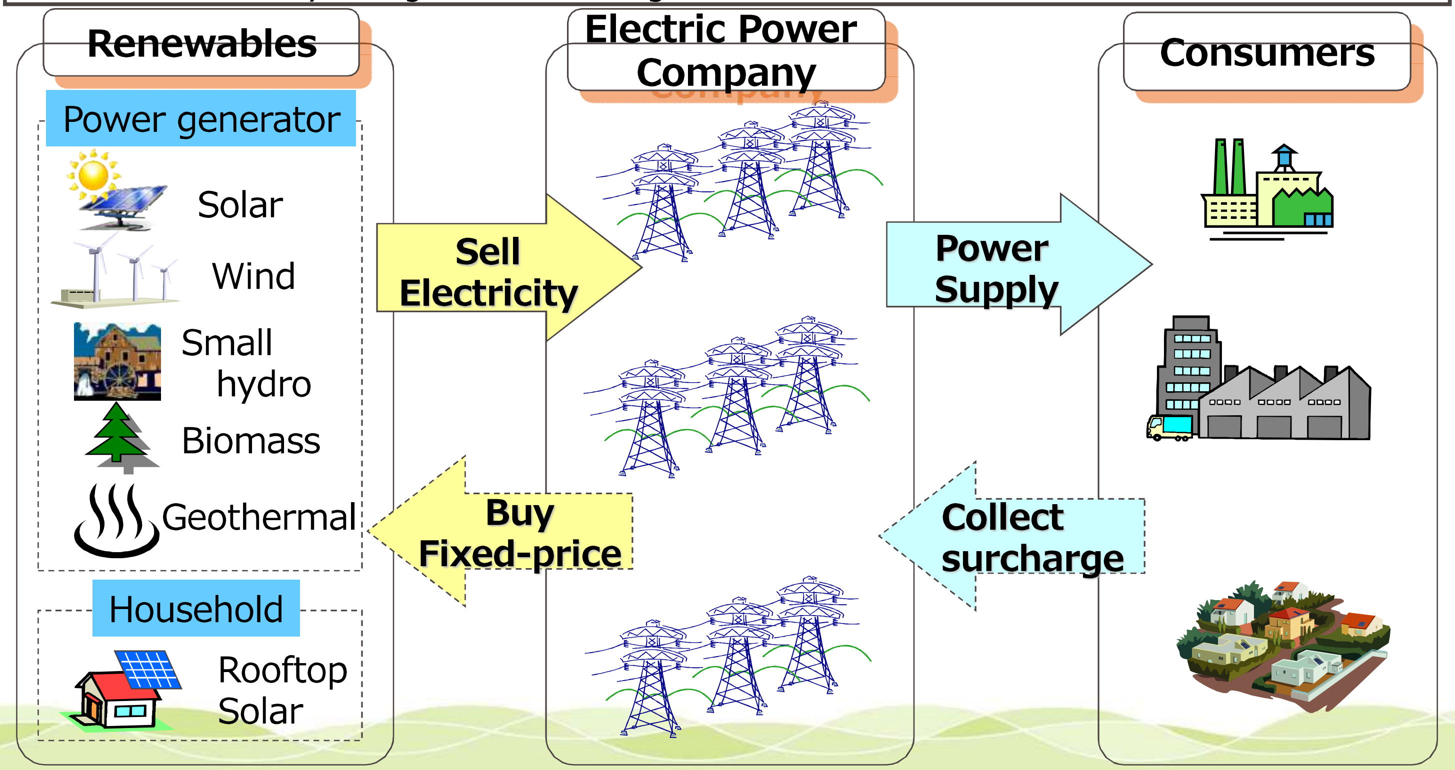
Self-sufficiency rate
Rise to about 24.3%
(including Nuclear)

Electricity Tariff
Reduce to 2～5%
(Compare with FY2013)

Greenhouse gas
Reduce to 26%
(Compare with FY2013)

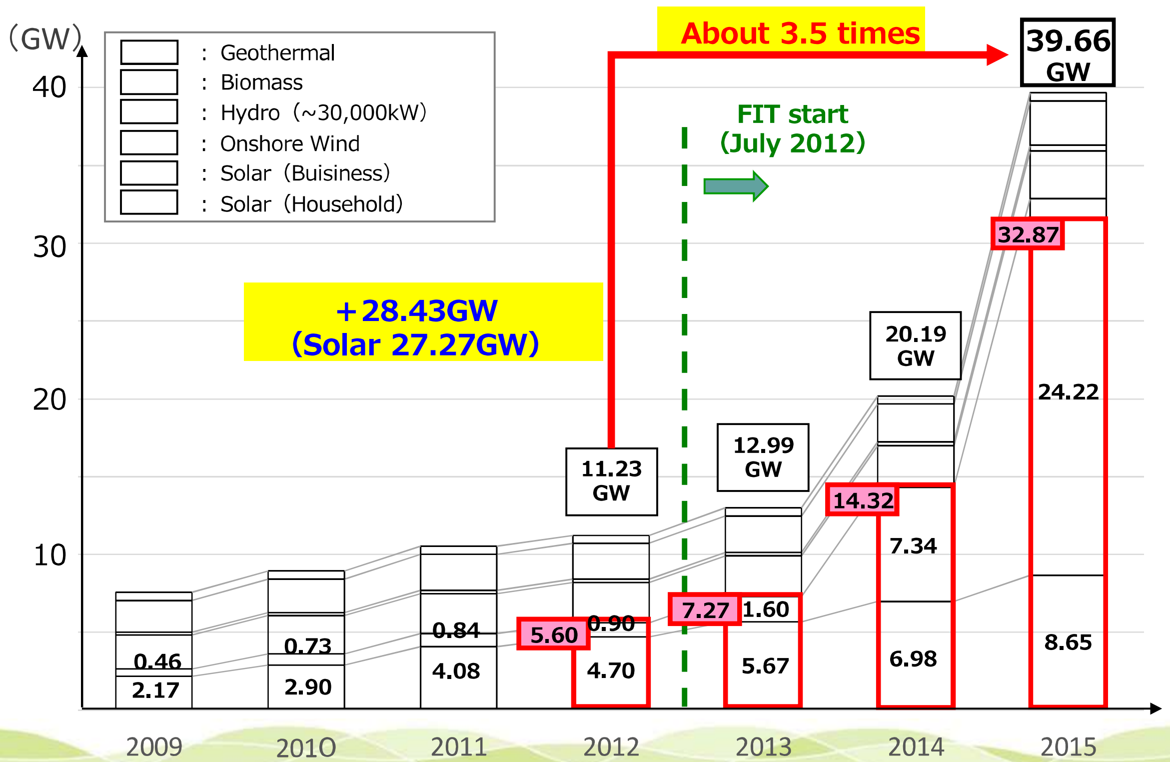
Feed-in Tariff (FIT)

- FIT has been begun in July 2012 for maximizing the penetration of renewable energy
- **FIT Law that obligates retail utilities to purchase electricity generated by renewable energy for a certain period at fixed price.**
- The purchase cost under the FIT system is paid by all consumers at the same time as the electricity charge as a surcharge

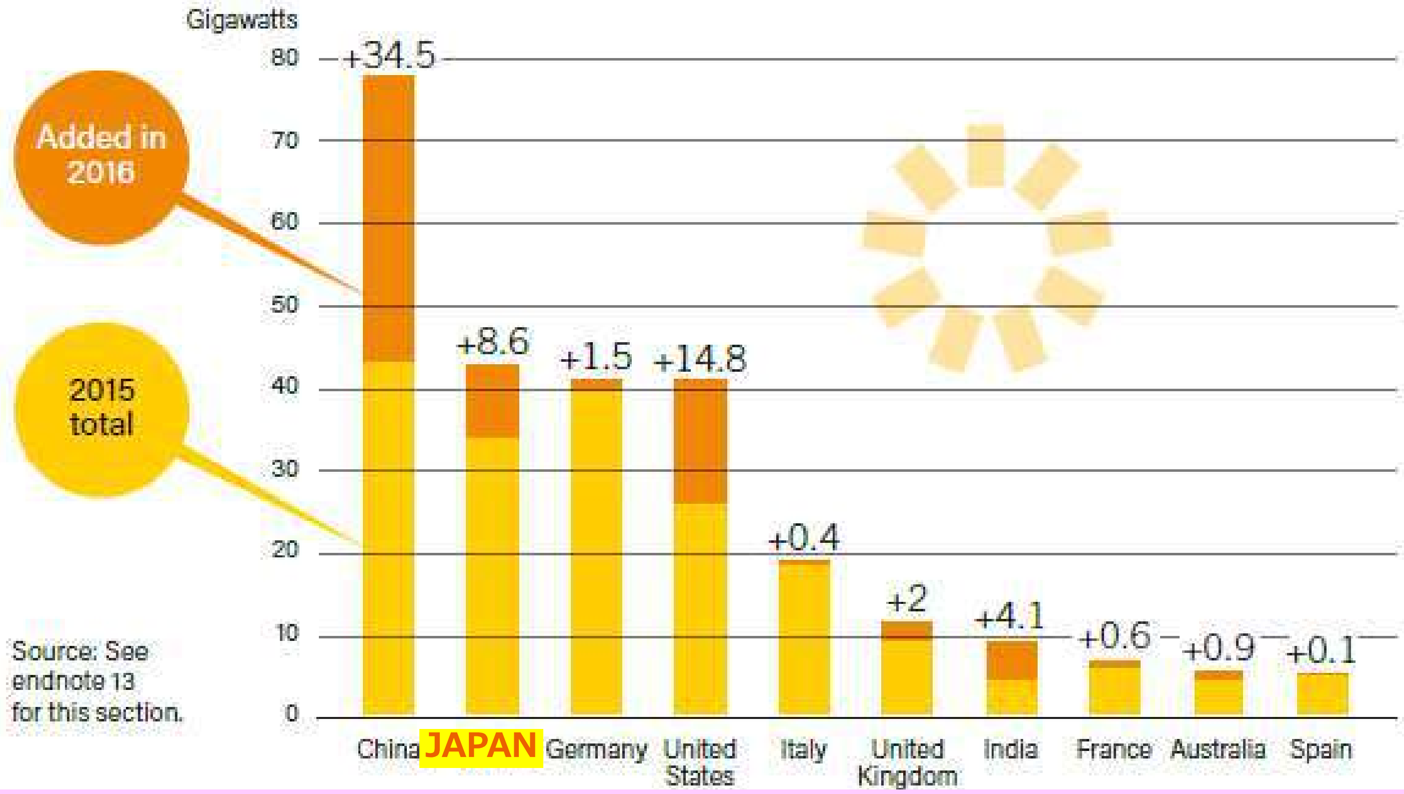


Penetration Trends in Japan's Renewable Energy Facilities

- At the end of FY 2015 the amount of renewable energy was 39.66 GW, about 3.5 times compared with before starting the FIT system.
- Solar accounts for 96% (27.27 GW) out of the power plant capacity (28.43 GW) since starting the FIT formulation



Solar PV Capacity and Additions, Top 10 Countries, 2016

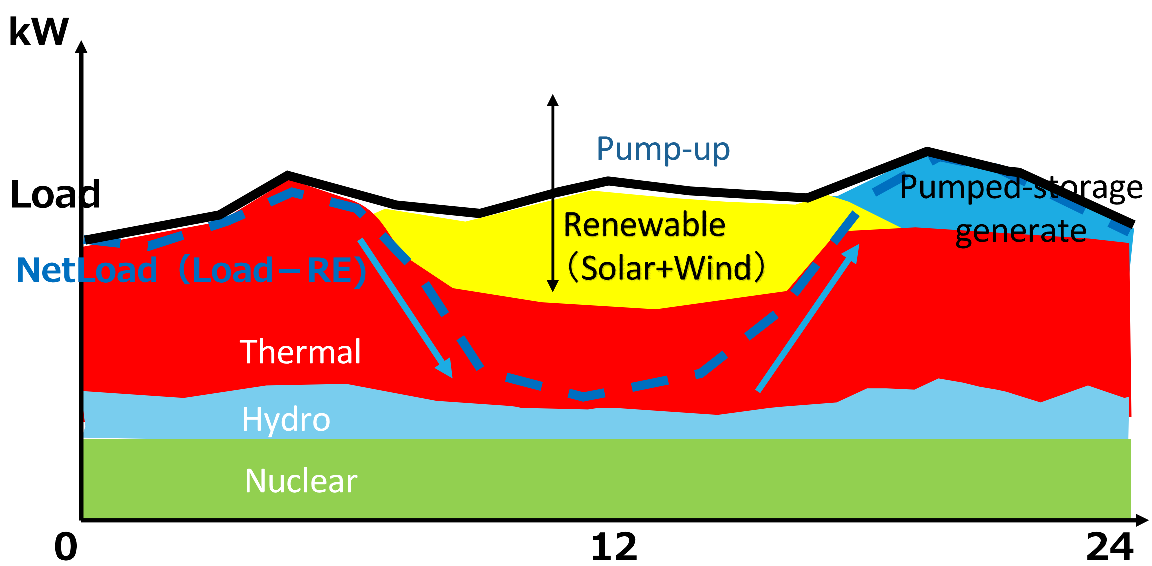


Japan became the 2nd country in accumulated PV introduction in the world

［Resource］: REN21／Renewables 2017 Global Status Report
www.ren21.net/wp-content/.../2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

Challenges of power supply dispatching for the mass penetration of variable renewables

- Increase in proportion of Solar and wind during light load period
- In the daytime, the supply-demand balance is maintained by the pump-up of pumped-storage power generation.
  As solar increases further, it is necessary to curtail solar power.
- Net load sharply drops in the morning and rises sharply in the evening. This makes supply / demand balance difficult. (Duck curve problem)



Exmple:Image of supply-demand balance in Kyushu area

Contents

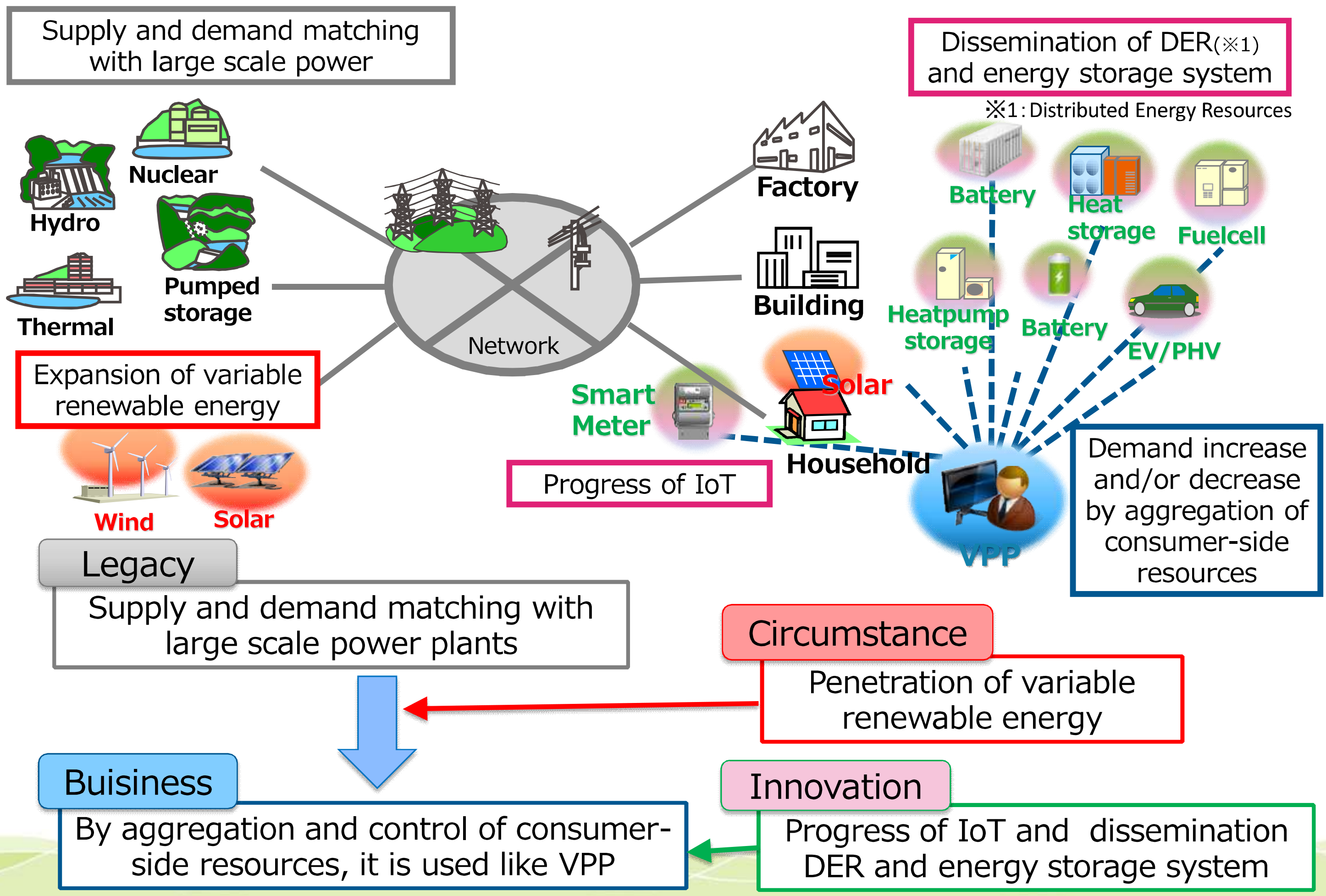
<1> Introduction of KANSAI Electric Power Company (KANSAI EPCO) & Japan

<2> KANSAI EPCO's VPP (Virtual Power Plant)

<3> Feasibility/Profitability of VPP

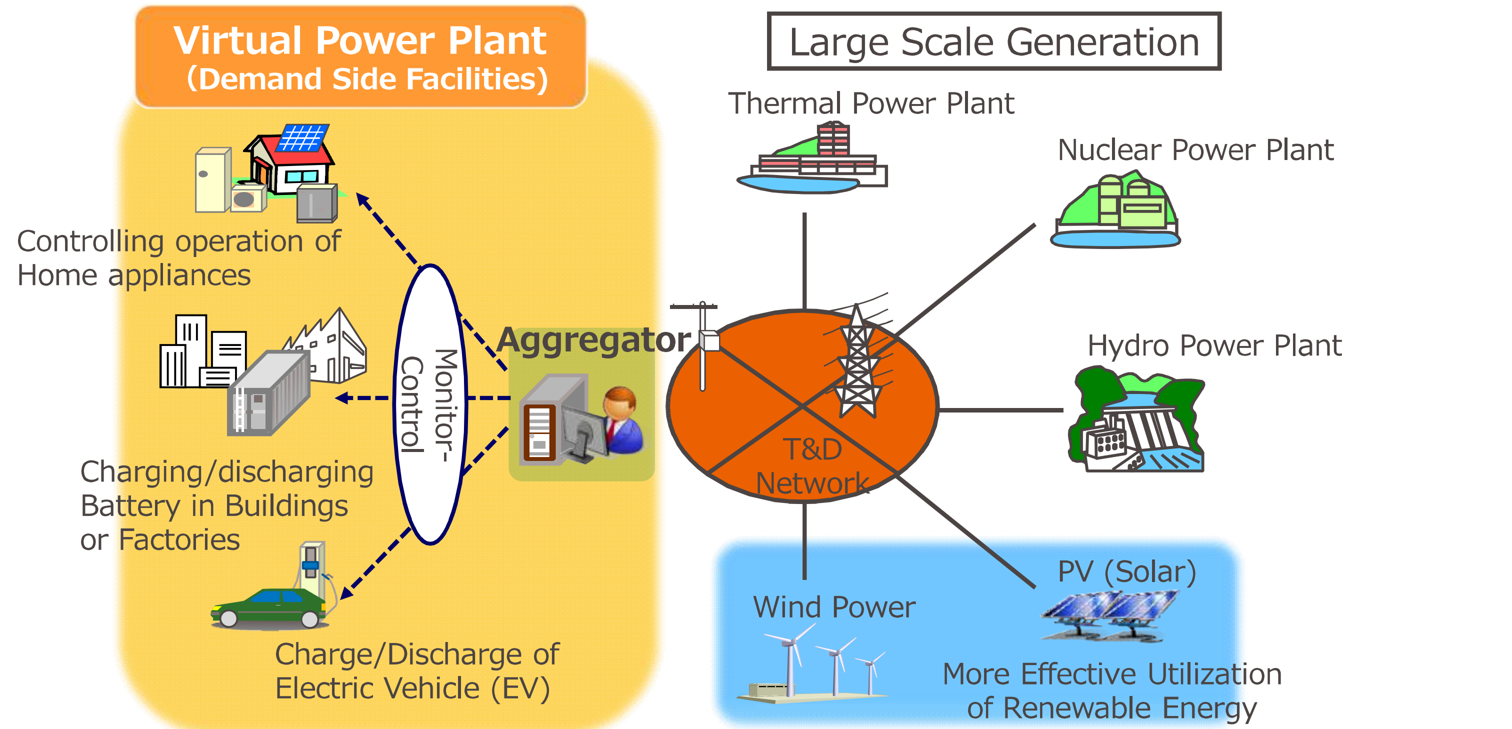
(Moukarimakka? ／もうかりまっか？in KANSAI dialect
：How is business?)

Energy Resource Aggregation Business (ERAB) ＝VPP



VPP (Virtual Power Project) Image

[Outline of VPP] By changing demand-side facilities which scatter in electricity-network (Resources) into IOT (Internet of Things) and by contorting these resources together at the same time, we aim at developing system/mechanism to utilize effectively demand-supply regulating power from demand-side facilities and making them function as if it were a Virtual Power Plant (VPP).
As a result, demand-supply regulating power are reinforced and further introduction of Renewable Energy become able to be realized.

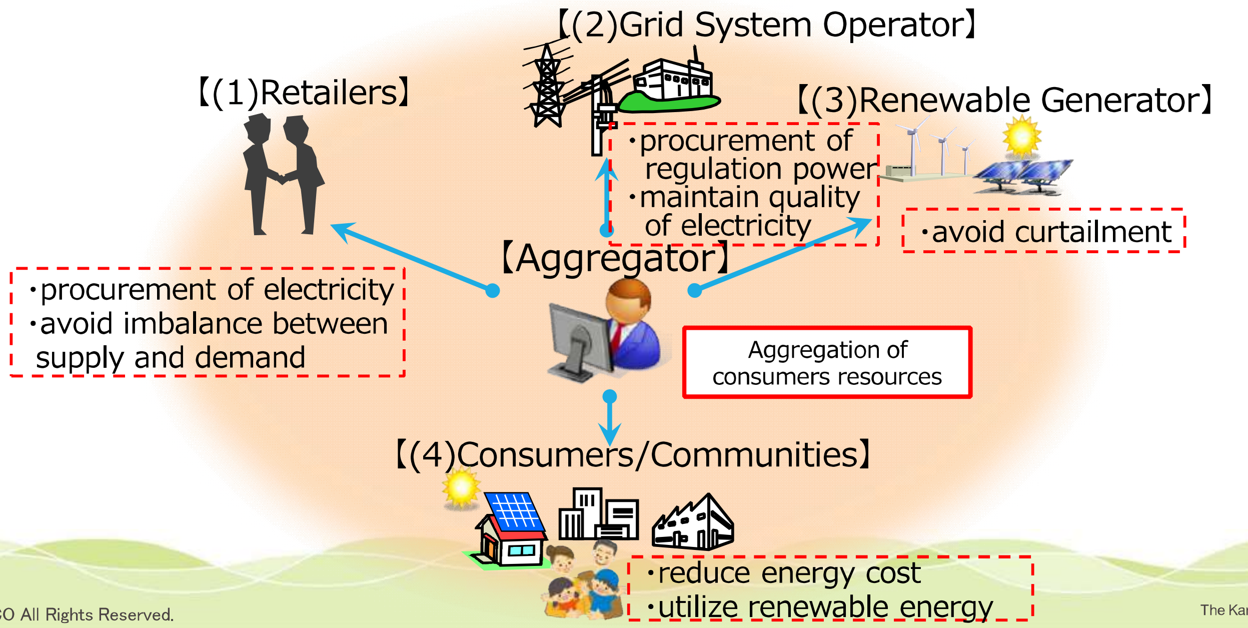


In case of Generation Surplus : Demand Increase Control (Charging Battery, Thermal Storage, etc.)
In case of Generation Shortage: Demand Decrease Control (Discharge, Decreasing Demand (e.g Air-Conditionor)

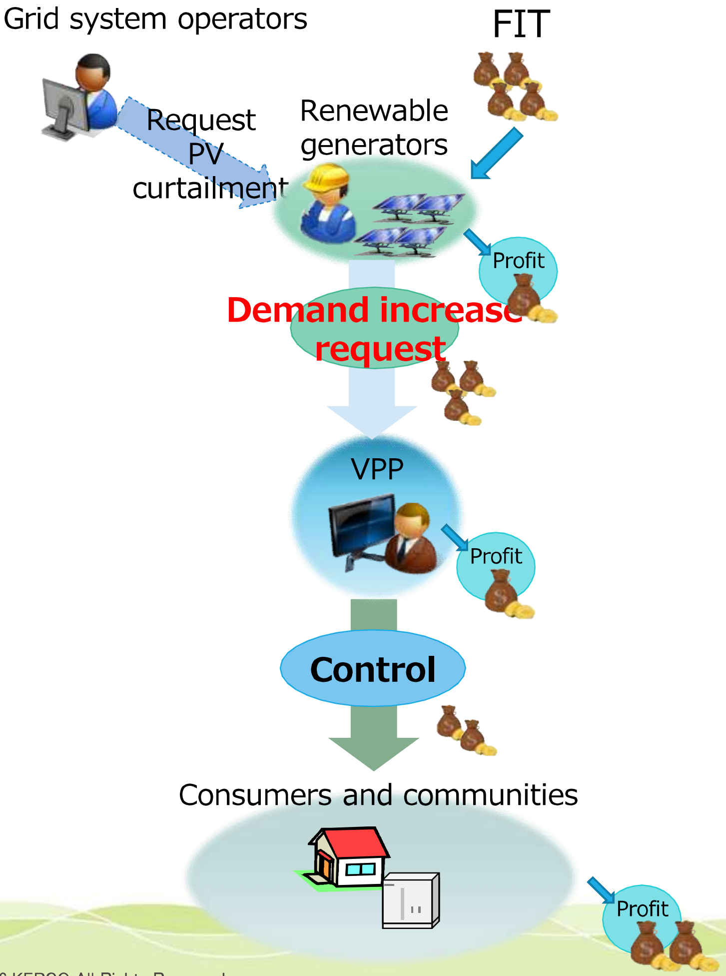
Services to be provided by VPP

By remotely controlling end-use devices and adjusting for demand, aggregators will be able to provide the following services;

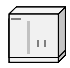
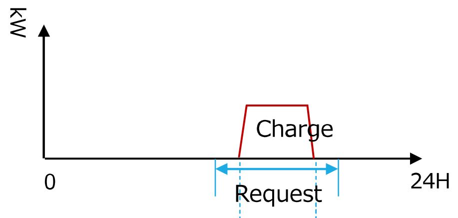
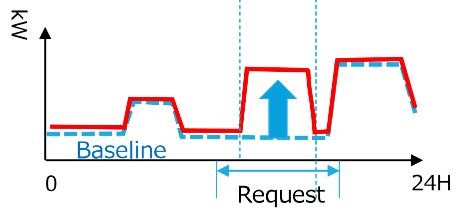
- To【(1)Retailers】:
  Secure greater balance between demand & supply by controlling demand of consumers / communities
- To【(2)grid system operators】:
  Create additional demand or supply by keeping a balance between supply and demand
- To【(3)renewable generators】:
  Help avoid sudden curtailment by creating demand
- To【(4)consumers and communities】:
  Facilitate “self-consumption” by utilizing renewable behind the meter, and reduce energy costs



Service image of " Avoid for Solar curtailment"



【Example:Use of battery for VPP】

	Demand increase request
Battery 	Charge in daytime 
House Hold Load	
Profit	■VPP Insentive from Renewable generators ■Consumers and communities Insentive from VPP

Kansai VPP Project Overview

14 Japanese companies* launched "Virtual Power Plant Experimental Project"

* Kansai Electric Power Company, Fuji Electric, Sansha Electric Manufacturing, GS Yuasa, Sumitomo Electric , Nihon Unisys, NTT Smile Energy, Enegate, ELIIY Power, Obayashi, Kansai Electrical Safety Inspection Association, DAIHEN, Nature Japan, Mitsubishi Corporation

- Government support:
  - Initiative subsidized by the arm of Japan's Ministry of Economy Trade and Industry
  - In line with government's plan to rebalance Japan's energy mix**

    **
  - Contribute to develop for a new energy management system to facilitate energy use more effectively in the context of deregulation and reform of power system in Japan.
- VPP:
  - The objective is adjustment with demand and supply can be more effectively for available capacity by creating VPP to device across power grids through IoT.
  - Enhancing the system for adjusting electricity supply & demand will make it easier to introduce renewables into the power grid.
- Goal:
  - Set up a comprehensive system for controlling end-use devices and to develop new energy management systems through bundled technology and the installation of renewables
  - Contribute to low-carbon society

Kansai VPP Project and its VPP resources (FY2017)

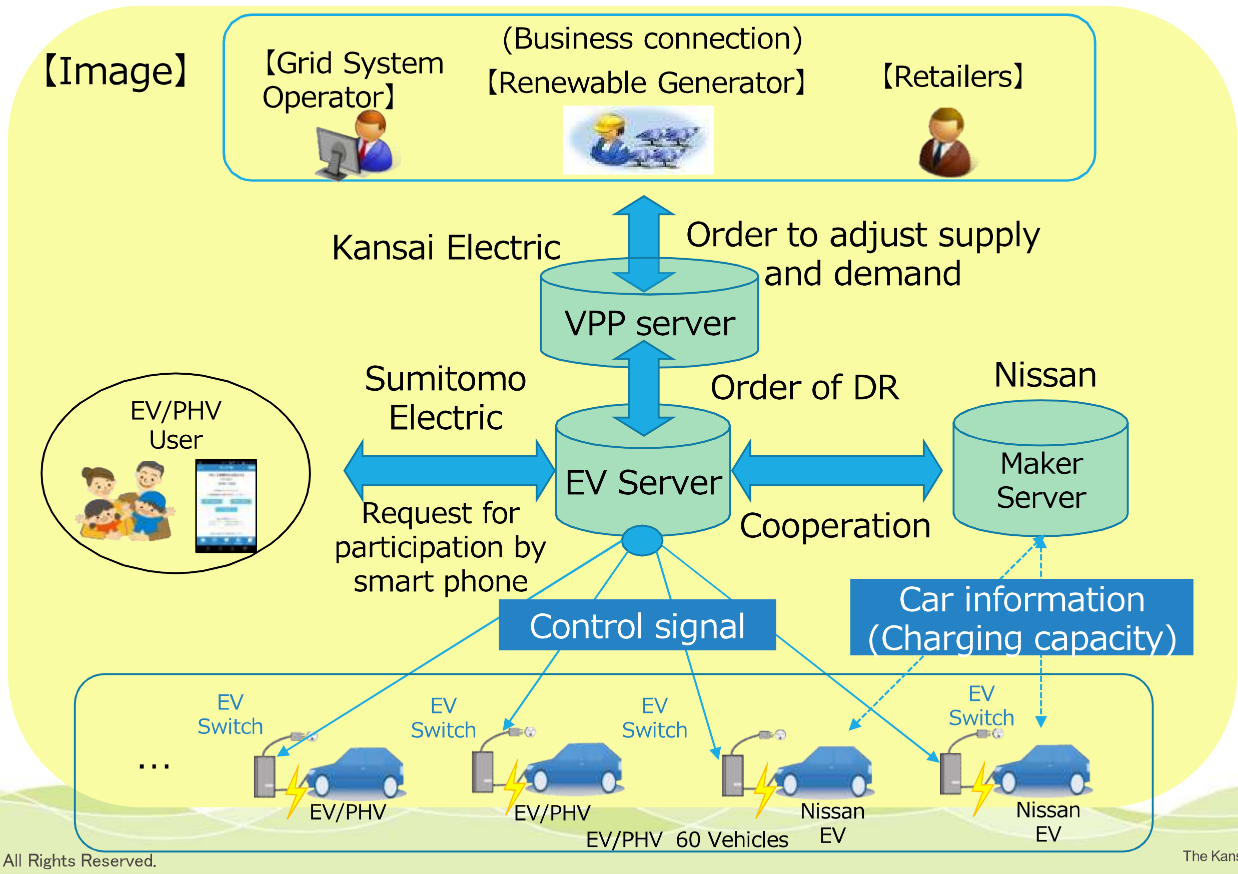
16 Companies applied for demonstration project and have been doing
(Project A) Kansai Electric, Fuji Electric , Sumitomo Electric, Nihon Unisys, Yokogawa Electric
(Project B) NTT Smile Energy, Enegate, ELIIY Power, DAIHEN, Nature Japan, Mitsubishi Corporation, Kyocera, Sharp, Panasonic, Fukushima Industry, Yokogawa Solution Service

【Role sharing】 Resources of FY 2017

	EMS	Air Conditioner	Boiler	EV・PHV	Battery	PV	Generator
House hold	HEMS	Air conditioner	Household HP boiler	Private car	Small scale battery	Roof PV	Household Co-generation
	Enegate	Nature Japan	Kansai Electric Sumitomo Electric Nihon Unisys Enegate	Kansai Electric Sumitomo Electric	NTT Smile Energy ELIIy Power Mitsubishi Corporation Kyocera Panasonic Sharp	Mitsubishi Corporation	
Industry	BEMS FEMS	Industrial Air conditioner	Industrial HP boiler	Company Car	Large scale battery	Mega Solar Power	Co-generation
	Sumitomo Electric DAIHEN Fukushima Industry Yokogawa s.s.			Enegate	Kansai Electric Fuji Electric		

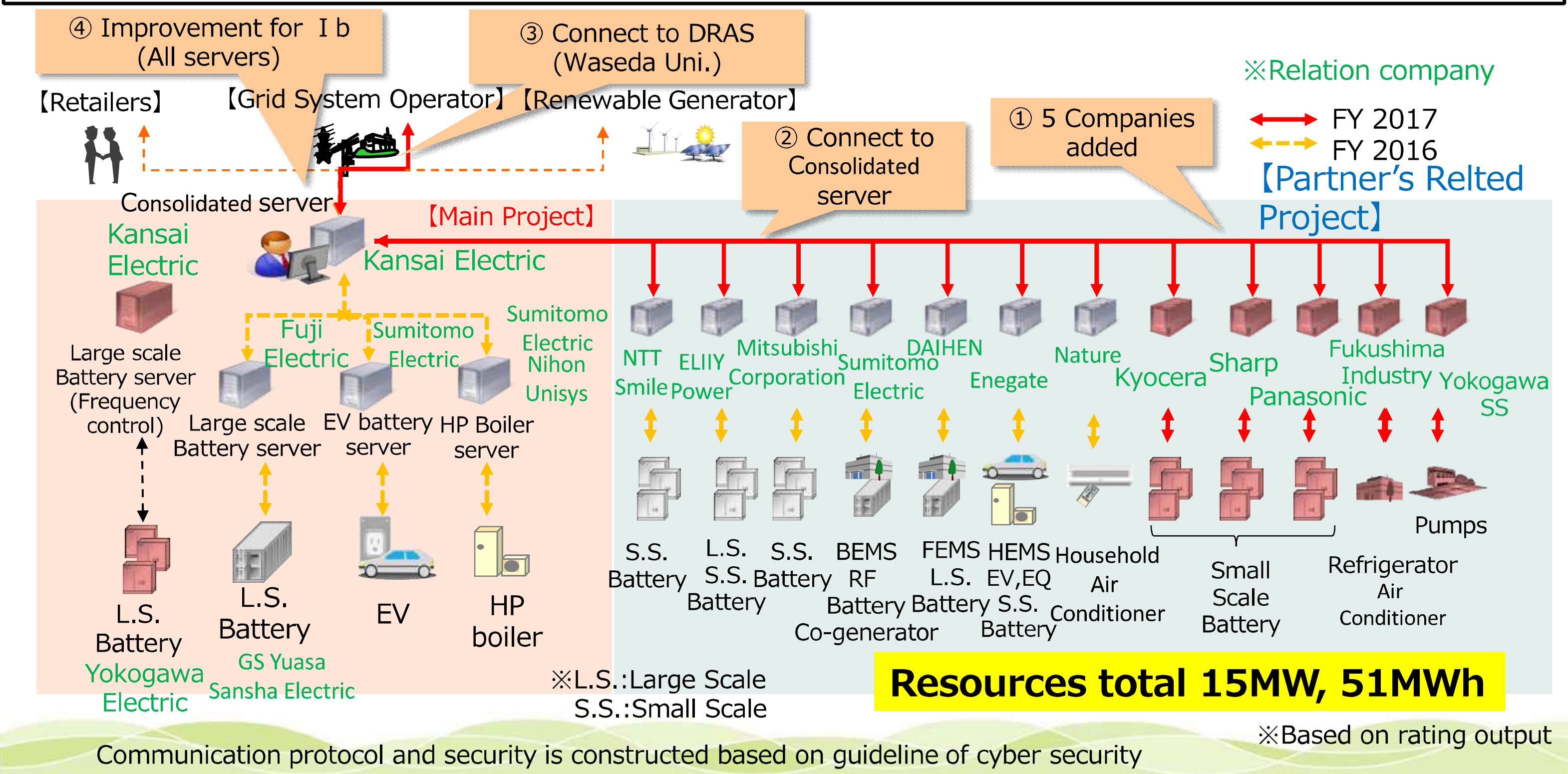
Demonstration of remote control for EV-charging

○ Grasp charging capacity based on information form VPP server connecting EV manufacture's server, and control charging remotely to adjust power



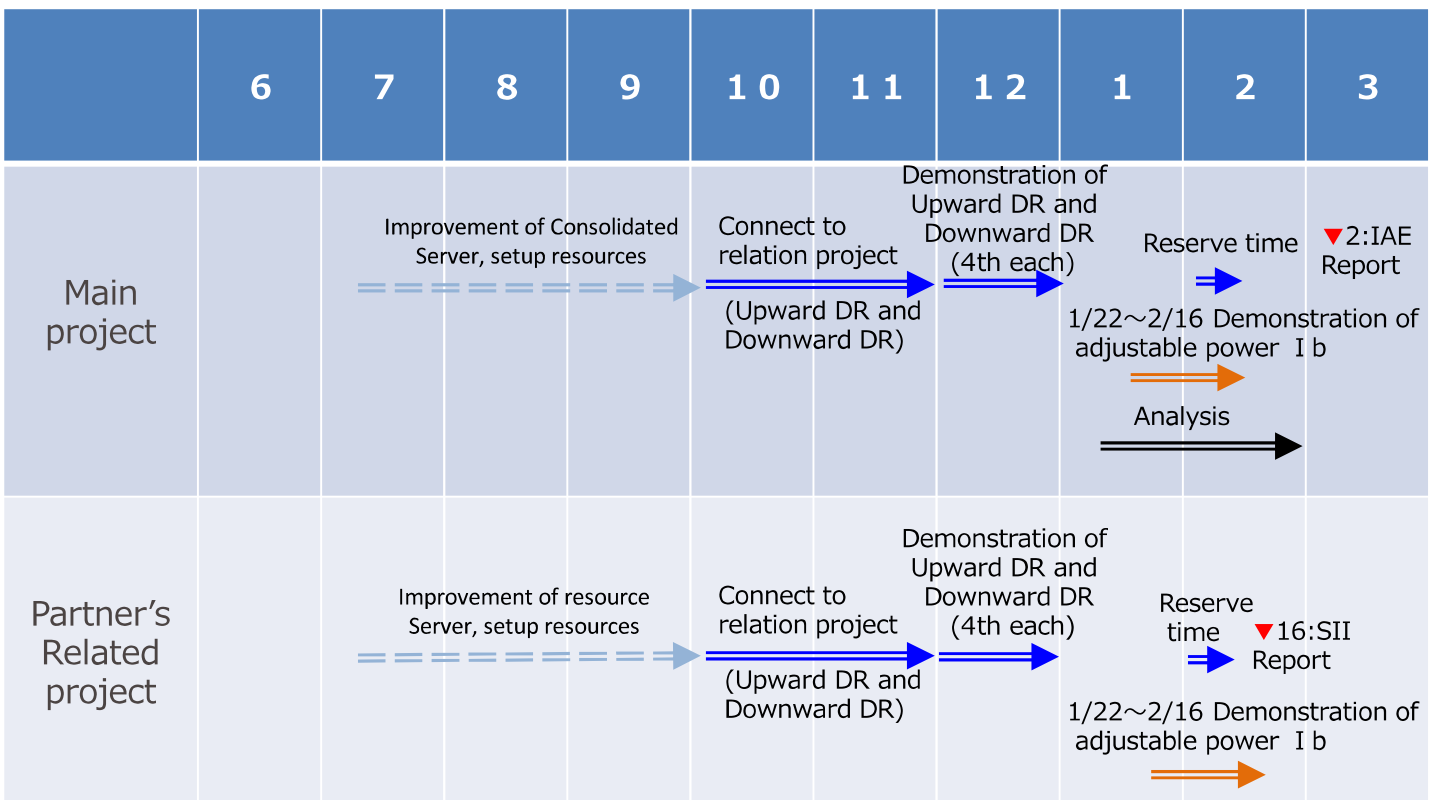
System configuration and contents of FY 2017

【Main Project】
Reinforcement of connection to service provider for upper side (Grid System Operator), resource server for down side (as a parent aggregator), and construct function to aggregate various resources (as a resource aggregator), not depend on manufactures (multi vendor)
【Related Project】 Gather resources, construct remote control system (resource aggregator)

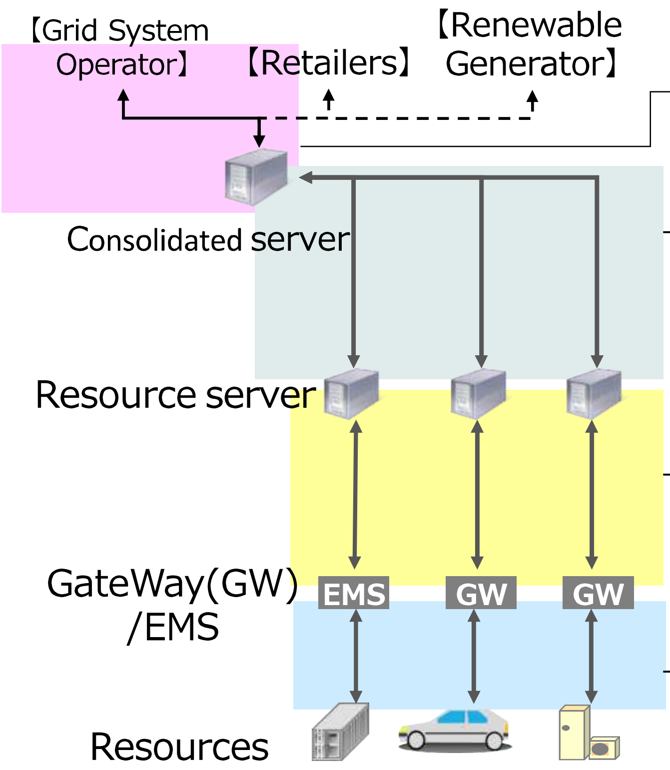


Communication protocol and security is constructed based on guideline of cyber security

Schedule（FY 2017）



■ Communication specification (protocol) and Cyber Security



TSO～Consolidated server

【Communication Protocol】OpenADR2.0b
【Cyber Security】"mutual authentication" & "code"

Consolidated server ～ Resource server

【Communication Protocol】OpenADR2.0b
【Cyber Security】"mutual authentication" & "code"

Resource server ～GW/EMS

(Main PJ)
【Communication Protocol】OpenADR2.0b
【Cyber Security】certification and cipher code
(Related PJ)
【Communication Protocol】
-OpenADR2.0b, MQTT, original protocol, etc.
【Cyber Security】"mutual authentication" & "code"

GW/EMS～ Resources

(Household)【Communication Protocol】
- ECHONET Lite, and original protocol
(Industry)【Communication Protocol】
- Modbus/TCP, and original protocol

○ Check whether aggregator can "change demand to the ordered target within 15 or 5 minutes" and "maintain target demand for 4 hours" based on the order from (TSO's) dispatching system.
○ Check whether "change speed" and "control time" is appropriate or not by measuring several demand ammount when under control

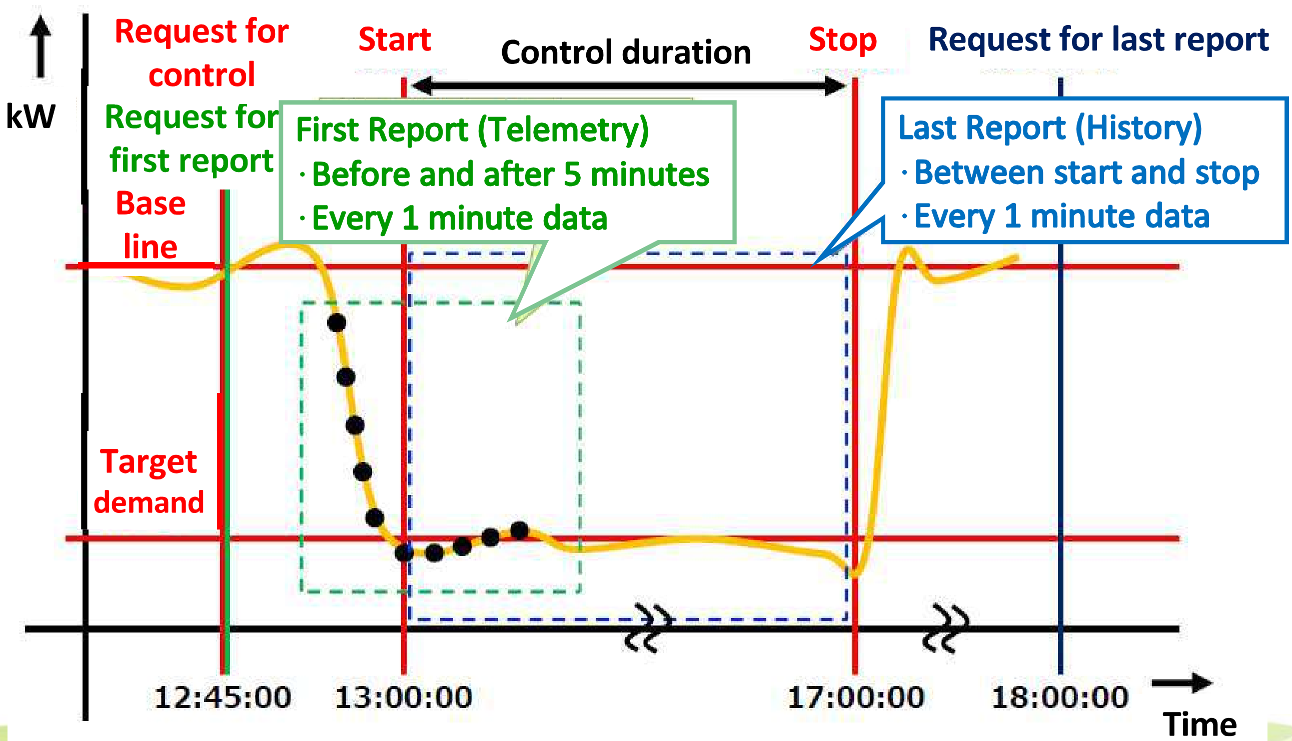
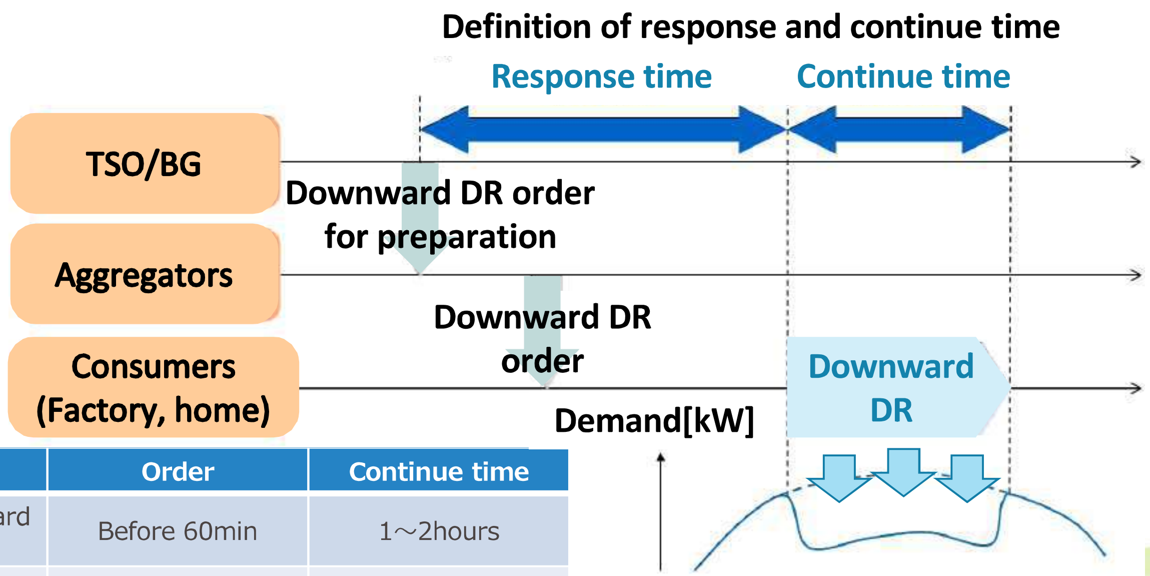


*Image of menu A (time is example)

[Outline 2/2] Demonstration of Upward Demand Response* (DR) and Downward DR

<Downward DR>
○ [Assumption] severe supply and demand, ➡ decrease demand in 60 minutes after order
○ check whether demand is decreased until target demand every 30 minutes or not
<Upward DR>
○[Assumption]avoid to renewable resources curtailment ➡ increase demand of tomorrow
○ Check whether demand is increased/produced until target demand every 30 minutes or not

*Upward DR (means increase demand when there is surplus of electricity)⇔ Downward DR

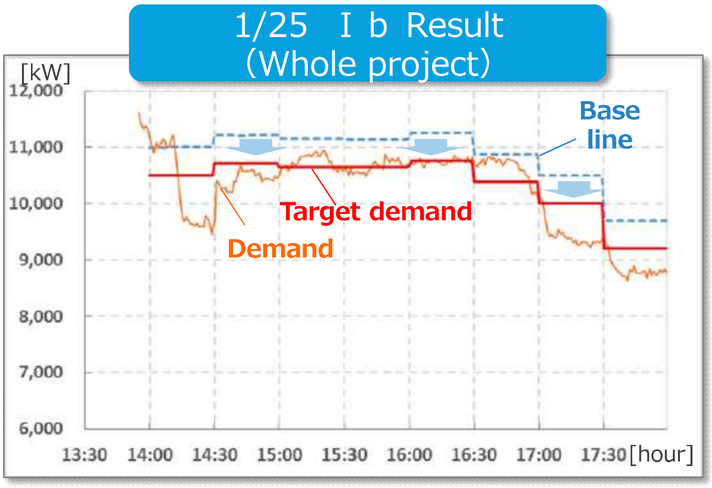


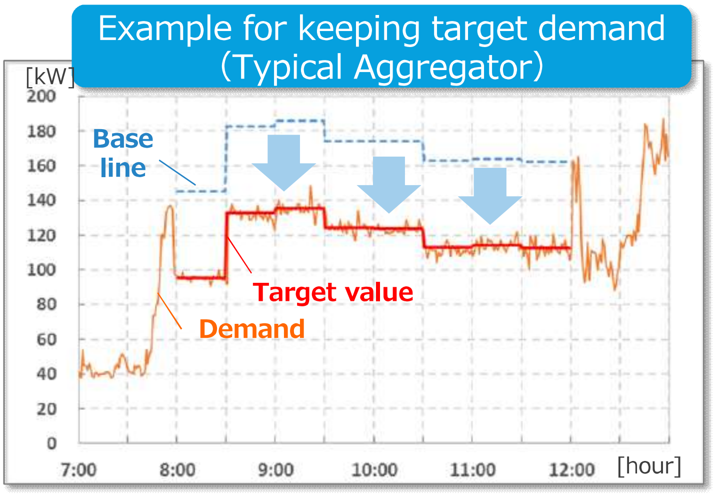
Example

DR	Order	Continue time
Downward DR	Before 60min	1～2hours
Upward DR	Previous day 18:00	1～2hours

[Result 1/3] Demonstration of Regulation Power Ⅰb（Secondary Control）

■Content　1/22～2/16 8 times（Menu A : 4 times, Menu B : 4 times）DR





※3 Area（Tokyo, Kansai, kyusyu）Summation

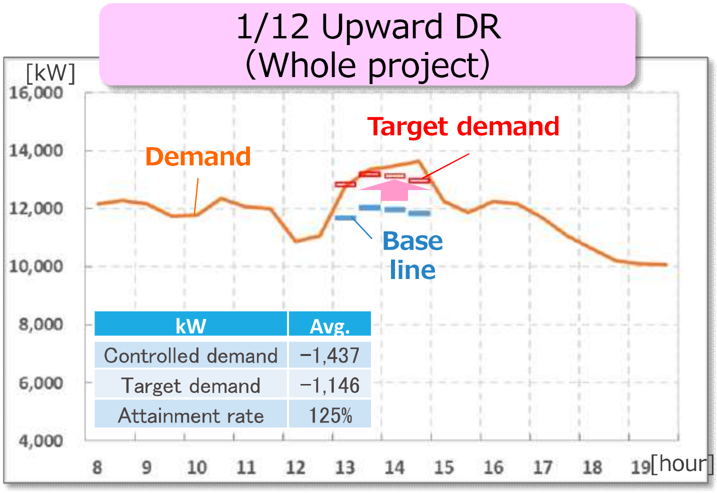
■Results

[Measure] ･Almost reported in 1 minutes. But a few resources aggregators delayed in report.
･There were variations of measuring time and time stamps among Aggregators.
It is necessary to measure within “seconds - 1 minute” and unify time stamps in order to improve accuracy of control.

[Control] ･Almost controlled to target demand in several time as a whole, but not controlled cases were seen, and a few subjects are found.　(above figure left side)
･Some Aggregator controlled correctly（right side）, but not cases were seen.
･Forming adequate portfolio and feedback control are required to improve control.

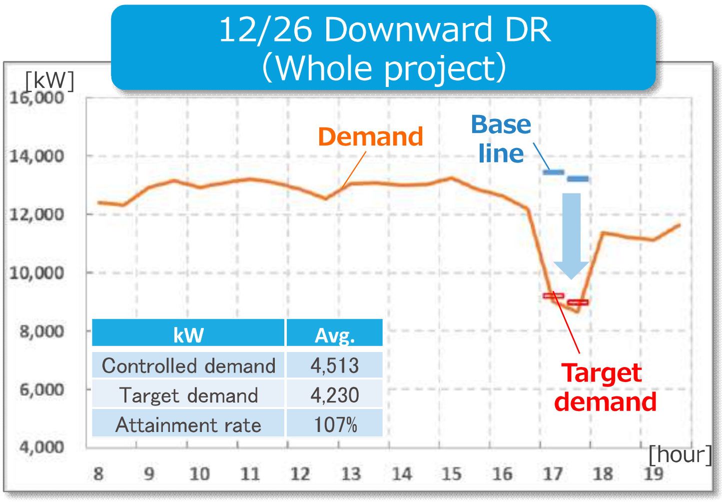
[Result 2/3] Demonstration of Upward DR and Downward DR

■Content 12/25～1/12, 2/19～2/23 Upward DR: 3 times, Downward DR:4times DR



kW	Avg.
Controlled demand	−1,437
Target demand	−1,146
Attainment rate	125%

※4 Area（Tokyo, Kansai, kyusyu, Chugoku）Summation



kW	Avg.
Controlled demand	4,513
Target demand	4,230
Attainment rate	107%

※6 Area（Tokyo, Kansai, kyusyu, Chubu, Chugoku, Shikoku）Summation

■Results

[Control]

・Adequate results were gotten as a whole , both in Upward DR and Downward DR (above figures)

・Difference of ability are seen among resource aggregators for accuracy of control and responsibility of capacity

・In order to increase accuracy, it is necessary to form optimum portfolio by main (parents) aggregator and to make feedback-control, although required accuracy is different depending on each use case.

[Result 3/3] Demonstration of Upward DR and Downward DR（EV Charge）

■Content

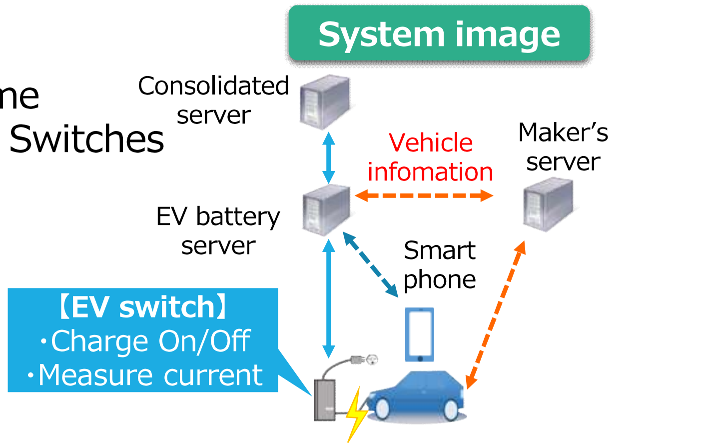
・Upward DR, Downward DR: one time

・Control EV／PHV 60 vehicles by EV Switches

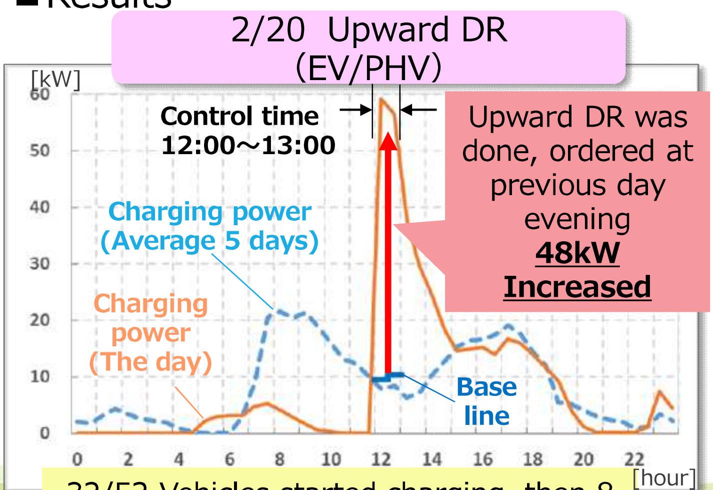
Place and use	Vehicles
Working Vehicles	4 2
Commute to office	1 0
Household	8

※Charging in office

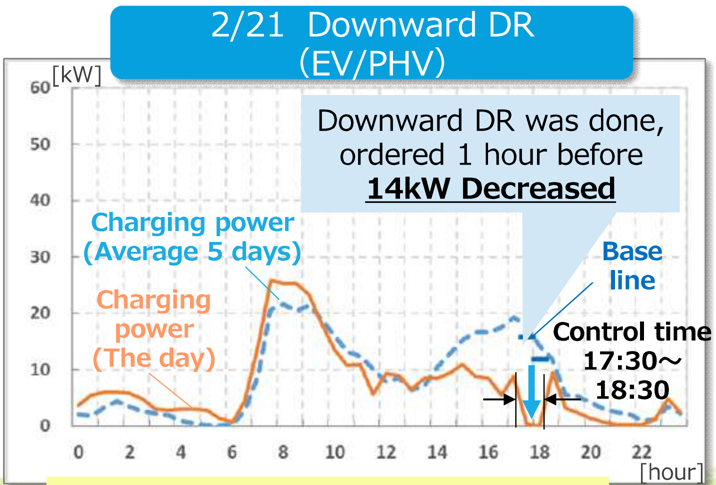
※Valuated at charging point



■Results



32/52 Vehicles started charging, then 8 vehicles stopped in a few minutes



4/58 Vehicles stopped charging

FY 2017 Results (Summary) ・FY 2018～ future plan

■Summary of demonstration-results in FY2017

・Develop VPP system for Regulation Power Ⅰb (Secondary Control), connect all resource aggregators and did some demonstrations

・Ⅰb (Secondary Control) : Some subjects are found in measurement and control

・Upward DR and Downward DR : Adequate results were gotten as a whole, both in Upward DR and Downward DR

■Issues as Aggregators and future plan after FY 2018

(2) Improvement of accuracy in measurement and control for Regulation Power Ⅰb

(2)Securing accuracy of control in Upward DR and Downward DR, in accordance with each use case

(3)Further Expansion of aggregation scale (VPP resources and aggregators)

Contents

<3> Feasibility/Profitability of VPP

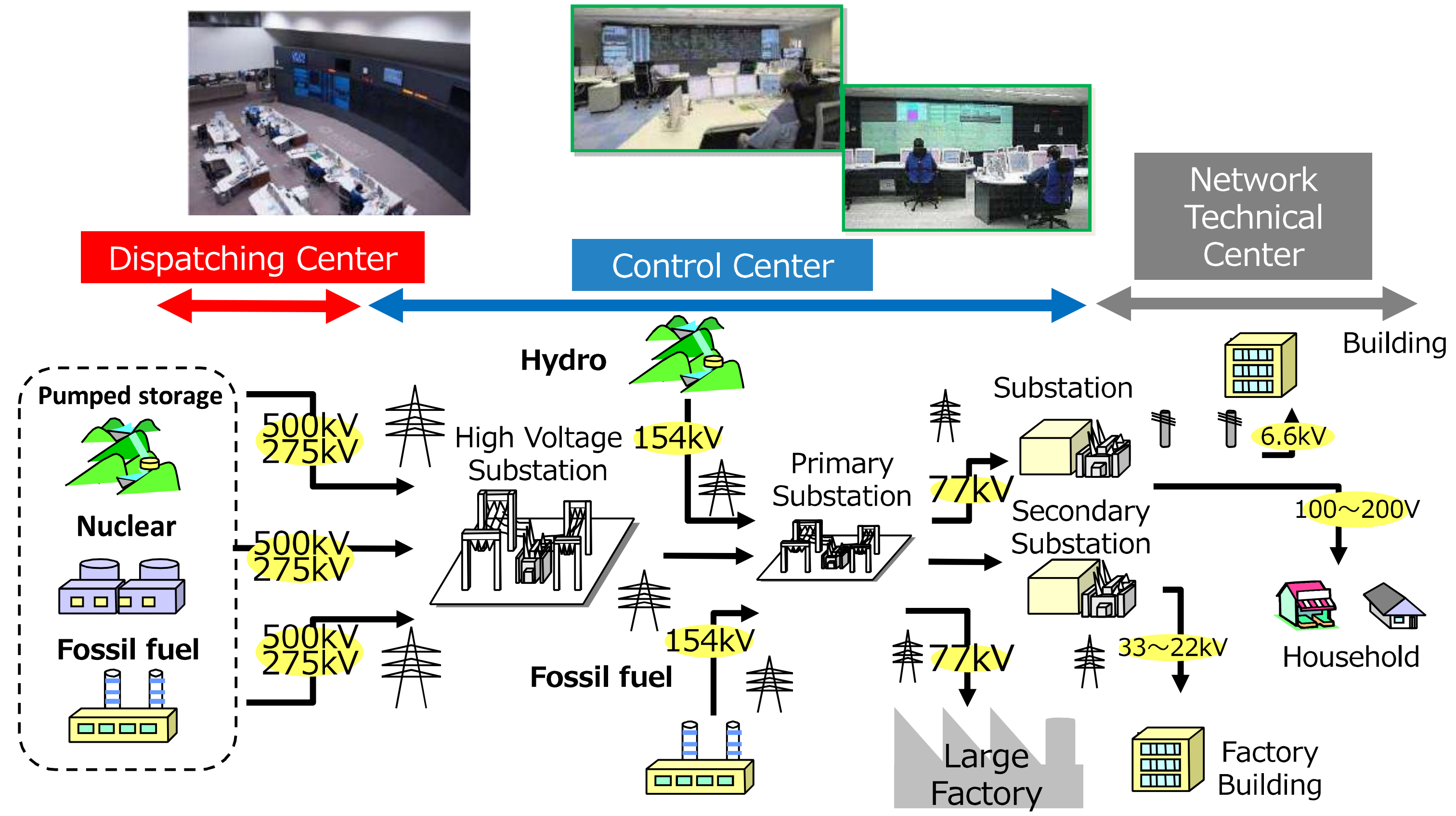
○Feasibility to realize VPP system

○Profitability of VPP Business

(Moukarimakka? ／もうかりまっか？in KANAI dialect

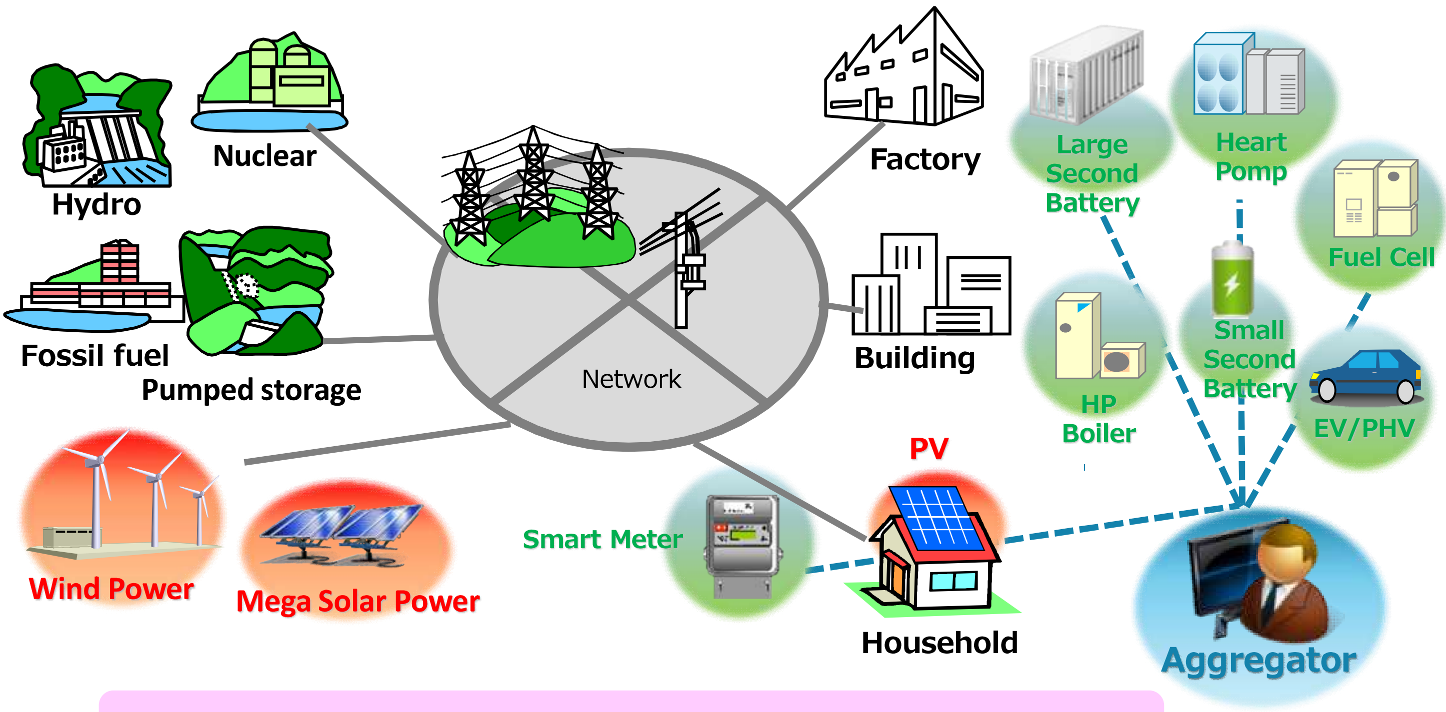
：How is business?)

Remote control system of electric power company



Exclusive design + Exclusive line = High reliability (High security) / High cost

Remote control system of VPP



Low cost ＝ General technique ＋ IoT

Subject : Cyber security ＋ Communication speed

Contents

<3> Feasibility/Profitability of VPP

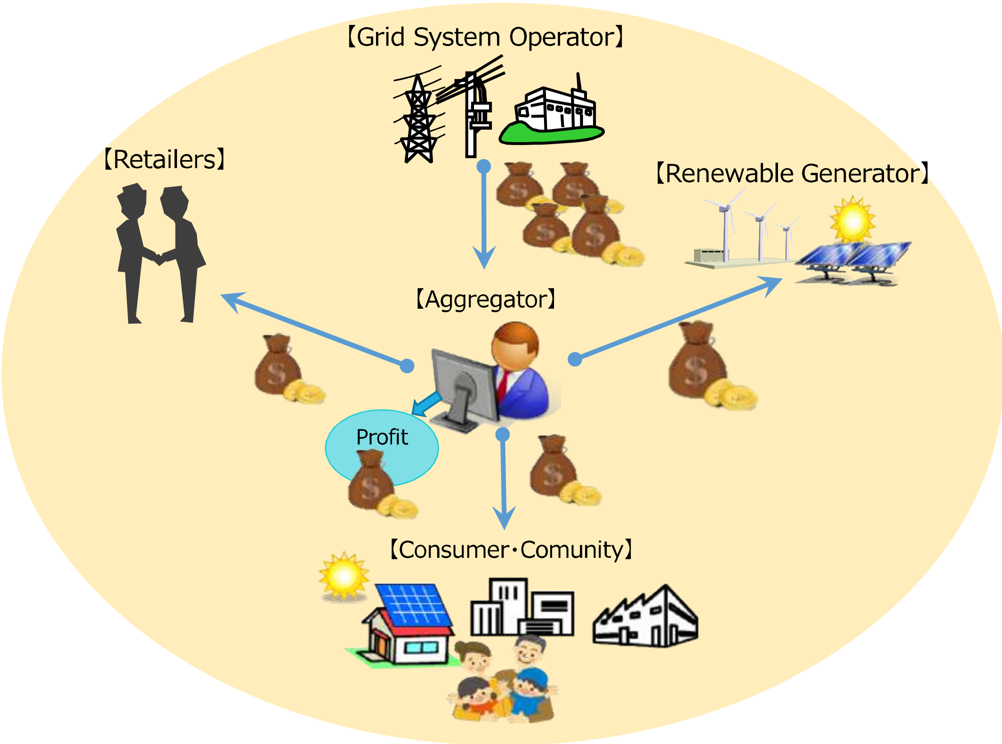
○Feasibility to realize VPP system

○Profitability of VPP Business

(Moukarimakka? ／もうかりまっか？in KANAI dialect
：How is business?)

Booming/Profitable? or Not?

Value for Participation of VPP



◎How much value for VPP

◎Preparation of market-design is important

Introduction schedule of each markets

Markets	FY2005	FY2009	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022 ～
Spot Market	Start ★ →	→	→	→	→	→	→	→
Pre-trade Market	Start ★ (Fixed trade)	Start ★ (Market trade) →	→	→	→	→	→	→
Hours ahead Market		Start ★ →	→	→	→	→	→	→
Base Load Market					Start(Trade) ★ →	Start(Delivery) ★ →	→	→
Capacity Market						Start ★ →	Capacity contract publish →	★ →
RegulationMarket							Market foundation ★ →	→
Non-fossil fuel Market			Start (FIT Power only) ★ →	→	Start (Non-fossil fuel power) ★ →	→	→	→
⋮								

Suitable market design is Key for VPP's profitability

Thank you.

Estimation of Time-series Data of Electricity Demand in Distribution Network based on Public Statistical Data

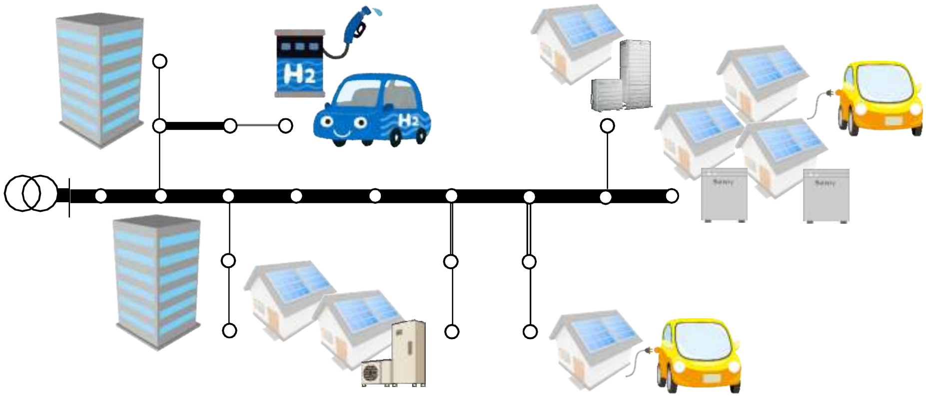
Power transmission and distribution systems in the next generation
The 18th IERE General Meeting & Japan Forum
May, 21 – 24, 2018 at Kyoto, Japan

Yasuyuki Kunii, Junzo Takemura
(Energy Applications R&D Center, Chubu Electric Power Co., Inc.)

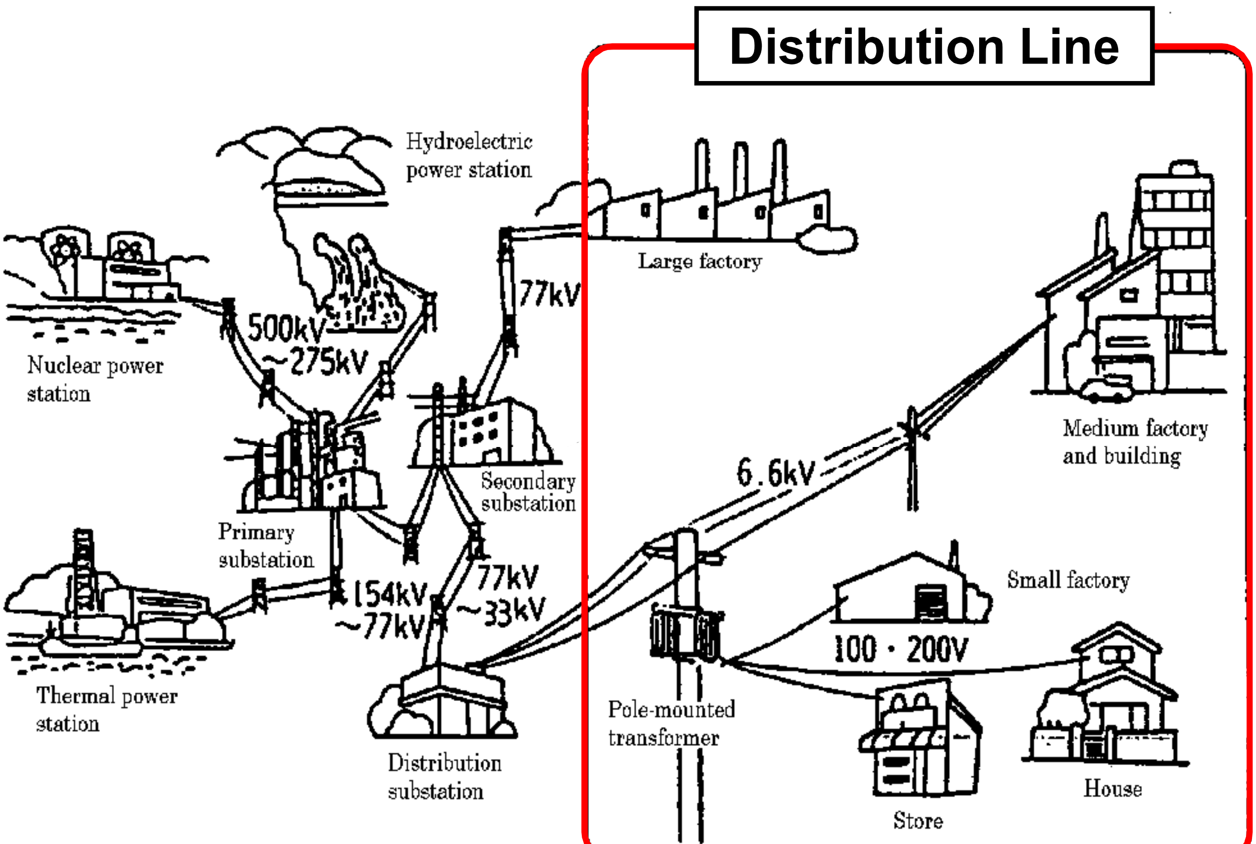
Tetsuya Matsuki, Muneaki Kurimoto, Takeyoshi Kato
(Institute of Materials and Systems for Sustainability (IMaSS) Nagoya University)

Background

- In order to realize effective asset management of a number of distribution networks, utilization status of individual distribution network for the next few decades should be evaluated.
- Proper estimation of future installation number and geographical distribution of distributed generators, electric vehicles, stationary batteries, electric water-heater pump is essential.
- For this purpose, social statistical dataset, such as grid-square statistics provided by government is useful.



Considered Voltage Class in this study



Requirements of Modeling

- Modeling can be only based on social statistic datasets without using any observations of line current, metering data, etc.
- Following items can be taken into account:
  - Electricity demand of various consumer types
  - Future electricity demand by change in population density/distribution
  - PV power output in consideration of spatial distribution of irradiance

Objective

To Develop estimation model of electricity demand in distribution network based on social statistical dataset

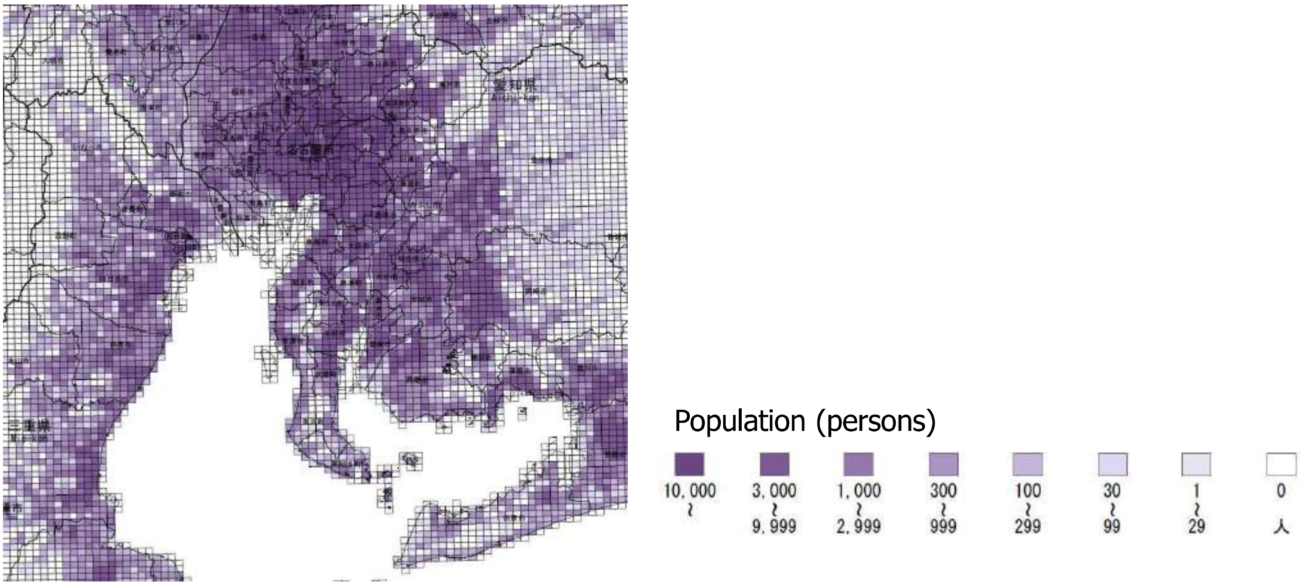
〈Contents〉

1. Modeling procedure
2. Validation of model
3. An example of application of model

1. Modeling procedure

Preparation of grid-square statistics

- Provided by Statistics Bureau in Japan
- Reorganized dataset in terms of the Population Census, the Economic Census and the Establishment and Enterprise Census in small region of approximately 1km square and 500m square by dividing the whole area of Japan by latitude and the longitude



1. Modeling procedure

Estimation of hourly electricity demand

Based on unit demand value per floor space by purpose and total floor space in each 500m square for each user type in residential and commercial sectors

Industrial and nighttime demand is calculated by distributing observed annual value into each 500m square

Total floor space in each 500m square is estimated based on social statistics

1. Modeling procedure

Estimation of total floor space for each user type

< Residential sector (detached house and apartment) >

- estimated by multiplying a number of households in 500m square[1] and percentage of households by space classification[2]

< Commercial sector (office, store, hotel, hospital, restaurant, school) >

- estimated by multiplying the national average floor space per an employee and the number of employees in each 500m square[3]

[1] 2010 census
[2] 2008 Residential land statistics survey
[3] 2006 Statistical survey of companies and offices

1. Modeling procedure

Estimation of electricity demand for industries and street lighting

< Industrial electricity demand >

- Total industrial electricity demand in utility area is assumed to be about half of electricity demand directly supplied with 6.6 kV line
- Total industrial electricity demand is divided into each 500m square based on share of land use data in each 100m square

< Nighttime electricity demand >

- Total nighttime electricity demand is for the public street lightning etc.
- Total nighttime electricity demand is divided to each 500 m mesh based on total floor space of residential and commercial sector

Objective

To Develop estimation model of electricity demand in distribution network based on social statistical dataset

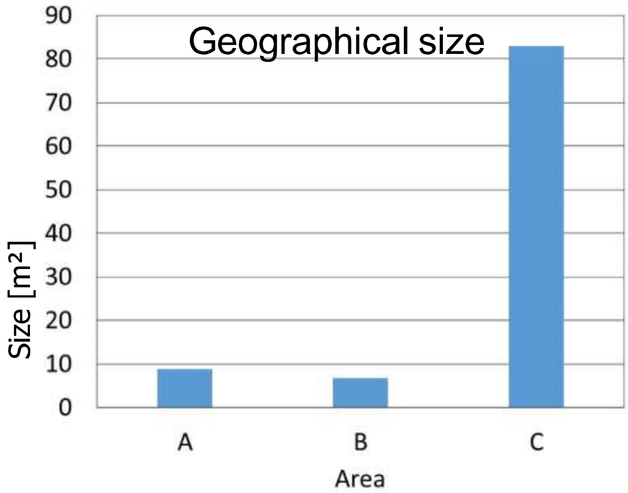
〈Contents〉

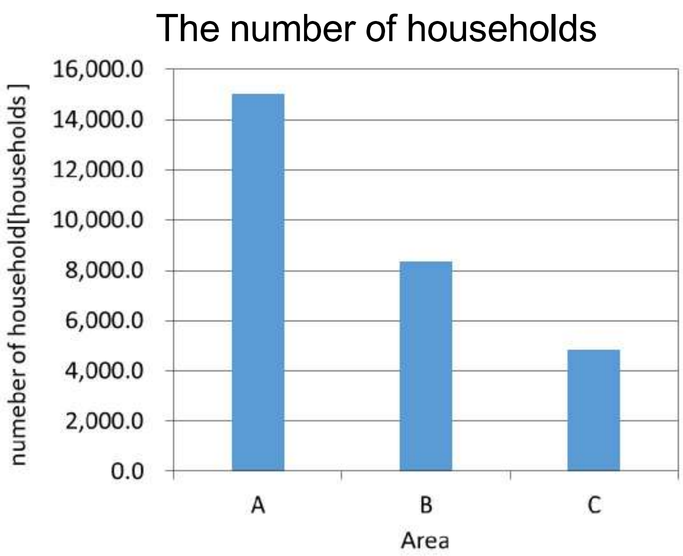
1. Modeling procedure
2. Validation of model
3. An example of application of model

2. Validation of model

Three distribution network areas

Area A : residential area dominated by detached house
Area B : residence and factories complex area
Area C : farms dominated area with some factories





2. Validation of model

Bird's eye view of Area-A

CHUBU Electric Power Nagoya University

2. Validation of model

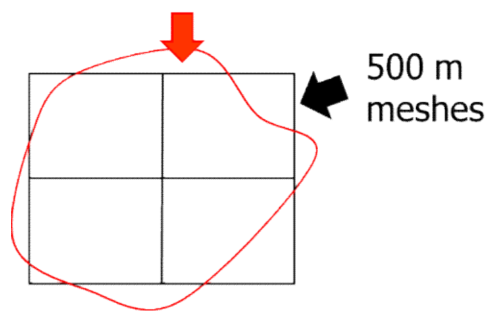
Estimated and observed value in each Area

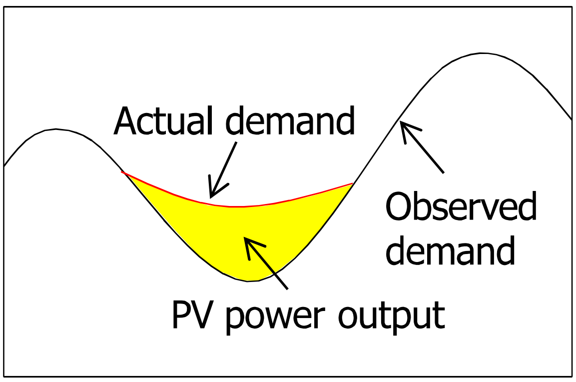
- Estimated demand is sum of electricity demand in 500m square included in a distribution network area

- Observed demand is adjusted by adding estimated PV power output because residual demand subtracting PV power output is observed

- Monthly average of observed demand and estimated demand for weekday and weekend is compared

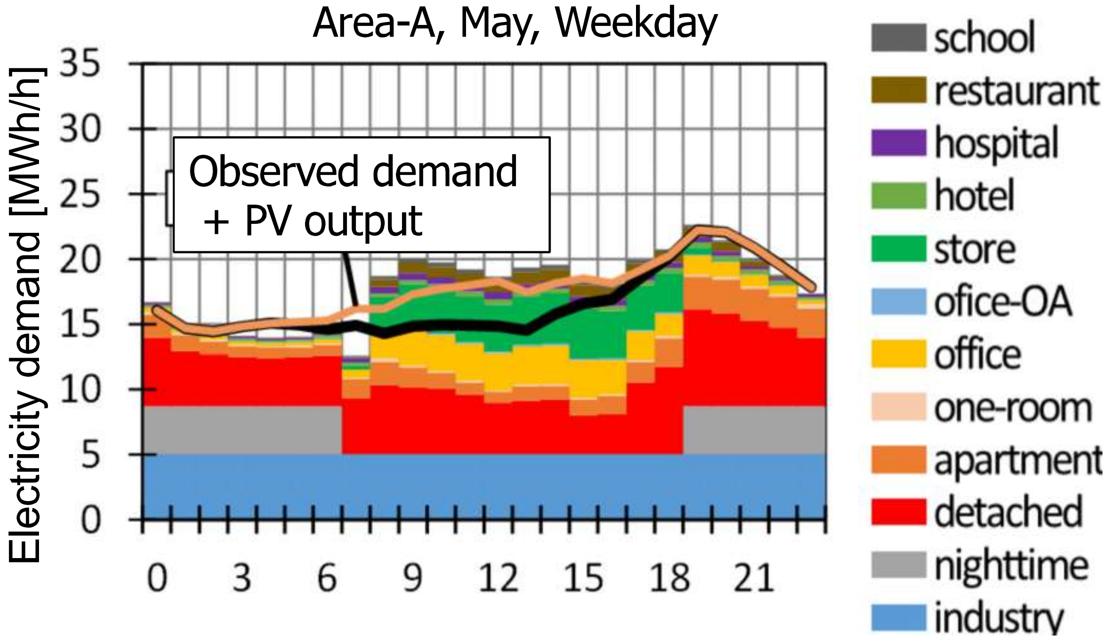
Distribution network area





2. Validation of model

Comparison of estimated demand and observed demand



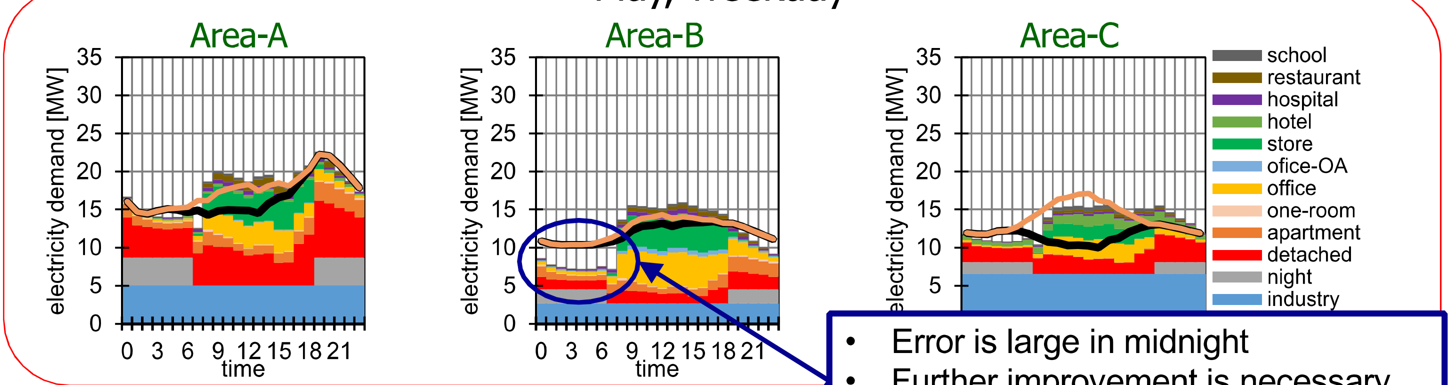
Estimated demand is almost same as observed demand

CHUBU Electric Power | Nagoya University

2. Validation of model

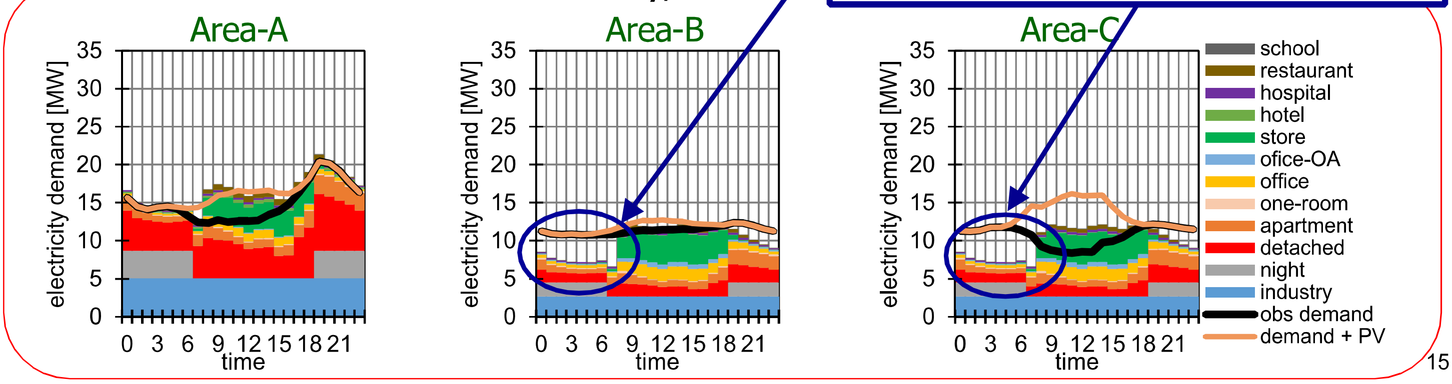
Comparison of estimated demand and observed demand

May, weekday



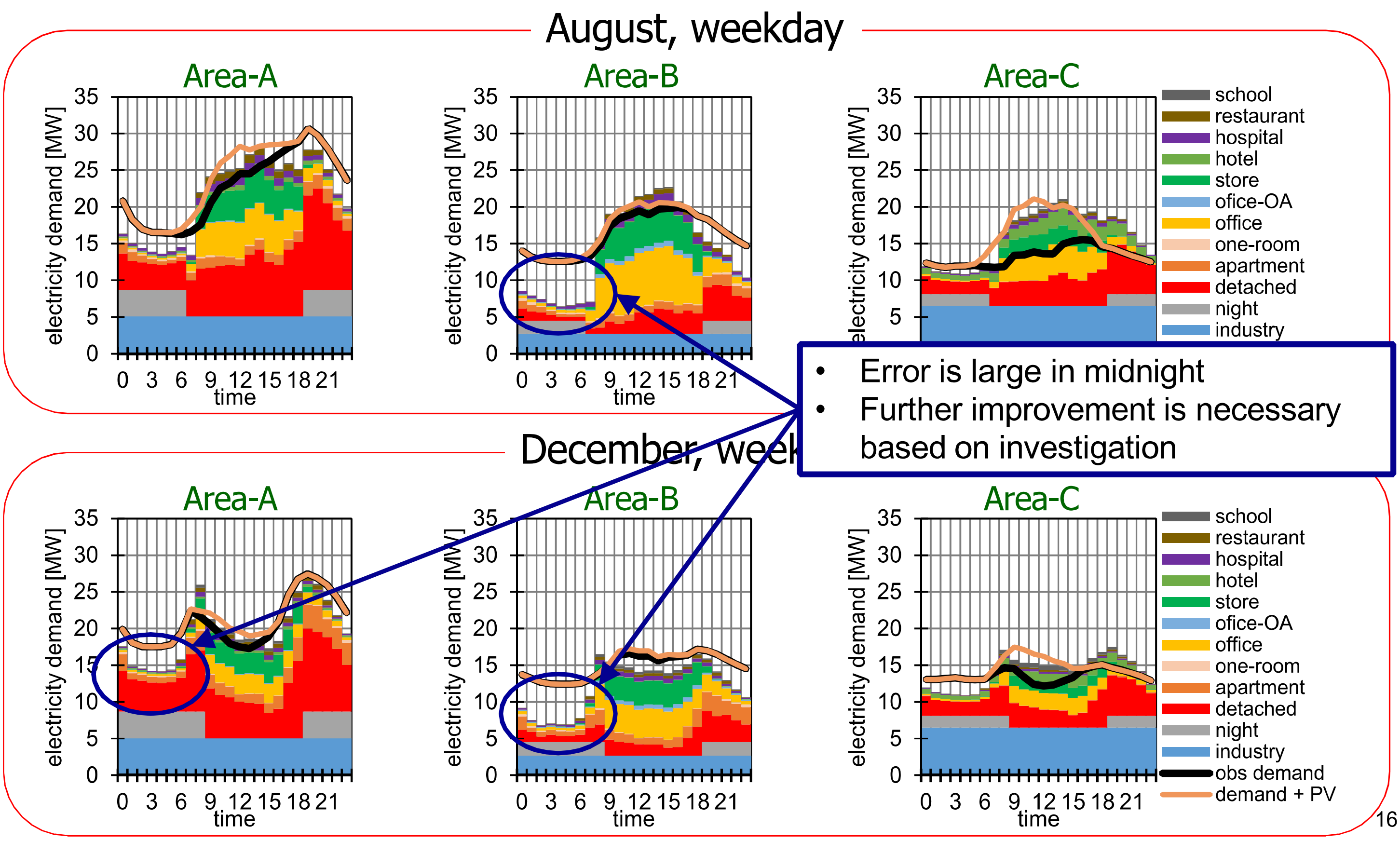
- Error is large in midnight
- Further improvement is necessary based on investigation

May, weekend



2. Validation of model

Comparison of estimated demand and observed demand



Objective

To Develop estimation model of electricity demand in distribution network based on social statistical dataset

〈Contents〉

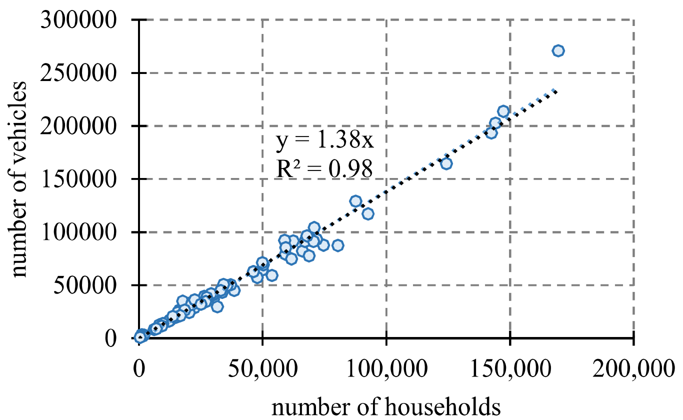
1. Modeling procedure
2. Validation of model
3. An example of application of model
   - ✓ Estimation of electricity demand with high penetration electric vehicle (EV)

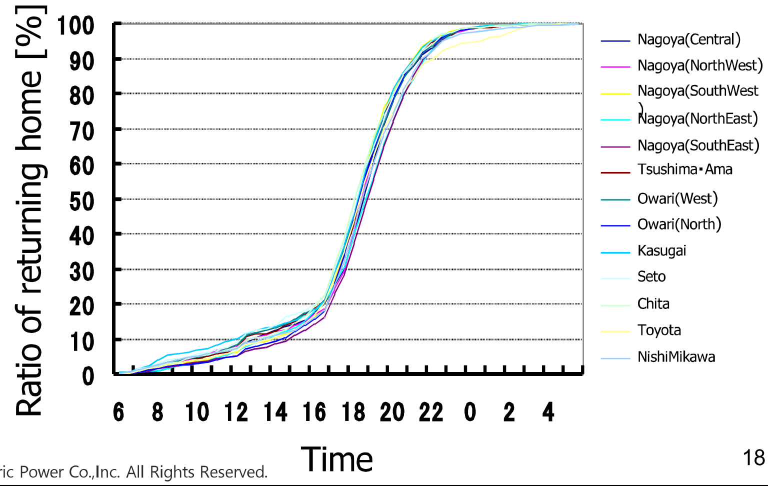
3. An example of application of model

Electricity demand with high penetration electric vehicle

Assumptions on EV penetration, usage, etc.

- Penetration rate of EV is 50 % of current passenger vehicles in distribution network, which is estimated based on relation to number of households (left graph).
- Energy efficiency of EV is 8 km/kWh.
- Vehicle usage only for commuting to workplace is taken into account.
- Cumulative ratio of returning home from workplace along with time and round trip distance is estimated based on person trip data (right graph).





3. An example of application of model

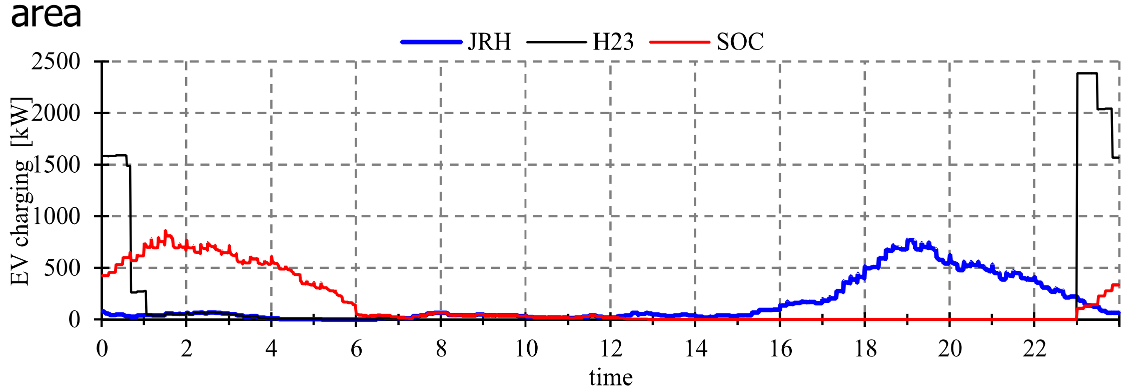
Electricity demand with high penetration electric vehicle

Assumptions on EV charging

- Charging rate: 3kW
- Schedule:
  - JRH case: Start charging just after returning home
  - H23 case: Start charging at 23:00
  - SOC case: Start charging based on predetermined schedule depending on SOC and time of returning

SOC at returning	Time of returning home			
	6:00 – 12:00	12:00 – 17:00	17:00 – 22:00	22:00 – 6:00
85% <	Just after	13 hours latter	7.5 hours latter	Finish at 6:00
75% - 85%	Just after	12 hours latter	7 hours latter	Finish at 6:00
< 75%	Just after	11 hours latter	6 hours latter	Start at 23:00

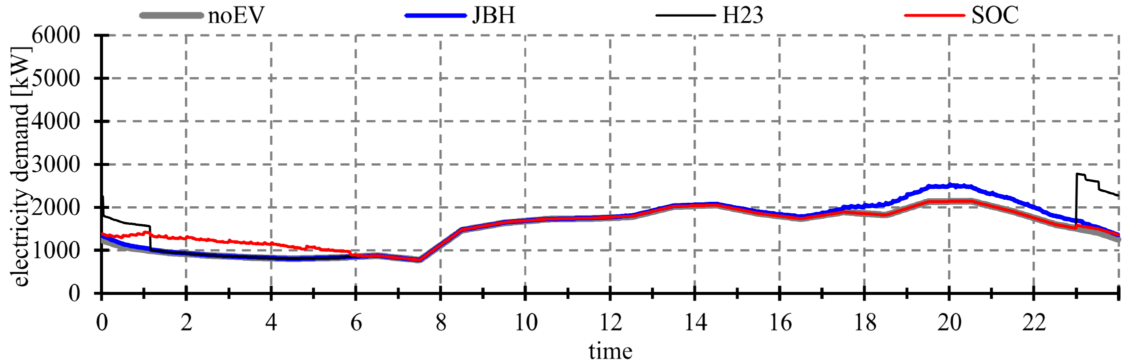
Rural area



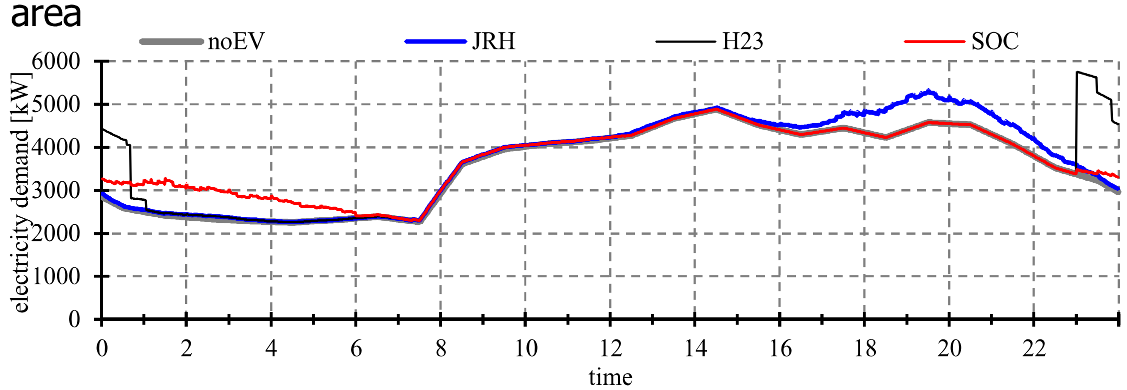
3. An example of application of model

Electricity demand with high penetration electric vehicle

Suburban area



Rural area



Conclusion and Future Works

Conclusion

- Modeling of electricity demand in distribution network is developed based on social statistics.
- Estimation accuracy is good enough for the first step analysis on influence of high penetration of photovoltaic power generation, electric vehicle, etc.

Future works

- Improvement of based on investigation of recent electricity demand profile, change in lifestyle, etc.
- Impact assessment of high penetration of PV, EV, etc. on utilization status, voltage profile, etc. of individual distribution networks.

Thank you for your attention

CHUBU Electric Power

Nagoya University

Development of Analysis Tool of Distribution System in Local Energy Community

Central Research Institute of Electric Power Industry
(CRIEPI, Japan)

Hiroyuki Hatta

The 18th IERE General Meeting & Japan Forum S1-6

22 May 2018

CRIEPI Central Research Institute of Electric Power Industry Energy Innovation Center

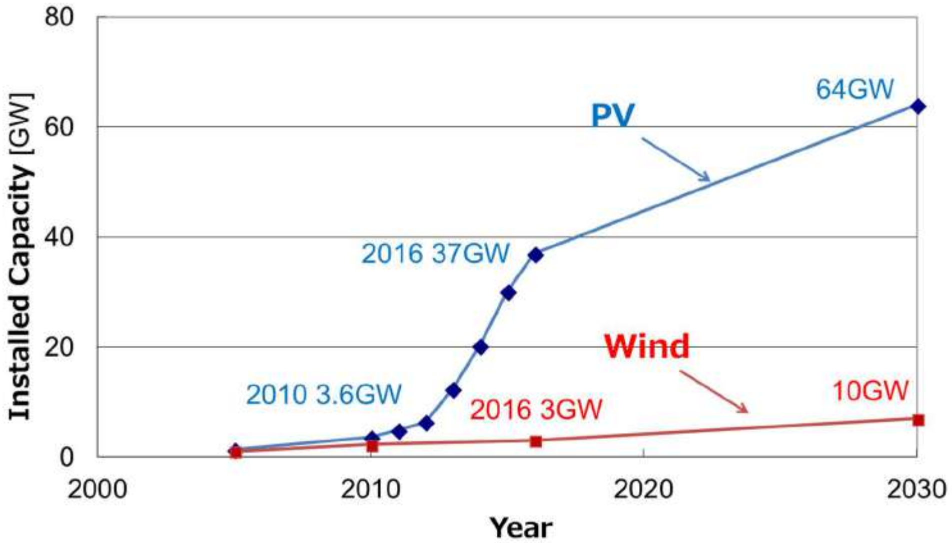
Background

- Installation of Renewable Energy (PV, Wind)
  - FIT scheme was started in 2012
- Self-consumption of PV power using Battery Energy Storage System (BESS)
  - FIT tariff will be cheaper than the electric price in near future
  - BESS cost will be decreased in near future

Smart Communities using various distributed energy resources (PV, BESS, EV, HP, etc.) will appear to realize efficient use of energy in demand areas.

Installation of PV in Japan

- In Japan, feed-in-tariff (FIT) scheme has been started in 2012, then Installation of Photovoltaic (PV) is accelerated.



Installed Capacity of PV in Japan

(After 2020: "Outlook of long-term energy demand", Ministry of Economy, Trade and Industry, 2015)

FIT scheme in Japan

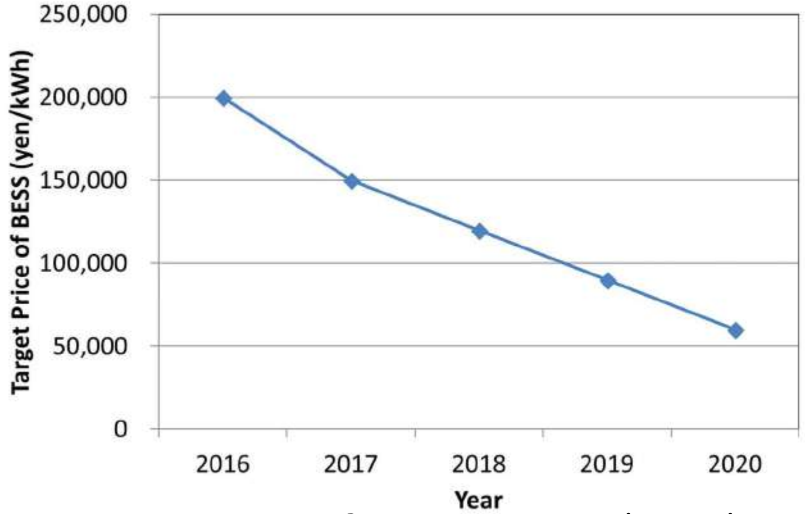
- FIT tariff was very high at the start of the FIT scheme in 2012.
- Now, FIT tariff becomes about the same level as electricity price.
- In future, FIT tariff will be lower than the electricity price.
  - ✓ Self-consumption will be economical for customers.

Energy Source	PV			
year	2012		2018	
Category	>= 10kW	< 10kW	>= 10kW	< 10kW
Tariff	**40 + Tax yen/kWh**	**42 yen/kWh**	**18 + Tax yen/kWh**	**26 yen/kWh**
Duration	20 years	10 years	20 years	10 years

Electricity charge for household customers is about **25 yen/kWh**

Cost of BESS

- Although the cost is high at present, BESS is expected to be installed in the future.
- If the target price of 2020 is achieved, BESS will be installed in more customers because investment recovery is possible.



Target Price of BESS in Japan (METI)

Contents

■ **Development of analysis tool of energy community**
  ✓ An analysis tool to evaluate the impact of the autonomous operation of a local energy community using DERs is developed.

■ **Simulation using the analysis tool**
  ✓ By simulation using the developed analysis tool, the impact on the voltage and current of the distribution system by smart community using BESS is estimated.

Purpose of the Analysis Tool

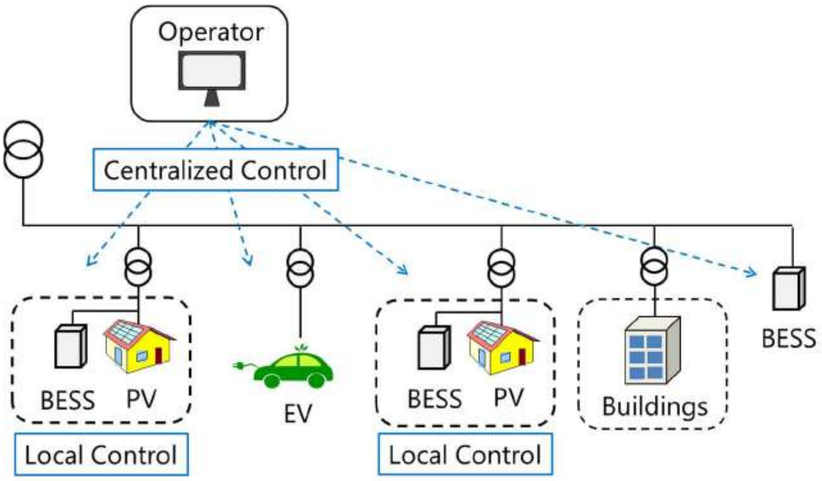
■When the flexible distributed energy resources (DERs) are installed in local energy communities, DERs may be operated as a virtual power plant (VPP) to realize their objectives.
  ✓ Cost minimization, efficient use of energy, load shifting, etc.

■If the DERs are operated to optimize the local objectives, it may cause problems on the distribution system operation.
  ✓ Voltage fluctuations, Increase of peak load, etc.

An analysis tool is necessary to evaluate the mutual impact between the community and the distribution system.

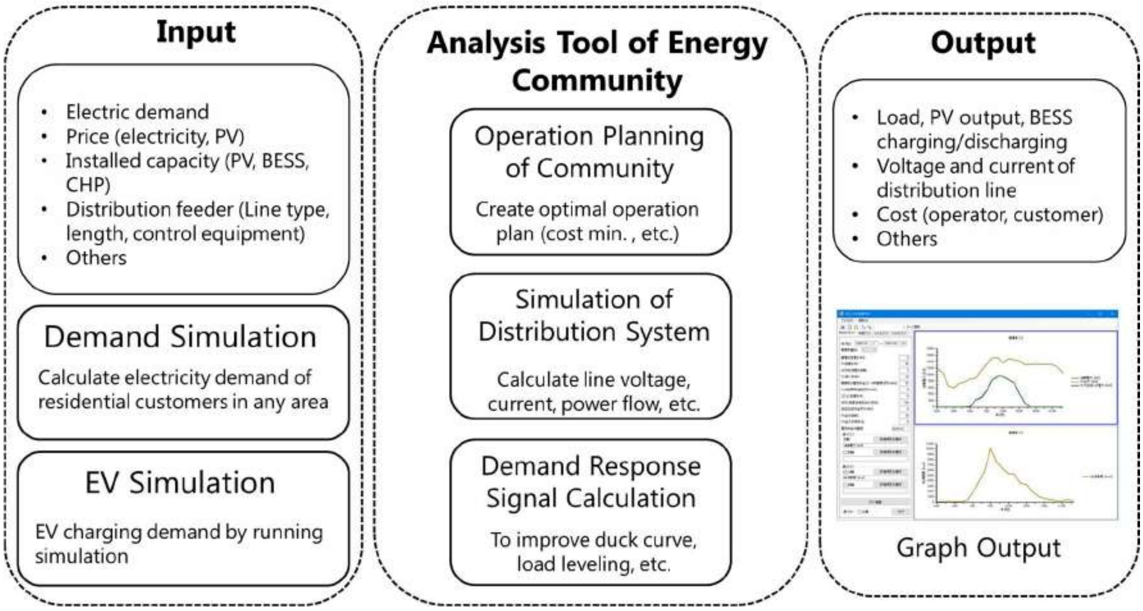
Community to be analyzed

- ■Autonomous operation using DERs (PV, BESS, EV, HP, etc.)
  - ✓Centralized control by the community operator
  - ✓Local control by the customer using HEMS
- ■Various conditions
  - ✓Target area, Installation ratio (PV, BESS, EV, HP)



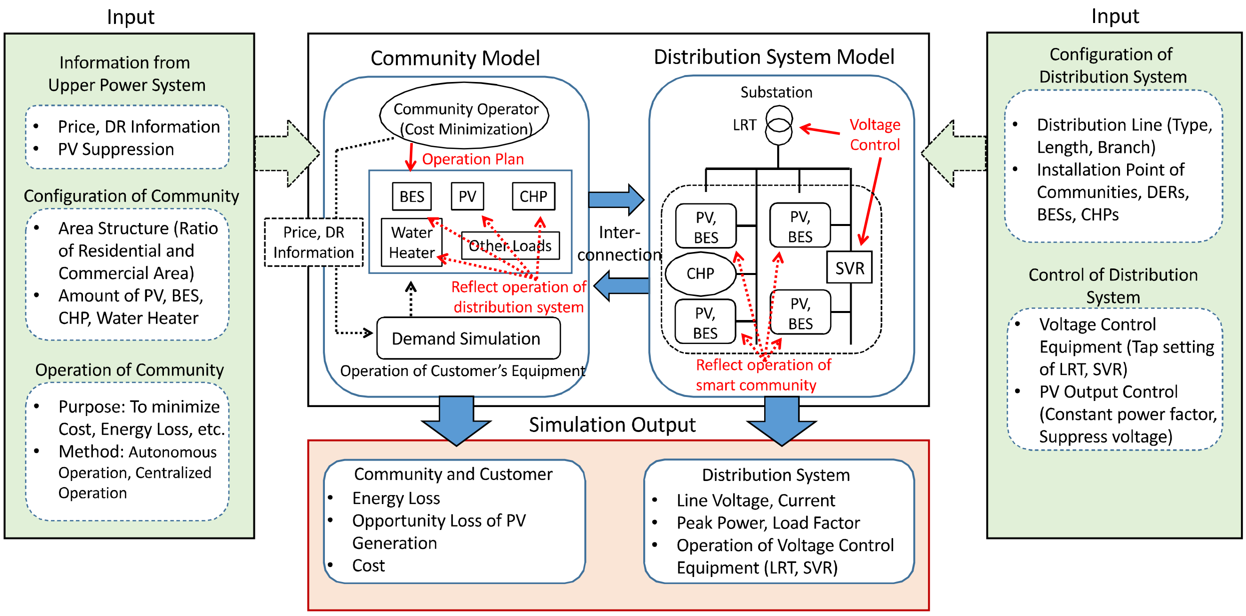
Analysis Tool of Energy Community

- ■Analysis tool to simulate community and distribution system
- ■Demand data can be created by developed programs
- ■The tool has DR calculation function to evaluate measures



Outline of Analysis Procedure

➢ The community model simulates the operation of a smart community and customers. The distribution system model simulates the operation of the distribution system. These models are interconnected.



Effectiveness of the Analysis Tool

Transmission and Distribution

✓ Appropriate planning of the distribution system with PVs and DERs (Voltage control equipment, Slimming of the distribution feeders)

✓ Efficient operation of distribution system voltage and power flow by aggregators

Community Operator and Aggregator

✓ To create an economical supply and demand plan under arbitrary conditions and DR signals

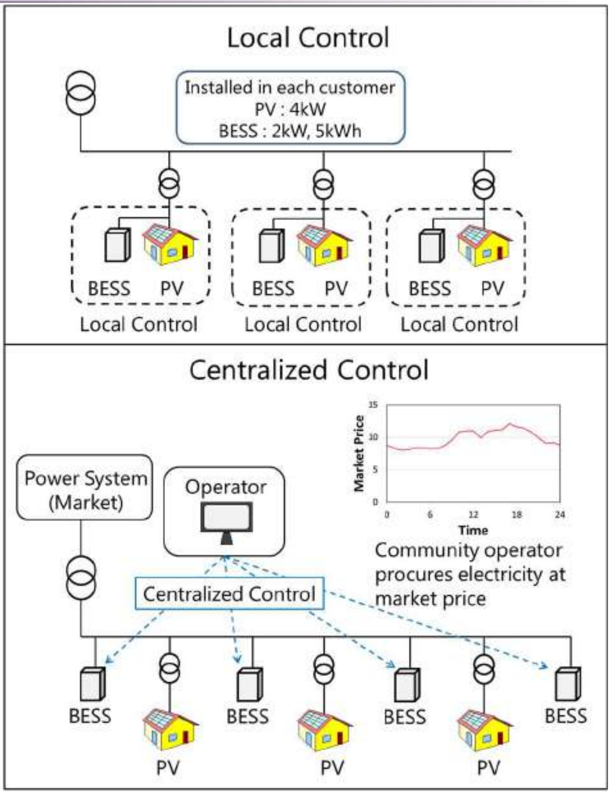
✓ To control the supply and demand of the power system without affecting the stable operation

Electricity Retailing

✓ To analyze pricing and revenue including DR

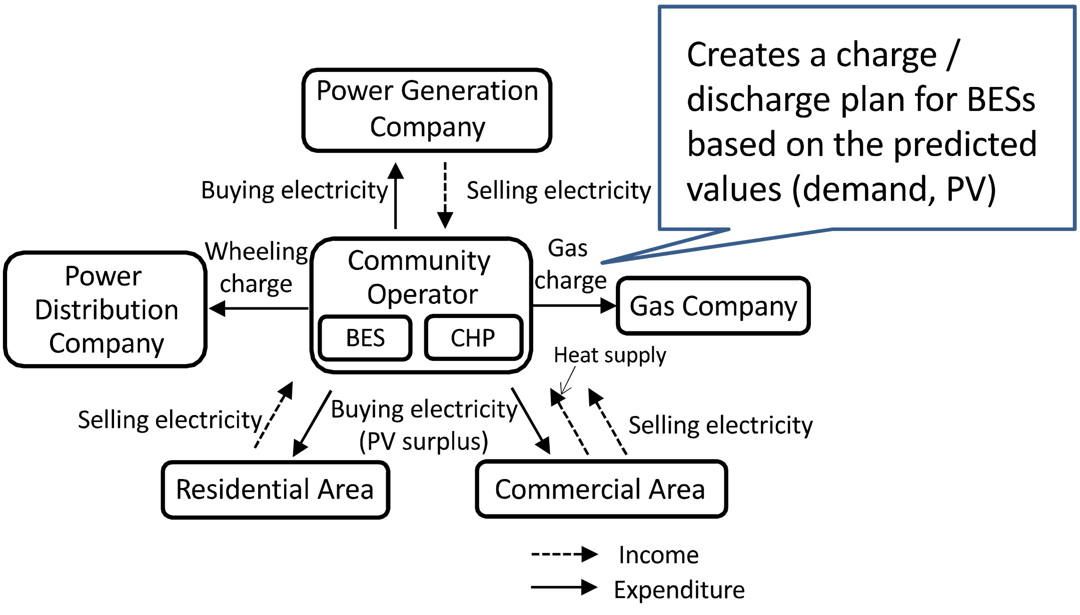
Simulation using the Analysis Tool

- BESS is the most flexible among the DERs.
- Impact on distribution system by economical operation of BESS is simulated.
  - Local Control
    - ✓ BESS is controlled by HEMS at each customer
  - Centralized Control
    - ✓ BESS is controlled by community operator



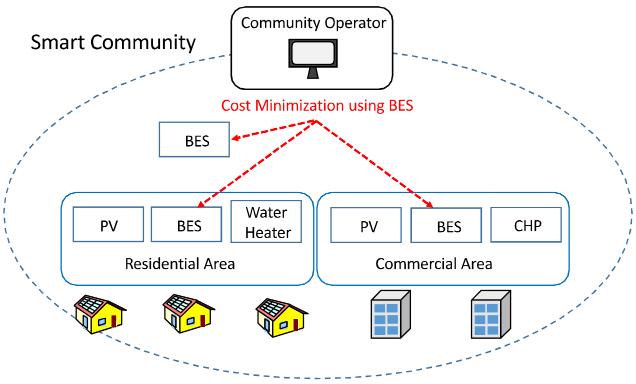
Community Operation

➢ Community operator creates an optimal plan to operate BESS considering economic efficiency of the smart community.



Simulation Conditions (1)

- Voltage and current of the distribution system are simulated when the BESs are operated by community operator to minimize cost of the community.
- Total charging capacity of the BESs is equal to 2 hours of the capacity of the distribution line.

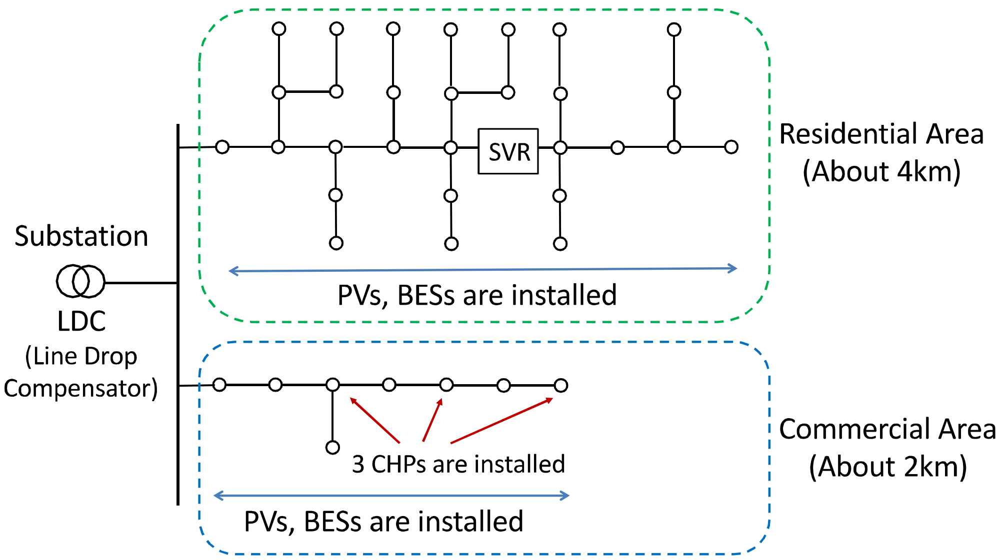


Simulation Cases

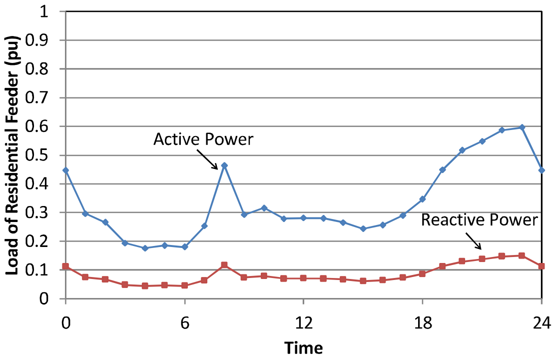
- Residential case
  - ✓ residential areas only
- Commercial case
  - ✓ commercial area only
- Mixed case
  - ✓ residential and commercial areas are mixed

Simulation Conditions (2)

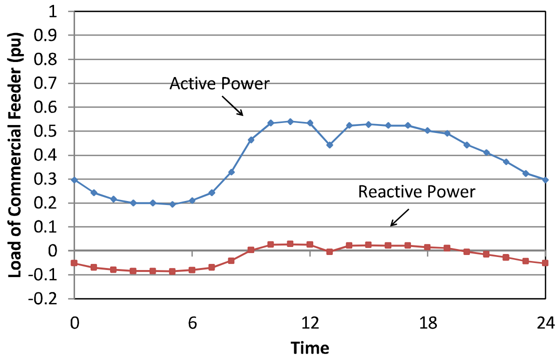
- Voltage and current of the distribution system were simulated using the distribution system model.
- Ratio of residential and commercial area, installed amount of PV and BESS, etc. are parameters.



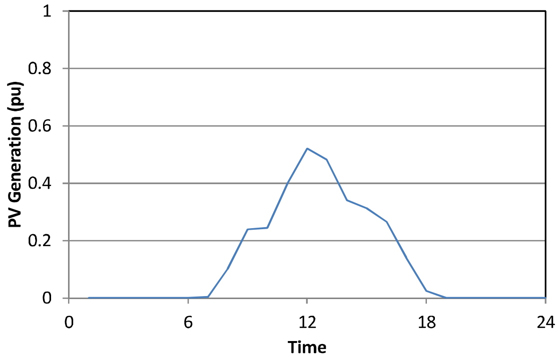
Simulation Conditions (3)



Load Curve of Residential Area

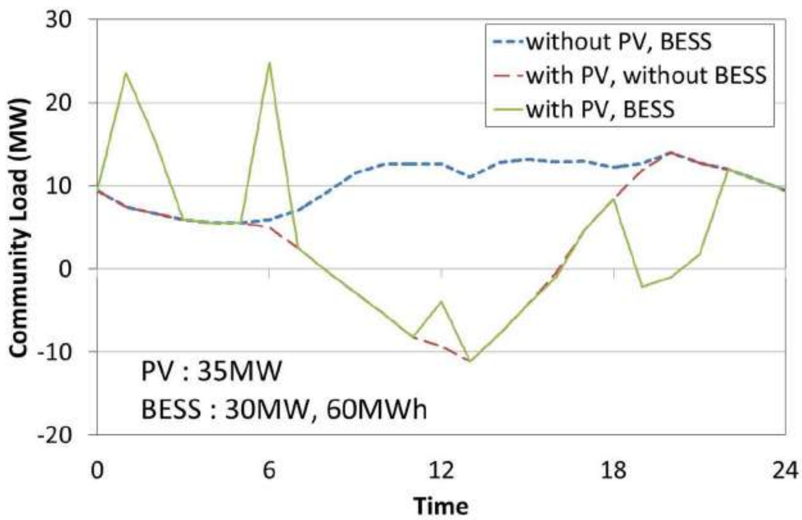


Load Curve of Commercial Area



PV Generation

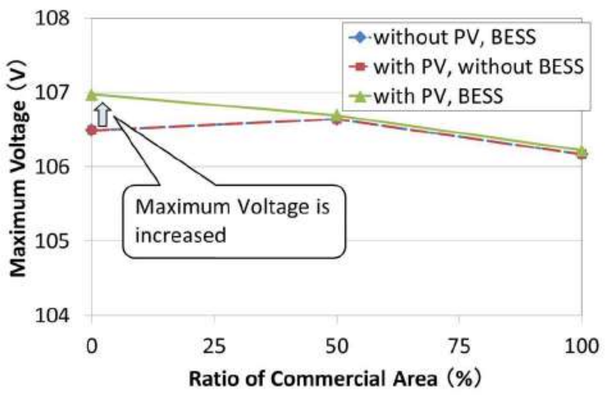
Simulation Results (1)



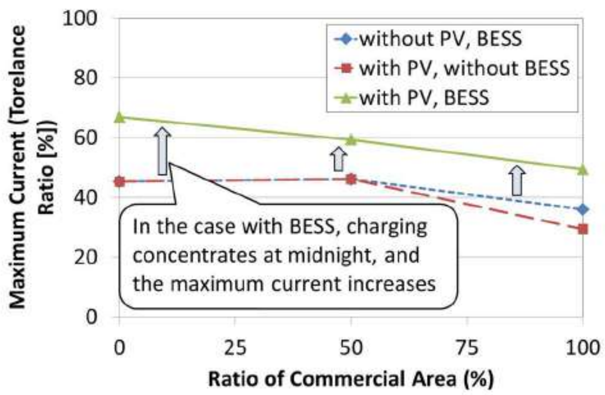
Community Load (Mixed Case)

Simulation Results (2)

- Voltage and current of the distribution system were simulated using the distribution system model.
- If the BESS is operated by community operator, the maximum voltage and current is increased.



Impact on maximum voltage



Impact on maximum current

Conclusions

- An analysis tool to evaluate the impact of the autonomous operation of a local energy community using DERs is developed.
- The impact on the voltage and current of the distribution system was calculated by some example cases.
  - The results show that if DERs are operated to optimize the local objectives such as cost minimization, the power quality becomes worse.
- The improvement of the analysis tool will be continued.

The new world of energy
And how to prepare it

Dr. Isabelle MORETTI, Engie Scientific Director

KYOTO - May 2018

IERE – CRIEPI – Kansai Electric Power system

Engie Research

ENGIE

A GLOBAL AND DIVERSIFIED FOOTPRINT*

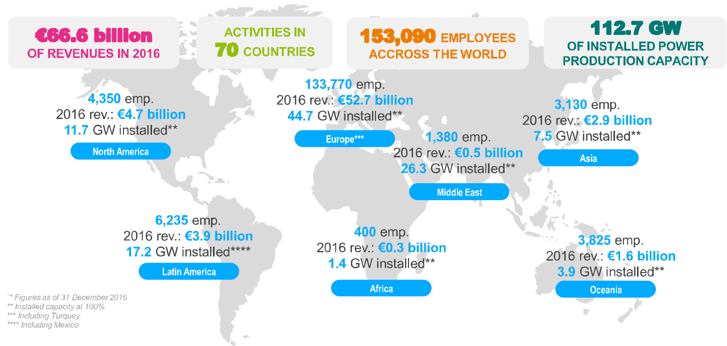
ENGIE ID card

€66.6 billion OF REVENUES IN 2016

ACTIVITIES IN **70** COUNTRIES

153,090 EMPLOYEES ACCROSS THE WORLD

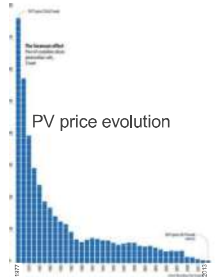
112.7 GW OF INSTALLED POWER PRODUCTION CAPACITY

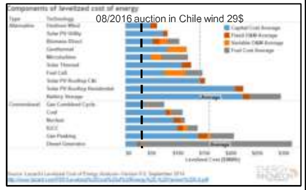


* Figures as of 31 December 2016
** Installed capacity at 100%
*** Including Turquey
**** Including Mexico

Energy Price

- Wind and solar are now cheap
- They may compete with fossil fuels even without tax incentives
- Pay back time for a solar farm in sunny area (like North Chile) could be as low as 7 years.





In Engie we consider that the energy is now cheap and could remain cheap.
Other points that change the game: sun, wind, among others, are **Decarbonized** and **Decentralized**, big installations are not necessary, a lot of citizens may produce there own electricity => the peer to peer of electron is starting, **Digitalization** is mandatory

The 3D

The new energy world is characterized by **decarbonization**, **decentralization** and **digitalization** (the 3 "D").

DECARBONIZATION
Worldwide renewable energies: annual additional capacity to grow by +70% in 2030 vs 2015

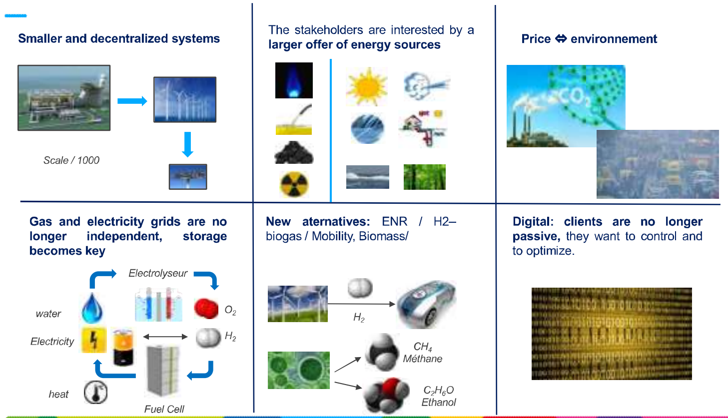
DECENTRALIZATION
Decentralized solutions to more than double by 2030

DIGITALIZATION
Digital disrupts energy systems and improves customer offers

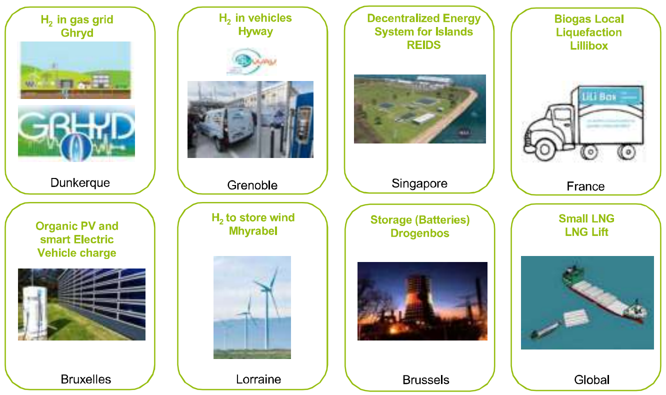
Engie's ambition

TO BE THE WORLD **LEADER** IN ENERGY TRANSITION

The ongoing ruptures



ENGIE RESEARCH : We manage **pilot projects** together with partners to co-develop and test new technology based solutions



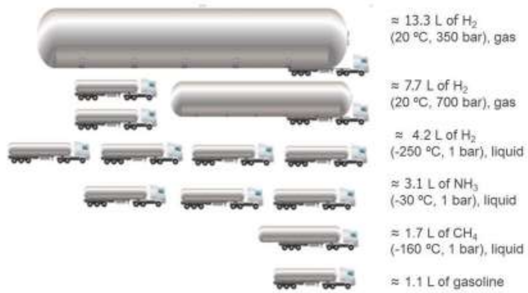
5/22/2018

Chemico-physical properties make H_2 a challenging energy vector to transport

- **Smallest element on earth**
  - High diffusivity (passes easily through a lot of materials)
- **Lightest element on earth**
  - Extreme low density
  - 1 Liter of H_2 (at 1 atm and 0 °C) weights only 0.2 g whilst one Liter of gasoline weighs 730 g
- **High energy content per kg but very low energy content per L**

Hydrogen transport implies the 'moving or storing' of large volumes per unit of energy

How to transport 10 kWh of energy?



CH_3OH not depicted but must be situated in between CH_4 and NH_3 @ 2.3 L

Decentralized energy system

- Local production: Solar + Wind
- Local storage: Battery + H2
- Local use: electricity + mobility (H2 fuel car)

What we test with our partners Schneider Electric

- Material
- Power Management System
- Energy Management System

Current issues arise when working on the interface between EMS and PMS and SCADA on the breakdown of functionalities and added value to the whole system.

The boundary EMS&PMS is not standard in the industry (both time and functionalities), although <15 min:
• Characteristic time for stabilization of a variation of load/production: ~ a few seconds
• Automation and real time control deals with issues on that particular time scale, so targets for the next 15 min is not sufficient as the information supplied to the PMS is too limited for the PMS to rely completely on it and have stability

Blending: H2 + Natural gaz or how to store the green electricity within the existing natural gas grid ?

- In the past we was using mainly town gas, from coal, which contained up to 50% of H2. So having this blend in the grid is not a major issue.
- Through hydrolysers one may transform the green electricity to H2, by mixing it with the natural gas we may use all the storage and transport facilities that already exist.
- Existing projects in Europ:
  - — Germany, UK (HyDeploy in the Keele university gas network), France (Dunkerque)
  - — FCHJU project: pre-normative effort to have a common law at the level of the EC (% of H2, quality ..)
- Hythane (H2 + CH4) as a fuel
- Which % and changes of % for the transport and distribution grids ?
- Another solution: synthetic methane ($2H_2 + CO_2 = CH_4 + O_2$)

GRHYD – Two pilots based on Hydrogen to assess the relevance of underlying Power to Gas supply chain

GRHYD Objective : Produce H2 from renewable electricity, supply it to customers as an NG-H2 mixture by means of the gas distribution grid, and consume it locally

Residential use, heating, cooking, hot water, CHP, and mobility (fuel for buses)

A NEW TYPE OF GAS FOR GRID

A new kind of gas for homes
A new 200-home estate will be supplied with NG-H2 blends.
The H2 content may fluctuate but will never exceed 20% vol.

SUSTAINABLE MOBILITY

A new fuel for urban buses
By piloting Hythane® fuel on a commercial level.
The NGV station and dozens of urban buses will be adapted to Hythane® (20% vol. H2)

To conclude: Gas/elec - Energy System Convergence

- Future Networks will work together
  - SMART
  - Integrated
  - Flexible
- The industry's biggest challenge since the last transformation
- Solar and wind farms extend the number of countries that are now producer (it extends even the stakeholder since individual consumer may be producer); it is the same for the biogas, countries without HC resource may generate biogas.
- H2 is a game changer to link both

In that context, the engie's strength : be present along the overall chain

Almost all our thematic labs are involved in designing the territories of tomorrow

Thanks for your attention

And for the invitation in the beautifully city of Kyoto

innogy

Grids and Bits - how DSO's can profit from innovative data & energy analytics

18th IERE General Meeting & Japan Forum

22nd May 2018
Dr. Felix Cebulla

innogy SE · Strategy & Technology · Corporate Technology innogy

1

Introduction

2

Data analytics: New business opportunities for DSO's?

3

Use Case I: Charging infrastructure for E-mobility

4

Use Case II: Predictive maintenance

5

Summary

How can data analytics enhance innogy's core business?

innogy

Renewables	**11.5 GW** RES capacity[1]	**#3** worldwide in offshore wind by installed capacity	DSOs have access to an extensive amount of data from the operation of their grids.
Grid & Infrastructure	**#1** largest electricity DSO in Germany	**€13.5bn** regulated Asset Base	
Retail	**#1** largest electricity retailer in Germany	**23m** customers	DSO's can develop new business models from this.

1 Installed capacity + projects in development

Data is everywhere: different sources from grid planning, operation, and maintenance can be interlinked

innogy

Structured data

- HV/MV stations
- Transformers
- Power poles
- Metering points
- Suppliers & clients
- Status reports
- Failure reports
- Maintenance plans
- Geo data

Unstructured data

- Innogy internal standards, e.g. maintenance guidelines, work safety
- Public data

DSO

Time-series

- @ sub-stations: voltage, current, frequency
- @ transformer: temperate, alarms
- Power data logging at customer premises
- Weather data

How can one use this data ?
Future DSO = Data Hub?

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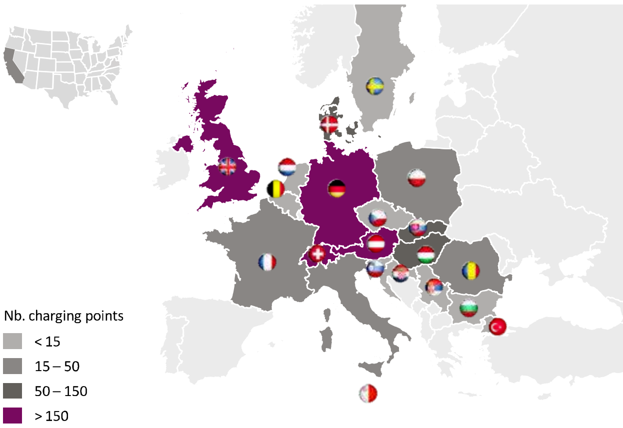
USE CASE I

Charging infrastructure for E-mobility

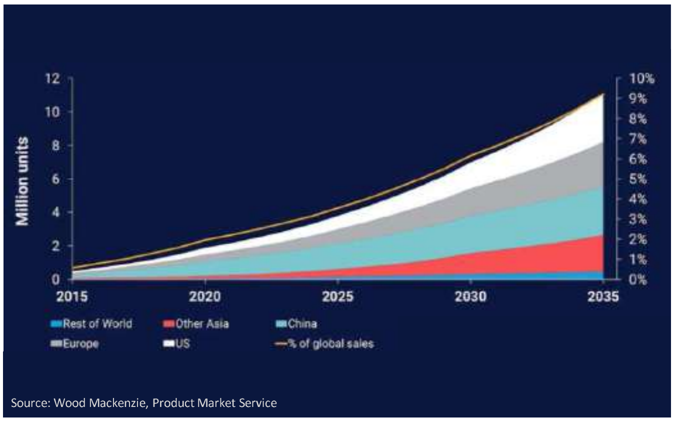
New challenges for utility companies & grid planning: increasing number of electric vehicles

innogy

17,000 charging points in over 20 countries



10 Mio. EVs by 2035 worldwide



Pro4Grid enables the identification of charging hotspots

innogy

Input

Geospatial data on street level

- Population density, income & age distribution
- Household type & size, purchasing power
- Commercial & infrastructure data, such as parking garages, motorway service areas, super markets & E-cars fleet locations

Scenario assumptions

- Different market penetration of EV's & charging stations:
    - 1 Mio. EV's & 731,500 wall boxes
    - 500,000 EV's & 360,000 wall boxes
    - 100,000 EV's & 87,500 wall boxes

Complementary data

(load curves, quick charging stations, …)

Model
(correlation of different data sources)

Local/regional hypothesis

(emphasis of locations, points of interests, …)

Charging "hotspots"

EV penetration not only affects the charging capacity, but also leads to a different spatial distribution of the charging hot spots

Example of the city of Essen, Germany

100,000 EVs | 500,000 EVs | 1,000,000 EVs

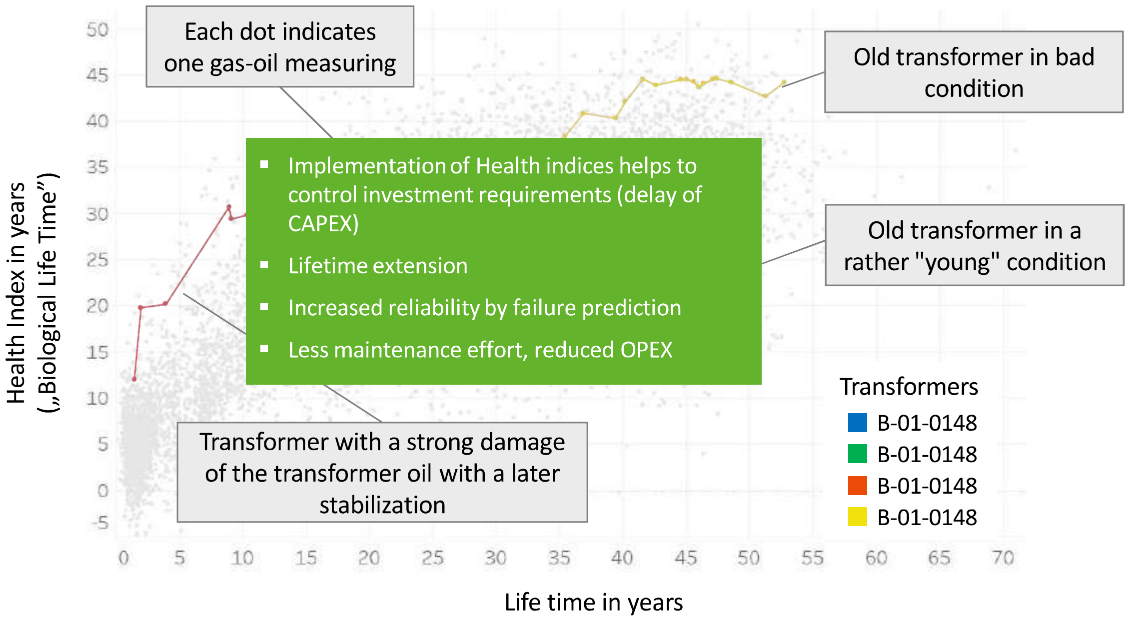
The tool offers a wide range of added value for different customers

- Tool focuses on **socio-demographical / socio-economical** impacts
- Developed by **innogy with Westnetz** and already in use at a utility company
- **Easy to use product** for grid planning and sales of charging stations (B2C, B2B)
- Extendible **for other countries and other applications**, e.g. rollout of FTTX, Smart Meter
- Potential Customers: DSOs, municipalities, real estate owners, operators of public buildings, stores, service stations, car-sharing companies, car manufacturers

USE CASE II

Predictive maintenance

A Health Index can help to control investment decisions and maintenance effort



4 Use case II: Online monitoring of 110 kV cables

A new concept for real-time monitoring of construction works to identify potential threats to electricity, gas, and water infrastructure

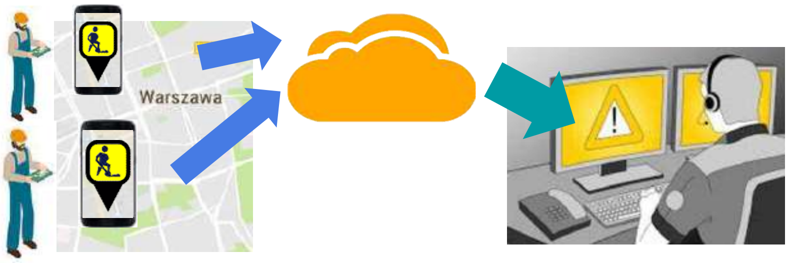
- Problem: high number of cable failures due to construction works
- Solution: an app was developed that tracks all construction work sites
- Dispatcher are able to locate potential threats due to construction works near the gas, electricity, and water infrastructure

How it works

Contractor places their marker in the app

Online submission of the construction site

Dispatcher efficiently can identify potential threats



5 Summary

Extended use of data promises manifold advantages for utilities. However, various challenges have to be addressed

Specific advantages of use cases

- DSO`s have access to large sets of data, which enables new business cases; the DSO of the future therefore is likely to act as a data hub
- Data analytics can help to predict the future E-Mobility charging infrastructure and thus enable various applications for different customers (e.g. efficient grid planning at DSO level)
- For life time predictions of transformers, data analytics enables the reduction of Capex and Opex
- Online monitoring of cables help to decrease the failure risk of the cable

Challenges

- Digital transformation in energy business is a complex tasks. Joint effort of various departments and integration of external stake-holders is key to success
- Extended use of data promises manifold advantages for utilities. However, various challenges have to be addressed, particularly with regard to Technical, Operational, and regulatory challenges

innogy

Thank you! Questions?

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The 18th IERE General Meeting and Japan Forum, Kyoto, Japan May 22, 2018

Estimation of Frequency of Lightning Strokes to Distribution Lines Based on An Observation of Lightning Channels

Kenichi Kanatani, Satoshi Morimatsu, Susumu Matsuura, Kazuo Shinjo
(Hokuriku Electric Power Company)

1. Introduction

- Outages on 6.6-kV overhead distribution lines caused by natural phenomena mainly occur due to lightning strokes in Japan.
- The lightning protection is important to prevent the outages.
- Several evaluation methods of lightning performance of distribution lines have been proposed.

However

- Lightning outage rate calculated using one of the proposed methods is several times larger than the actual lightning outage rate.

1. Introduction

- One of the causes may be that the frequency of lightning strokes to distribution lines used in the calculation deviates from actual conditions, particularly in winter.

- In order to find out the actual frequency of lightning strokes to distribution lines, an observation of lightning channels using lightning-video cameras has been carried out since 2016 in Hokuriku region, Japan.

1. Introduction

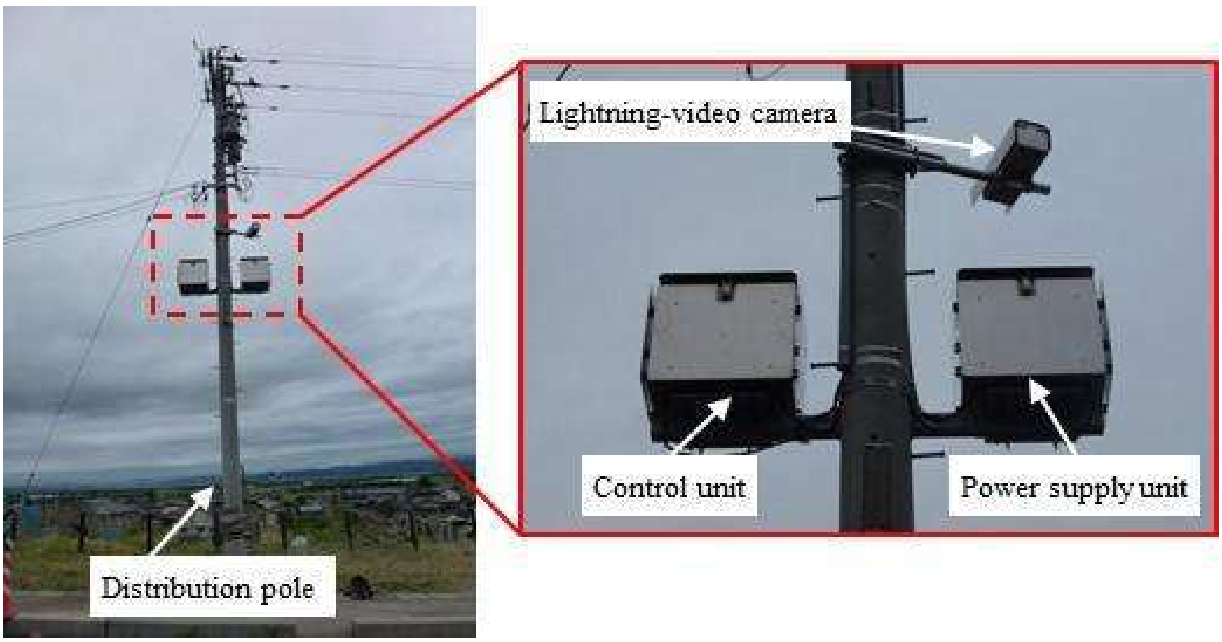
【Contents of This Study】

- We present the observation results of lightning channels captured by the video cameras. We estimate the location error with the video cameras.
- Based on the location error, We calculate the frequency of lightning strokes to distribution lines from observation data.

2. Observation Method

2.1 Lightning-Video Camera

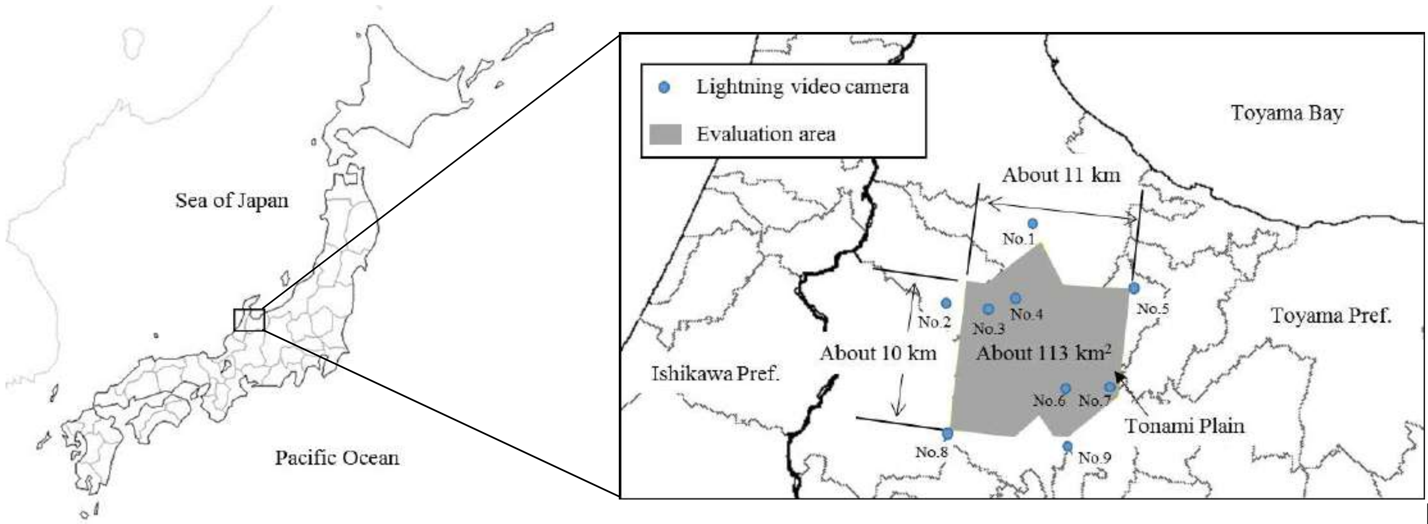
- The video camera system is installed on a distribution pole .



2. Observation Method

2.2 Observation Area

- Nine video cameras are placed to observe lightning channels widely.
- The range that can be recorded by three or more lightning video cameras is set as the "evaluation area" (about 113 km^2).



3. Observation Results

3.1 Observation Results of Lightning Channels

(from November 2016 to October 2017)

- The percentage of observation data of the video cameras to LLS is 177% (69/39) in winter, 109% (229/207) in summer.
- The video cameras have a high capture rate, especially in winter.

	Observation results of lightning video cameras	Location results of LLS	Number of data			Sub total			Total
Winter	Lightning stroke	Lightning stroke	39	(13)*1	[26]*2	69	(23)*1	[46]*2	85
		Non data	30	(10)*1	[20]*2				
	Cloud discharge	Lightning stroke	7			16			
		Non data	9						
	Non data	Lightning stroke	5			5			5
	Total in winter		90						
Summer	Lightning stroke	Lightning stroke	207	(76)*1	[131]*2	229	(83)*1	[146]*2	259
		Non data	22	(7)*1	[15]*2				
	Cloud discharge	Lightning stroke	26			30			
		Non data	4						
	Non data	Lightning stroke	93			93			93
	Total in summer		352						

*1 ( ) is number of lightning strokes recorded by two or more video cameras.
*2 [ ] is number of lightning strokes recorded by only one video camera.

3. Observation Results

3.2 Location Error

- Five lightning stroke points could be found out.
- Three data were the lightning strokes to transmission lines (Data 1, 3 and 4) and two data were the lightning strokes to distribution lines (Data 2 and 5).
- In all data, the lightning stroke points could be located by their images of the video cameras.

Data No.	1	2	3	4	5
Date	2016/12/9 14:11:05	2016/12/9 14:21:36	2017/5/31 22:39:25	2017/6/2 5:57:40	2017/11/15 22:57:31
Location error of lightning video camera	69 m	64 m	30 m	52 m	76 m
Location error of LLS	386 m	-	220 m	1,356 m	200 m

3. Observation Results

3.2 Location Error (Data 1)

2016/12/9

- The lightning struck to the overhead ground wire of the transmission line.
- The location error with the video camera data is 69 m.

Image of lightning video camera No.1

Image of lightning video camera No.2

3. Observation Results

3.3 Frequency of Lightning Strokes to Distribution Lines

- If the distribution lines exist within a radius of 100 m from the location point by the video cameras, we assume the lightning strokes to the distribution lines.
- The frequency in winter is 6.5% [(9.8-9.2)/9.2] higher than that in summer.

	Number of lightning strokes in evaluation area [strokes] (a)	Number of lightning strokes to distribution lines [strokes] (b)	Ground stroke density [strokes/km^2/year] (c=a/113km^2)	Frequency of lightning strokes to distribution lines [strokes/100km/year] (b/c/753km*100km)
Winter	23	15	0.20	9.8
Summer	83	51	0.74	9.2
Total	106	66	0.94	9.3

4. Conclusions

We have observed lightning channels using lightning-video cameras from November 2016 to October 2017, in order to find out the actual frequency of lightning strokes to distribution lines.

The observation results are summarized as follows;

4. Conclusions

- The video cameras have a high capture rate, especially in winter.
- The location errors of the video cameras are approximately from 30 m to 80 m.
- The frequency of lightning strokes to the distribution lines in winter is 6.5% higher than that in summer.

The 18th IERE General Meeting & Japan Forum

A Decentralized and Cooperative Voltage Control Scheme for Increasing Hosting Capacity

22th May, 2018

Won Nam Koong
KEPCO Research Institute

Contents

Current State of Renewable Energy in Korea

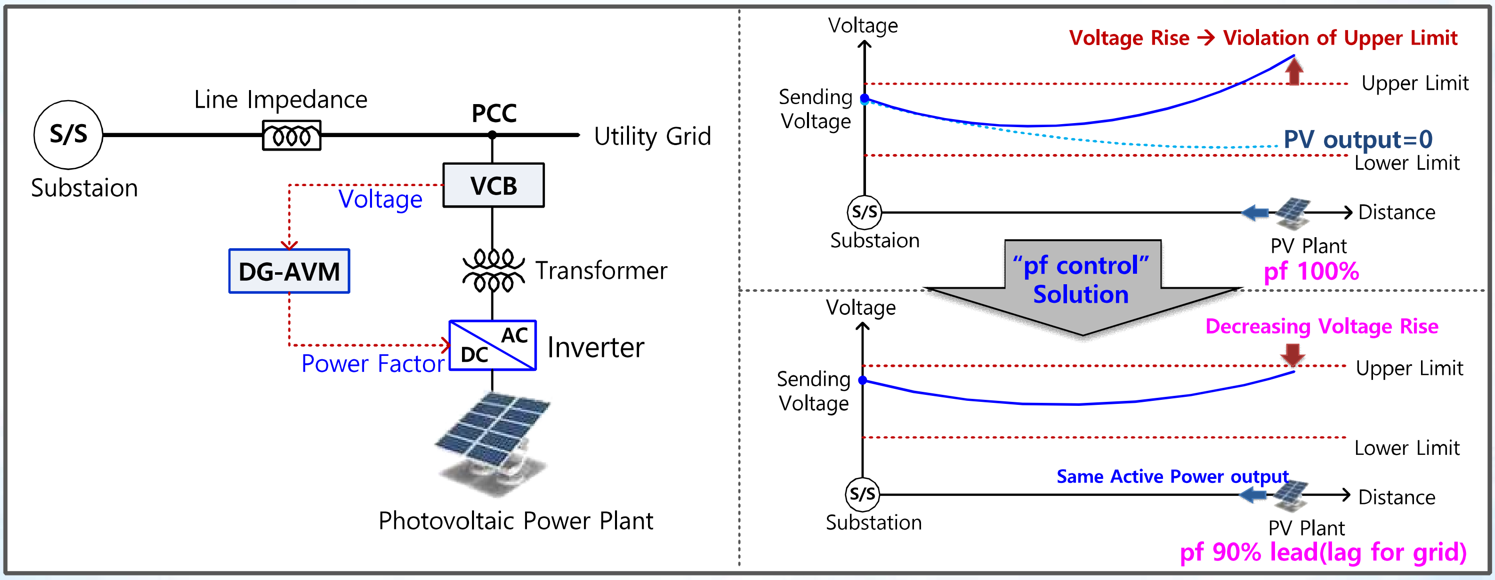
❖ Renewable Energy Interconnection Process

- Verification RE Interconnection Effect : Overvoltage, Accumulated volume, Protection Coordination etc.
- 61.9MW RE is waiting for Interconnecting to network due to overvoltage

Excess	M.tr	D/L	Overvoltage	Sum
Volume(MW)	345.9	113.2	**61.9**	521
%	66.4	21.7	**11.9**	100
Customer	516	137	**148**	801
%	64.4	17.1	**18.5**	100

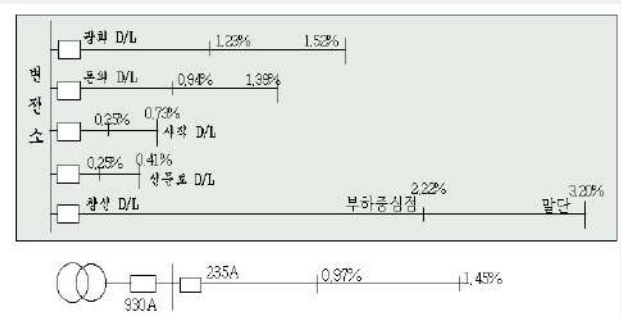
❖ DG Operation Setting

- Power Factor Control for Voltage Regulation at PCC



❖ OLTC Operation Setting

- No consideration LV customer, One Peak load case, Equivalent circuit



구분	부하중심점	선로길이	Lr	Lx	Ur	Ux	전류(A)	선종별거리(km)
광희	5	6	0.469	0.746	0.50	0.80	225	C(5.85), A(0.15)
돈의	3.5	5.15	0.328	0.522	0.39	0.62	248	C(5.15)
사직	1	2.16	0.093	0.149	0.10	0.16	235	C(1.6), A(0.56)
신문로	1	1.49	0.093	0.149	0.10	0.16	235	C(1.38), A(0.11)
창신	8.5	10.2	0.811	1.302	0.91	1.46	235	C(8.36), A(1.84)
평균	3.8	5	0.359	0.573	0.40	0.64	235	

- 부하중심점 : 3.8km, 선로길이 : 5km
- 변압비 : 22,900/110 = 208.18, 변류비 = 2,000/5 (400:1)
- 선종 : CNCV 325㎟, ALOC 160㎟ D/L 변류비 = 600/5 (120:1)
- D/L 1차 정격전류 : 600A, D/L 최대전류 : 235 A

Data Input — Center of Load, Peak Load; System conf.

Calculation — OLTC Setting (LDC, DVM)

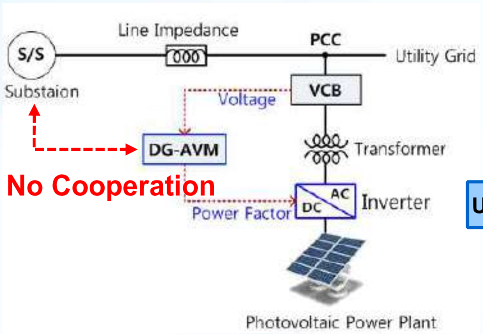
Customer — Voltage Problem Occurrence

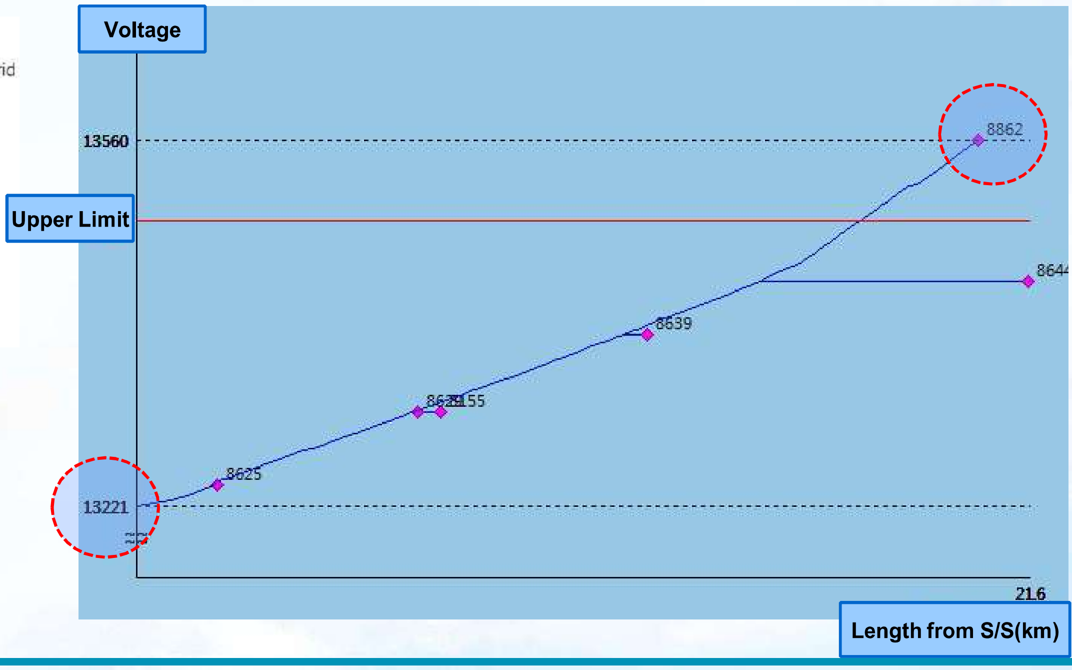
No real-time feed back

Current State of Renewable Energy in Korea

❖ Limit of a non-cooperative voltage control

- No cooperation with OLTC and DG makes voltage problem





Project Overview

❖ Objective

- Increasing DER hosting capacity without investments and voltage problem

❖ Proposed VVO method

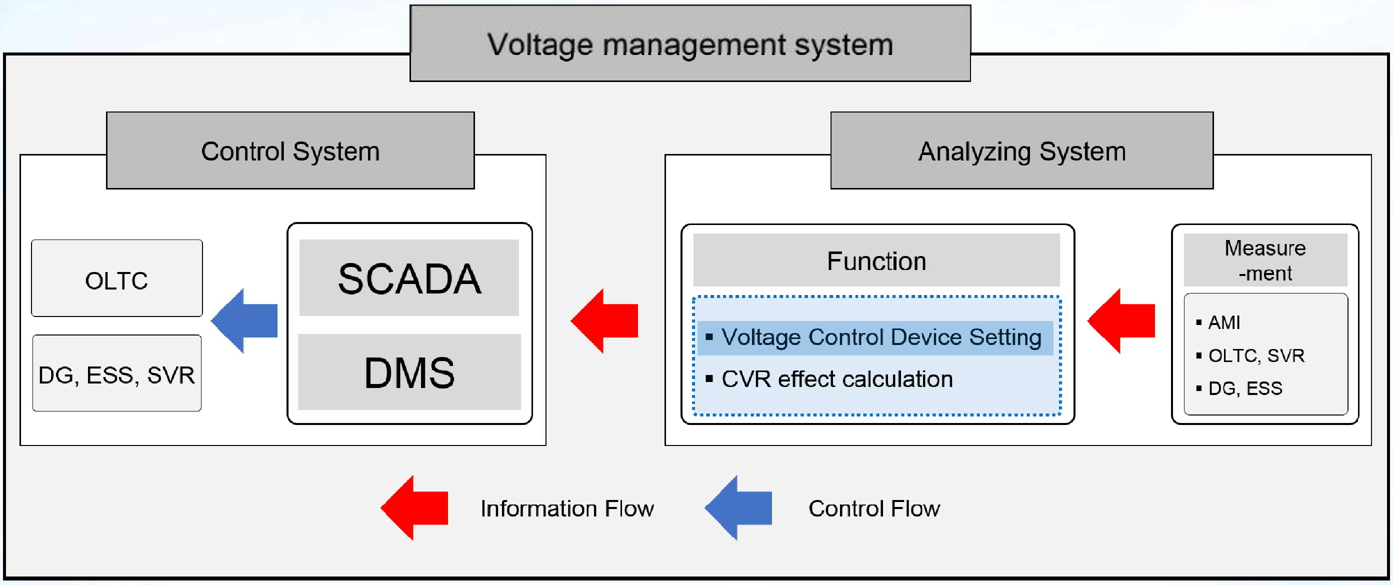
- Voltage control devices operate based on their local setting
- It don't need real-time central control and communication
- Local setting of each voltage control device is calculated from history data

➢ Real-time central control needs robust communication infrastructure

➢ Operator of each device could be different

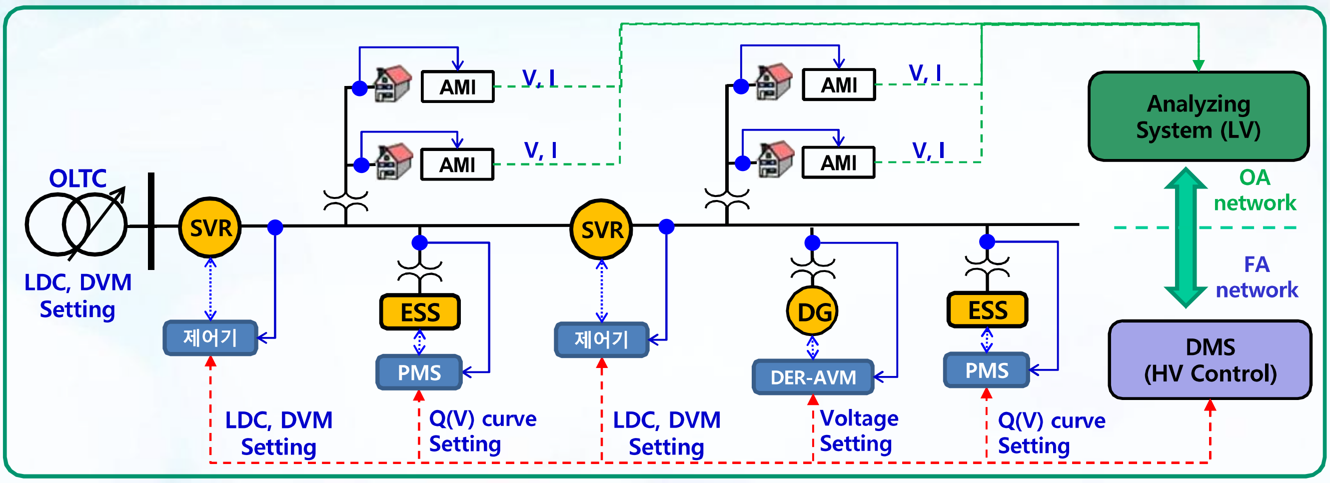
Project Overview

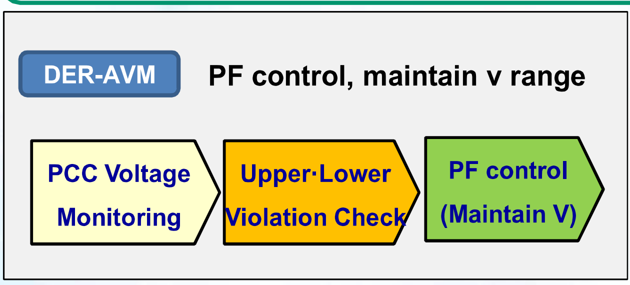
❖ System configuration

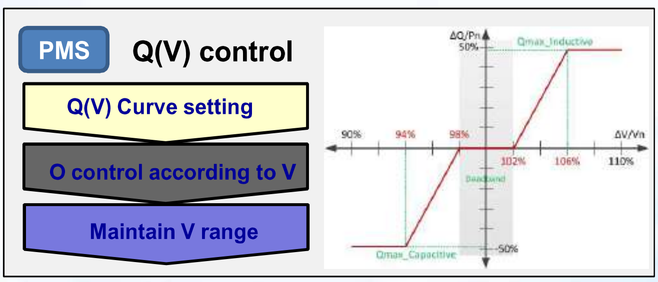


Project Overview

❖ System configuration







Cooperative Voltage Setting

❖ Feature

- Voltage control devices operate based on their **Local Setting**
- Local Setting is each Voltage control device is calculated
  - ✓ **History data** (AMI, OLTC, SVR, DG, ESS)
  - ✓ **Cooperation** among voltage control devices
- The Setting is changed by DMS periodically
  - ✓ System reconfiguration, a change of season, voltage problem occurrence

Cooperative Voltage Setting

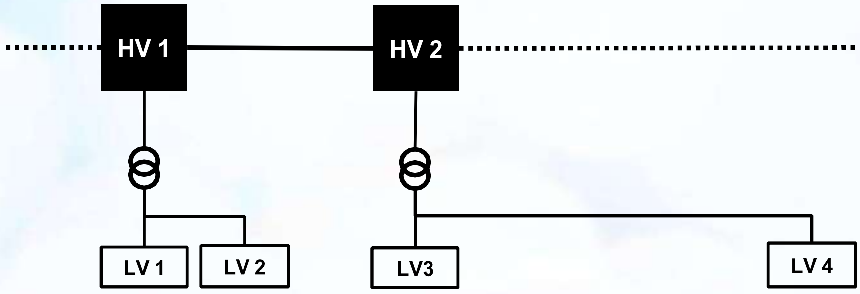
❖ Process

- 1st: **HV operation range** calculation
  - ✓ Calculation Proper HV range at each section by using AMI data
- 2nd: **Worst case** analysis
  - ✓ Voltage profile with DG and ESS reactive power support
  - ✓ Max (+), (-) voltage difference between S/S and H/V node
- 3rd: Voltage control device **Setting** calculation
  - ✓ DG: Upper and lower voltage limit, ESS: Q(V) curve
  - ✓ OLTC, SVR: LDC, DVM parameter

Cooperative Voltage Setting

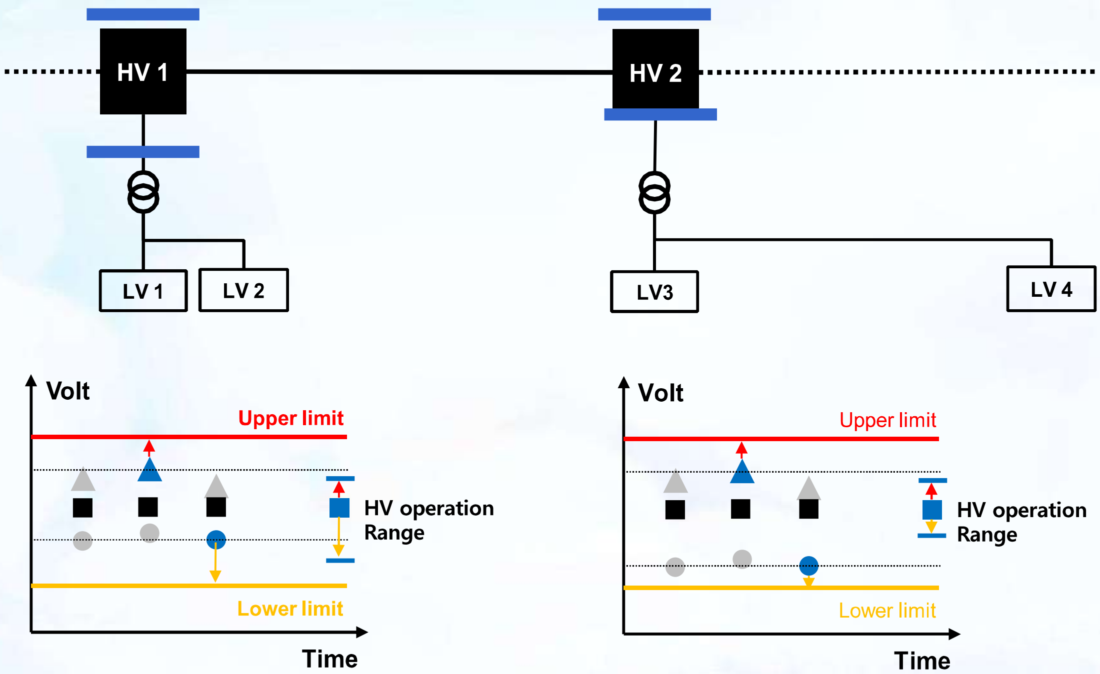
❖ HV operation range calculation

- There are various LV system design according to field characteristic
- Thus, it is not suitable to use fixed HV operation range



Cooperative Voltage Setting

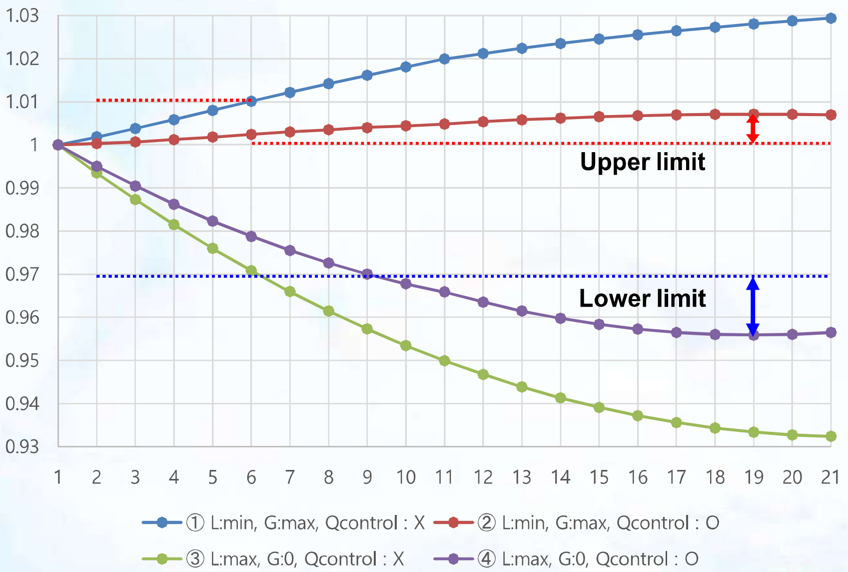
❖ HV operation range calculation



Cooperative Voltage Setting

❖ Worst case analysis

- Check max Volt difference case with DG, ESS reactive power support
- Voltage (max, min) margin can be obtained from the worst case



❖ ACSR 160sq, 20km

❖ Min/Max load: 2, 10MW, PF 0.95

❖ HV operation range

- ➢ 2~5 node: 0.97~1.01pu
- ➢ 6~21 node: 0.97~1.0pu

❖ Uncontrollable DG

- ➢ 5~10, 12~20 node, each 400kW

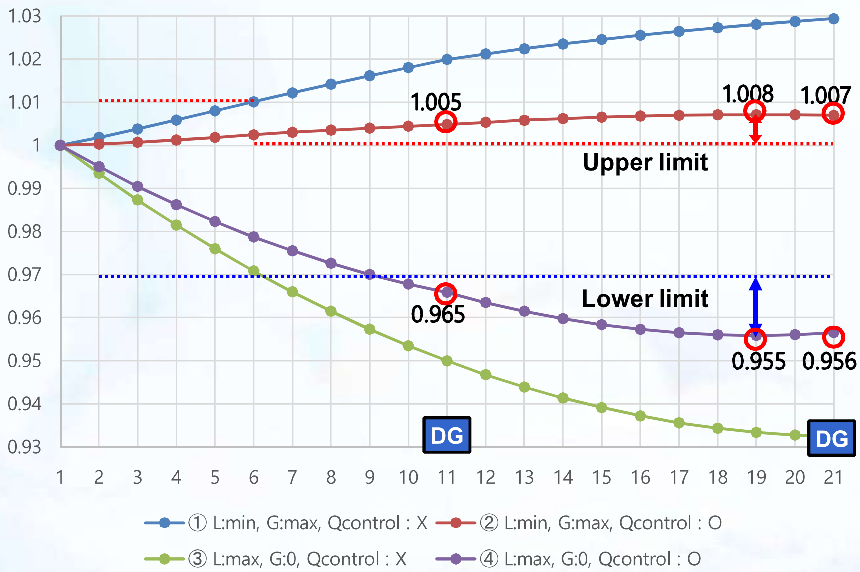
❖ Controllable DG

- ➢ 11, 21 node, each 2000kW
- ➢ Max Q output (+/-)1.0MVar

Cooperative Voltage Setting

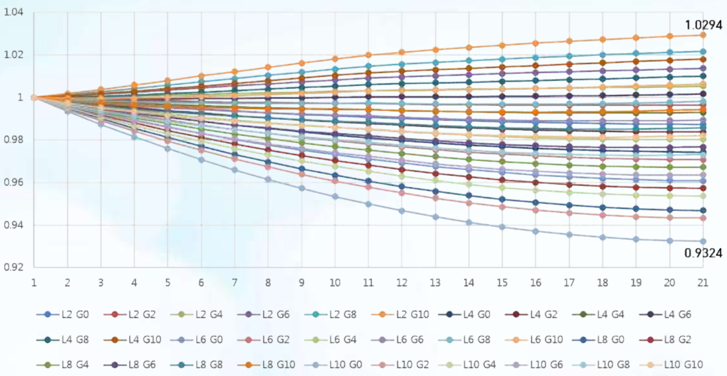
❖ Voltage control device setting calculation

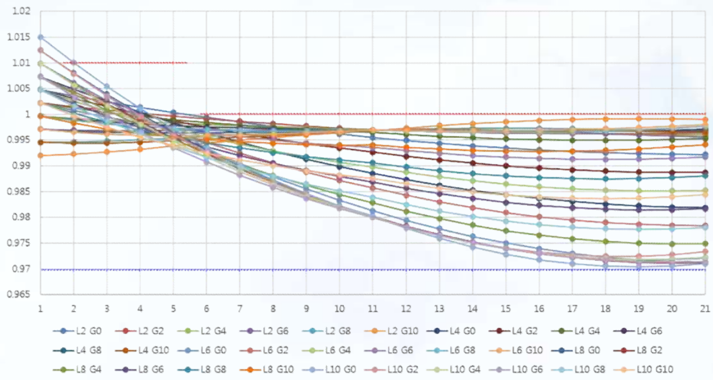
- Output: DG upper/lower voltage limit, OLTC LDC/DVM parameter



Cooperative Voltage Setting

❖ Example of cooperative voltage setting





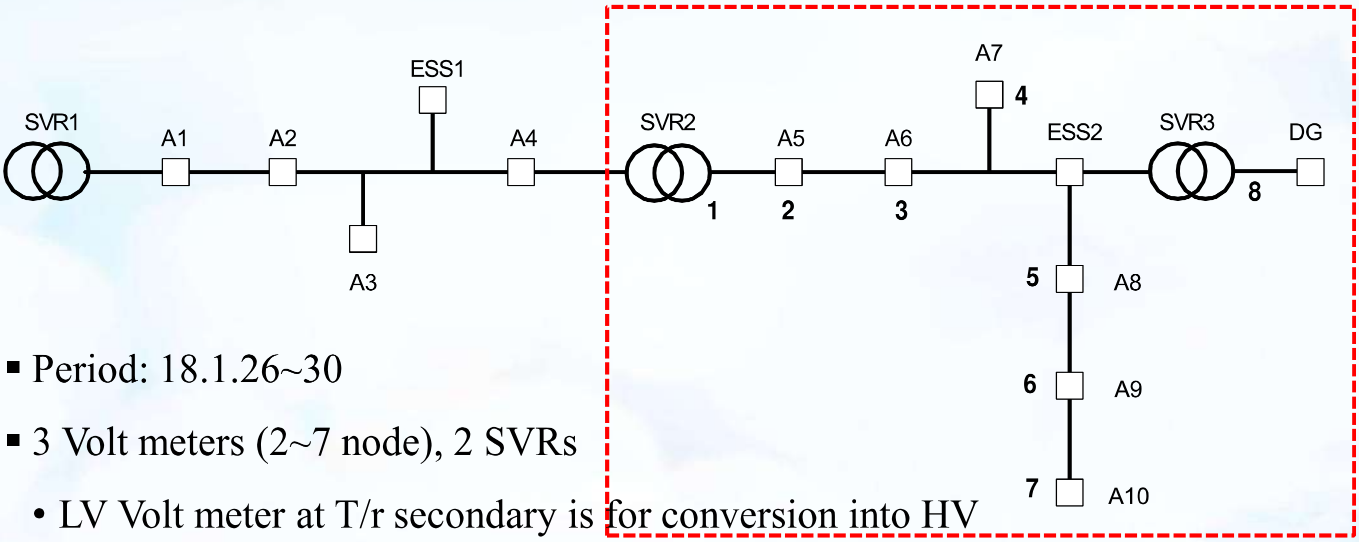
- No DG reactive power & OLTC operation
- Maximum voltage variation 9.7% at last node

- Application of CVS
- There is no violation at every point
- Voltage variation is under 3% at last node

Simulation & Field Test

❖ Simulation Information

- Single line diagram

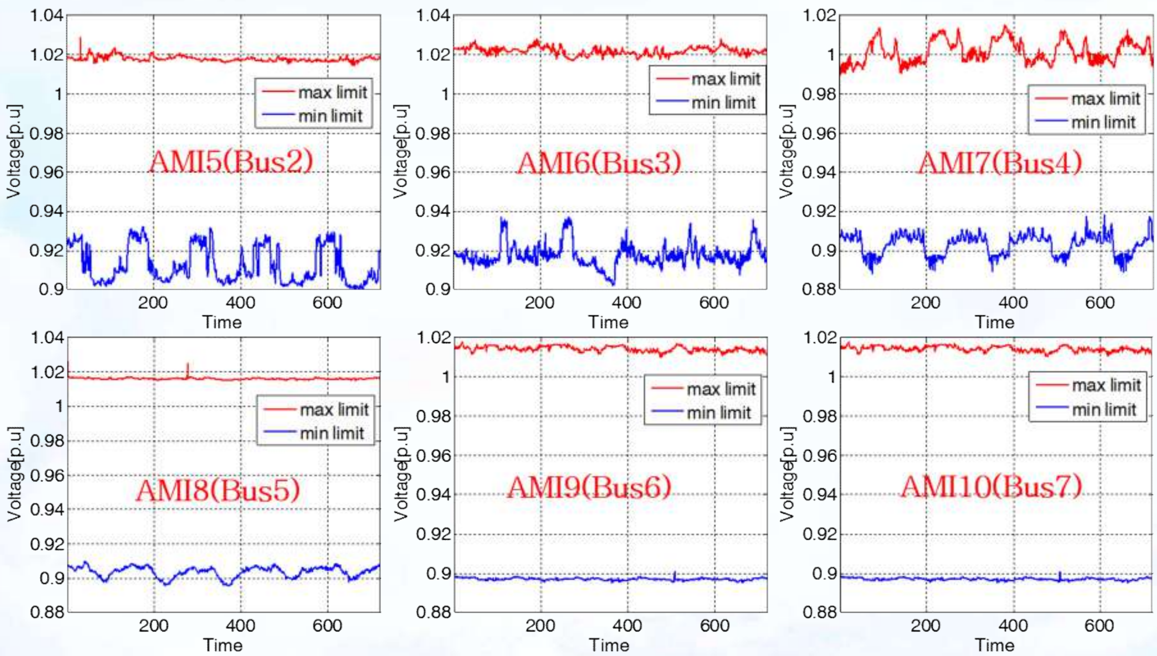


- Period: 18.1.26~30
- 3 Volt meters (2~7 node), 2 SVRs
  - LV Volt meter at T/r secondary is for conversion into HV
- Controllable DG (8 node), max Q is 500kVar

Simulation & Field Test

❖ HV operation range

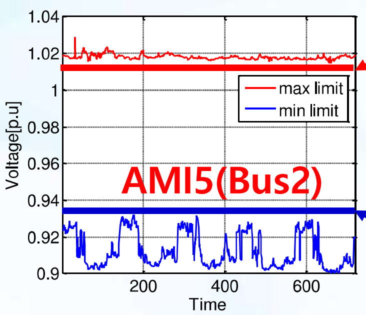
- LV standard voltage range (0.94~1.06pu, 207~233V)



Simulation & Field Test

❖ Calculation result

- HV operation range



Min(Hvmax(t))

	AMI5	AMI6	AMI7	AMI8	AMI9	AMI10
Vmax	1.0147	1.0172	0.9899	1.0151	1.01	1.0028
Vmin	0.9322	0.9376	0.9182	0.9095	0.9009	0.9178

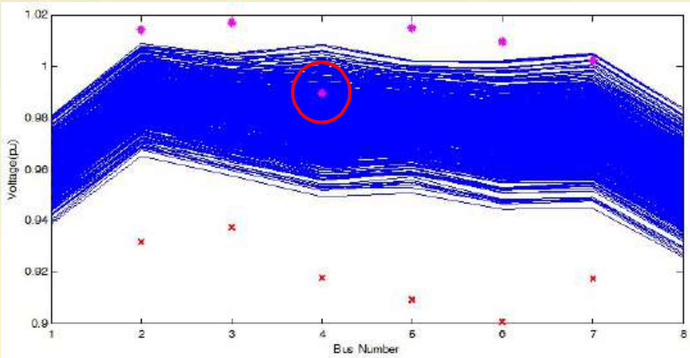
Max(Hvmin(t))

- SVR, DG operation setting

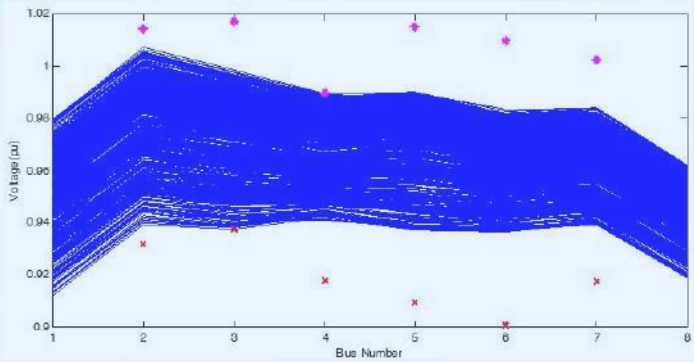
	Min	Max	Range
$V_{SVR\ (DVM)}$	0.9193	0.9642	0.0449
V_{DG}	0.9088	0.9626	0.0538

Simulation & Field Test

❖ Result comparison (No control Vs. Cooperation control)



- Only SVR control, No cooperation
- SVR range: 93.9~98.1% (4.2%)
- There is V violation possible



- Cooperation with SVR & DG
- SVR range(LDC): 91.2~98.0% (6.8%)
  - 2.6% is increased compared to before
- There is no V violation possible

Thank you

22th May, 2018 | KEPCO Research Institute (one_kepco@kepco.co.kr)

Advanced Challenges of Kyushu EPCO due to Rapid PV Penetration

Kyushu Electric Power Co., Inc.
May 22, 2018

Today's Topics

1. About Kyushu and Kyushu EPCO

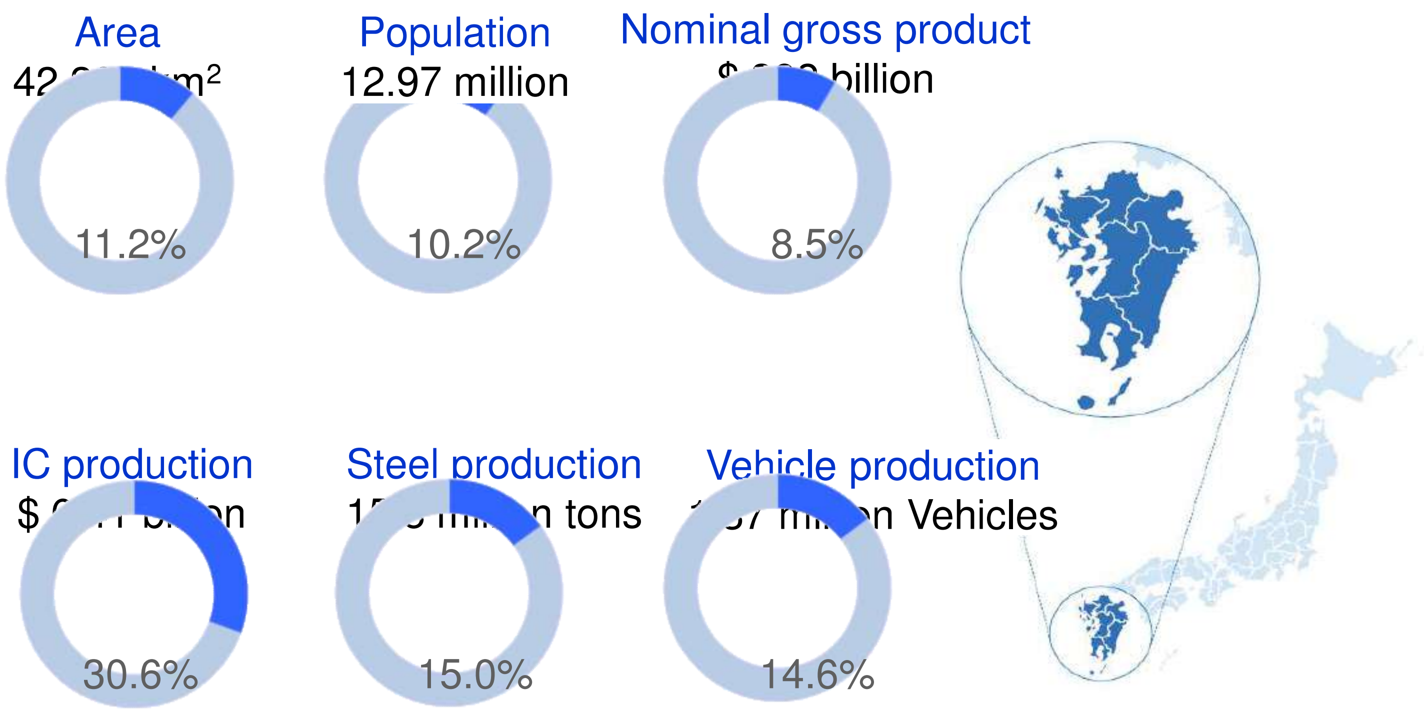
2. Issues of Rapid Spread of Photovoltaics (PV)
   (1) Demand-Supply Balance
      - Output-Control system
      - Large-Capacity Storage Battery
   (2) Power Quality
      - Voltage Flicker due to Reactive Power

3. Kyushu EPCO's Challenge

About Kyushu and Kyushu EPCO

Outline of Kyushu (principal indicators)

The economic scale, population and area of Kyushu account for approximately 10% of Japan.

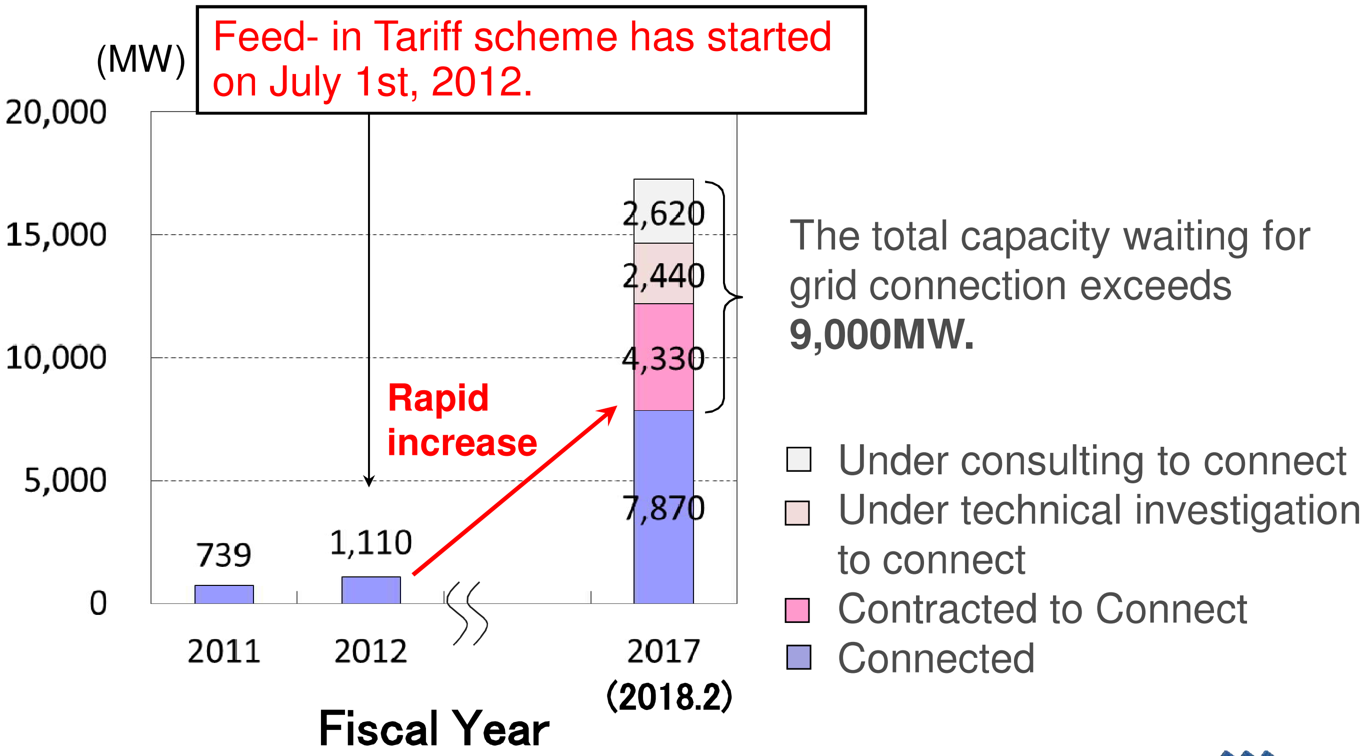


About Kyushu Electric Power Company

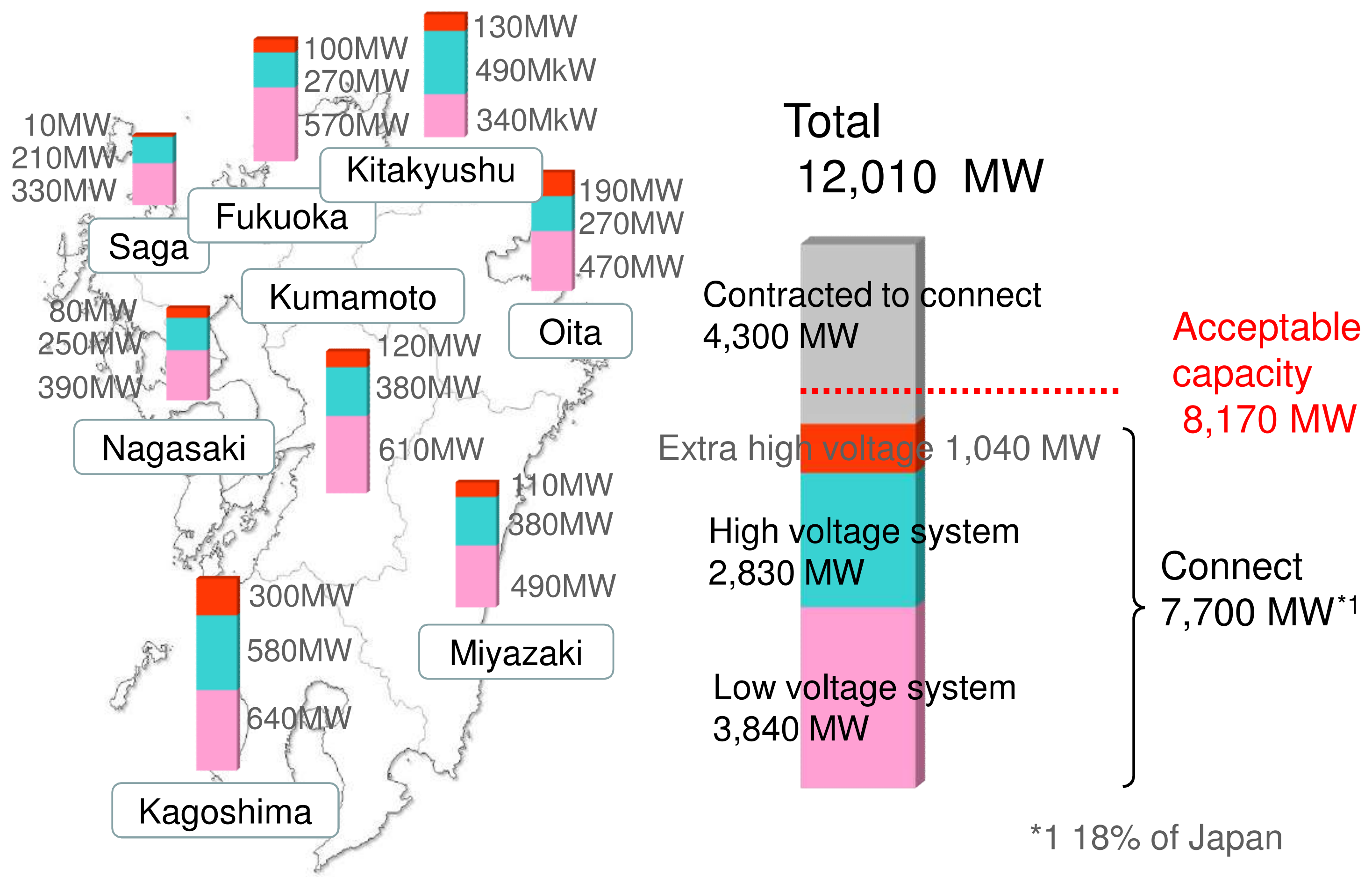
Amount of Sales	$ 15.1 billion	(1,696.3 billion JPY)
Total Asset	$ 36.9 billion	(4,141.5 billion JPY)
Number of Employees	13,053	
Electric Sales Volume	78,619 millions of kWh (10% of Japan) - light: 28,535 - power: 50,084	
Date of Establishment	May 1, 1951	
Capital Fund	$ 2.1 billion	(237.3 billion JPY)

Many Requests for PV Connecting to Power Grid

- Peak demand in summer time was about **15,500MW.** (2016)
- The capacity of connected PV was about **7,870MW**. (2018.2)

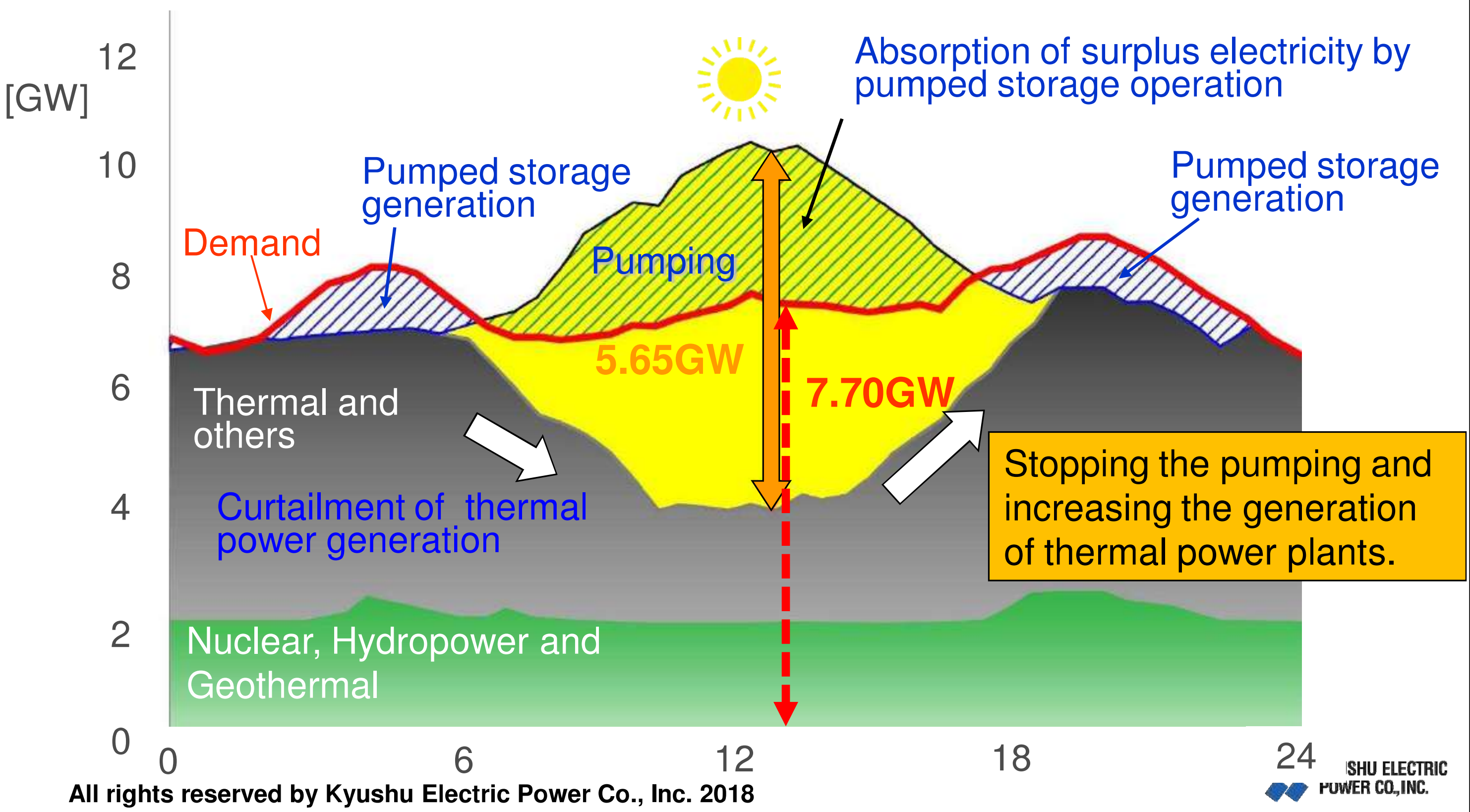


Capacity of PV Generators in December, 2017



Demand-Supply Balance on April 30, 2017

The power supplied from PV has exceeded 70% of the demand in April 30, 2017 in Kyushu area.



Issues of Rapid Spread of Photovoltaics - Demand-Supply Balance

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Development of Output-Control System

- To resolve the issue of adjusting the supply-demand balance, it is necessary to develop **the output control system of PV facilities** and introduce it quickly.
- Two types of output control system are developed to achieve the sure and precise output control.

- Connection Voltage ≧ 66kV :

  Interactive communication system , via dedicated line.

- Connection Voltage ＜ 66kV :

  One-way communication system , via the Internet.

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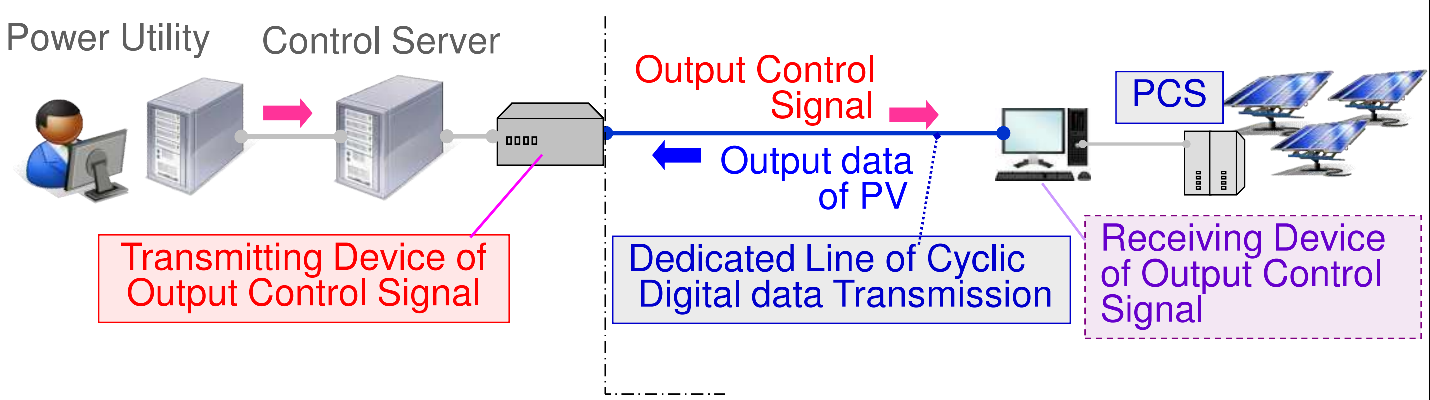
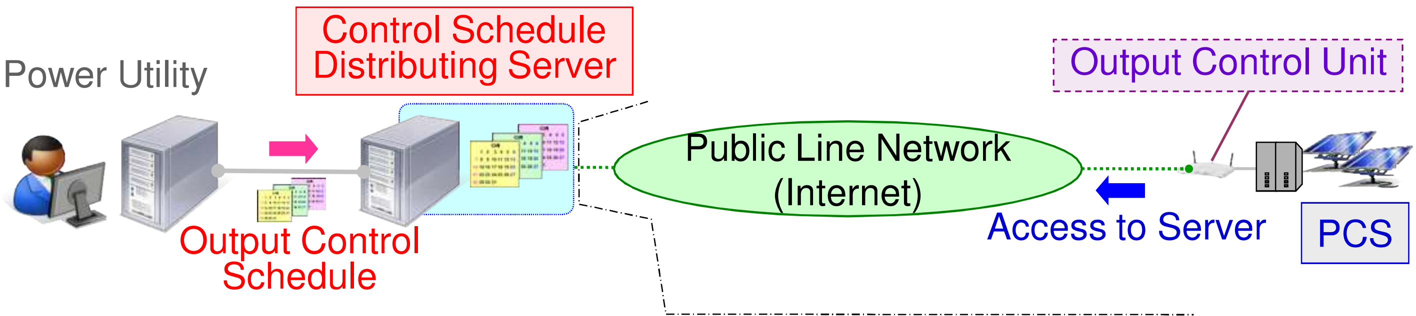
Details of Output-Control System

Connection Voltage ≧ 66kV : Interactive communication via dedicated line



Connection Voltage ＜ 66kV : One-Way communication via the Internet



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Demonstration Test of Output-Control System

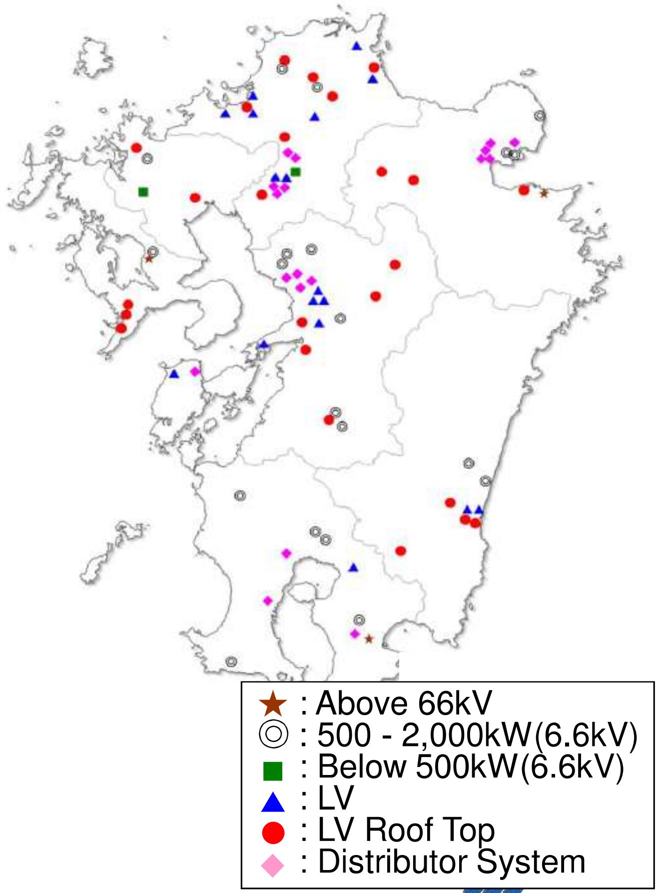
- The demonstration project to verify the reliability of output control system was started in June, 2015
- It completed successfully in February, 2016.

<Facilities under control*>

Connected Voltage	Number	kW
Extra High <66kV>	3	79,000
High <6.6kV>	22	27,000
Low <200V>	58	1,300
Total	83	107,300

* Facilities were selected by public offering.

Location of PV facilities



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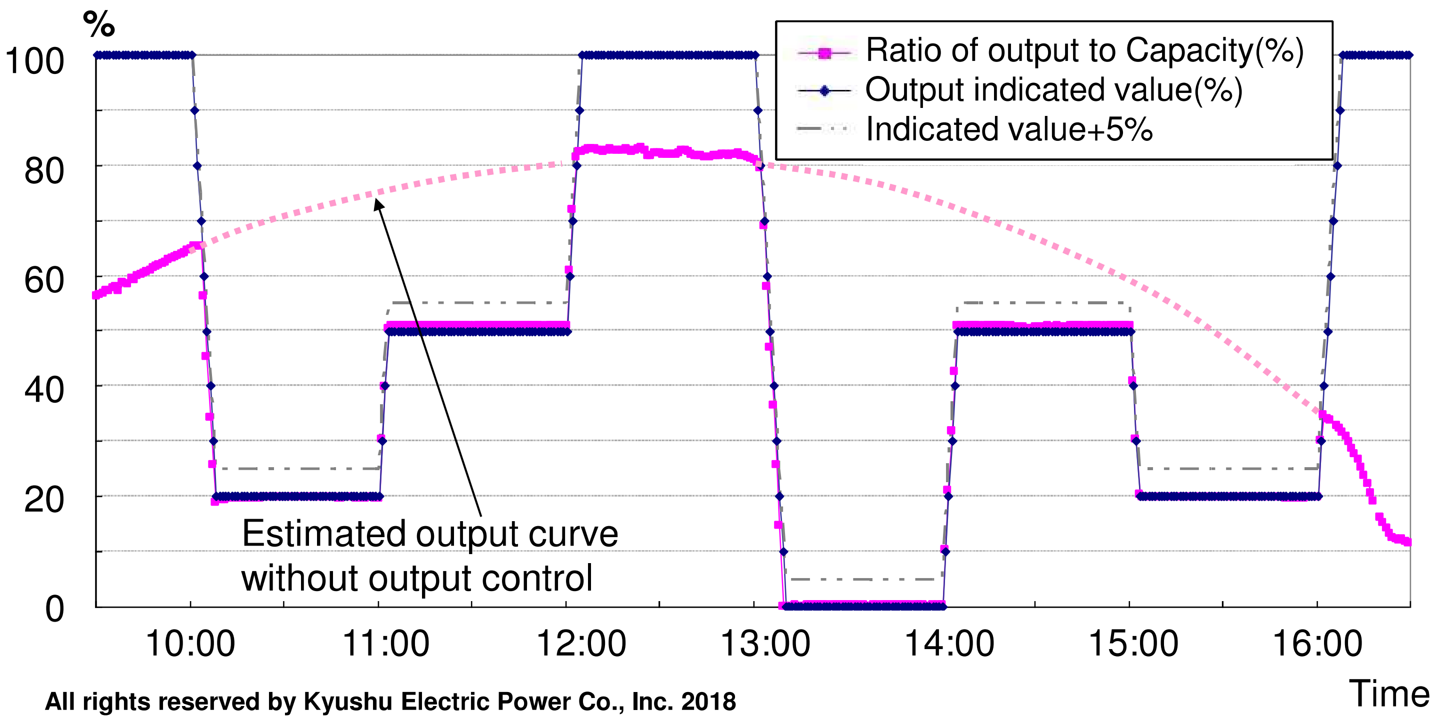
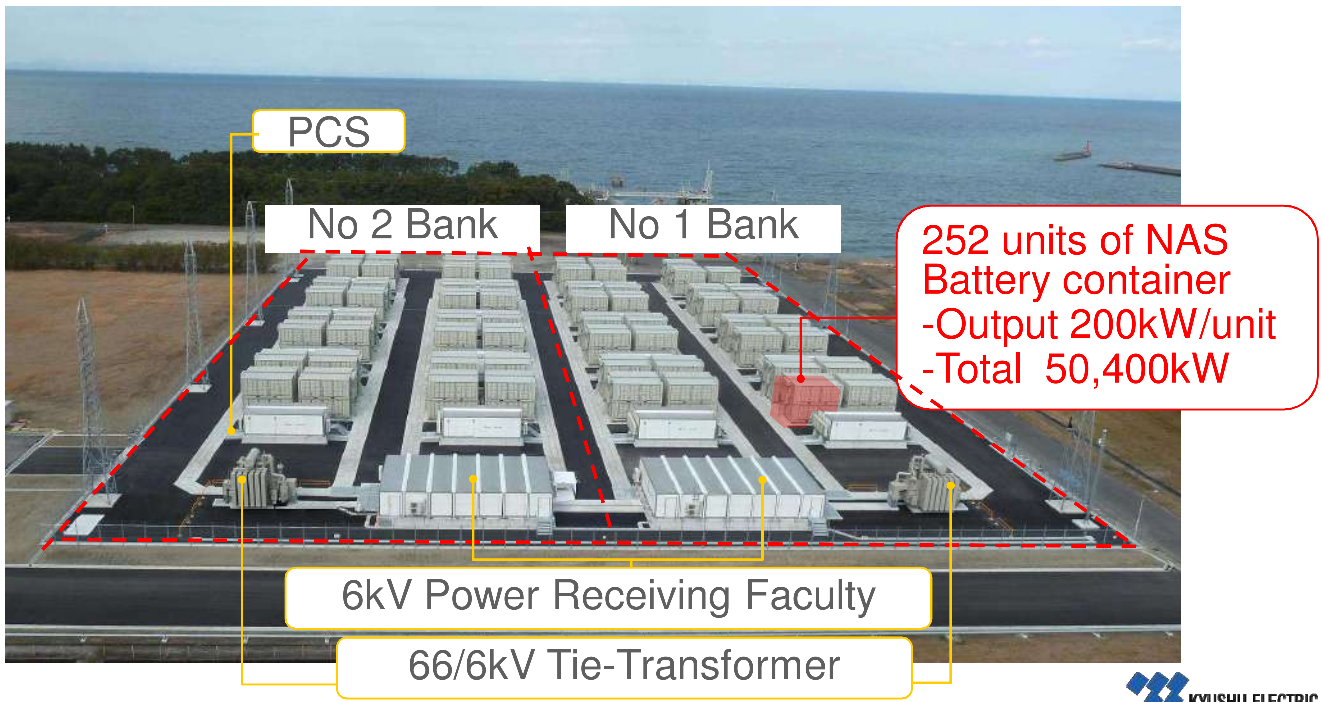
Result of Output-Control System Operation

Connected Voltage : 200V (One-way communication)
Date : January 20, 2016
Weather : fine and then cloudy
(The percentage of cloud cover is below 10%)



Large-Capacity Storage Battery

Buzen Battery Substation located in Fukuoka Prefecture
- Storage battery capacity: 50,000 kW (about 300,000 kWh)
  * One of the largest system in the world
  * Storage battery installation area: About 14,000m^2



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Issues of Rapid Spread of Photovoltaics - Power Quality

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Prevention of Islanding

- The Grid Code in Japan requires both **Passive** and **Active Methods** for surely detecting islanding.
  - When output of PV generators and load are almost equal, deviation of a reference voltage or frequency are too small for protective relay such as OVR, UVR, OFR, UFR to detect.

- **Reactive power** due to active method has caused **voltage flicker** in power system with rapid penetration of PV.

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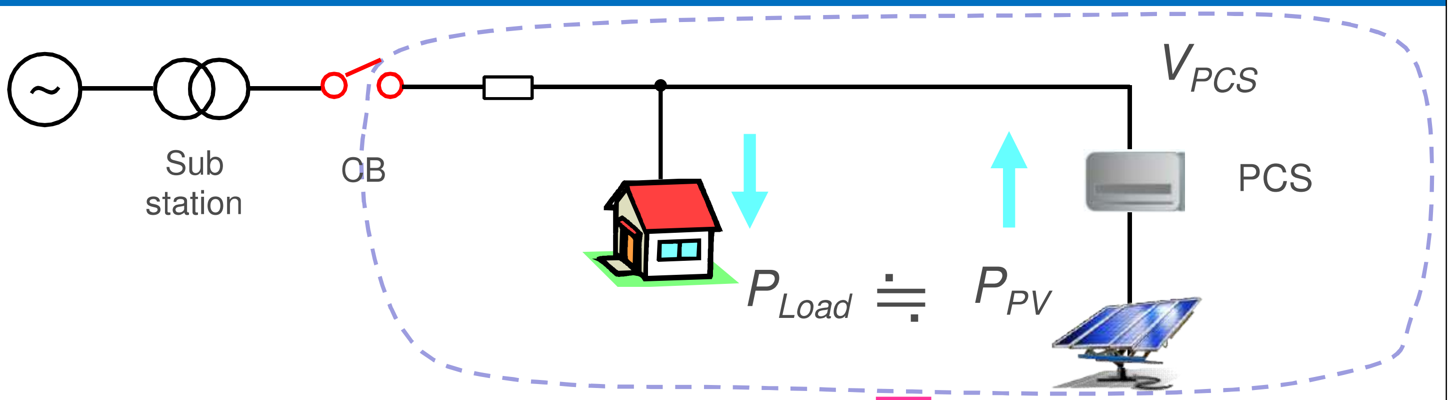
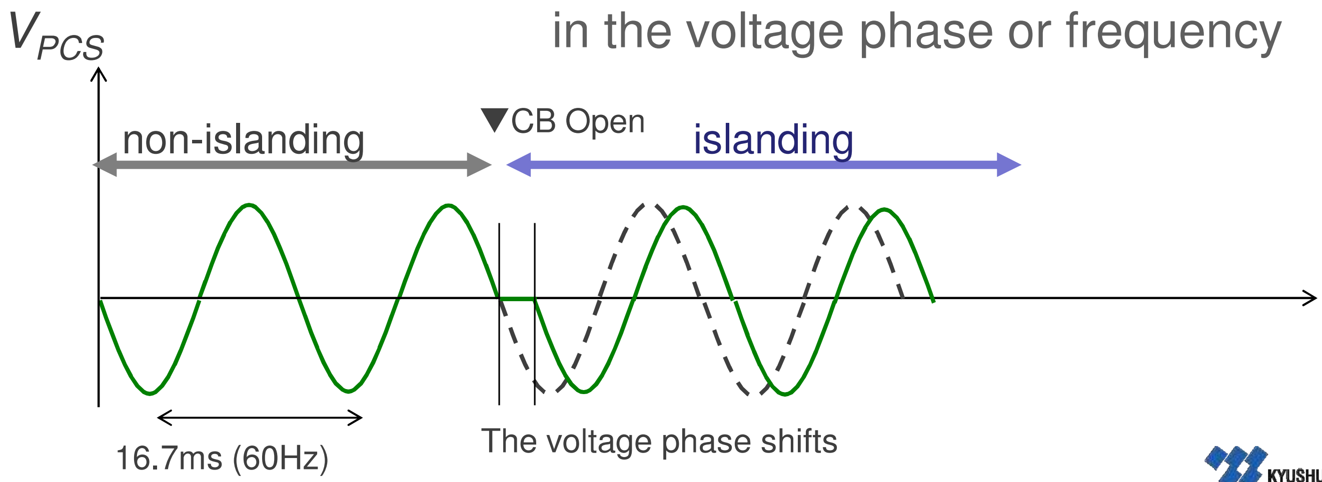
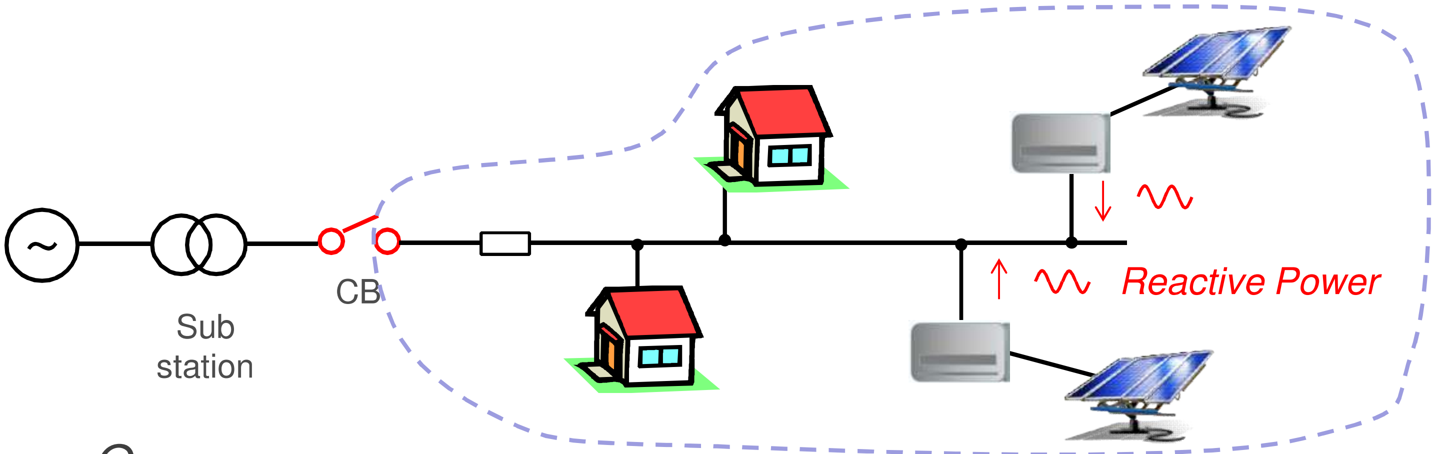
Passive method

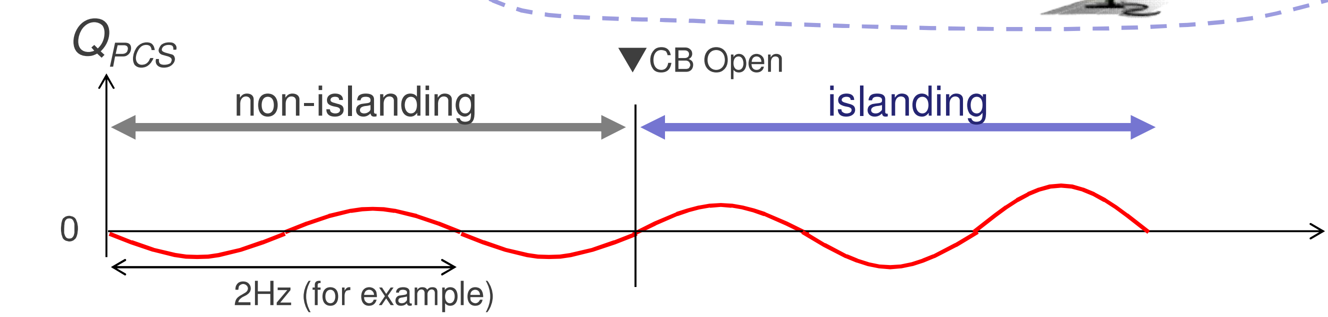


PCS detects **sudden changes** in the voltage phase or frequency

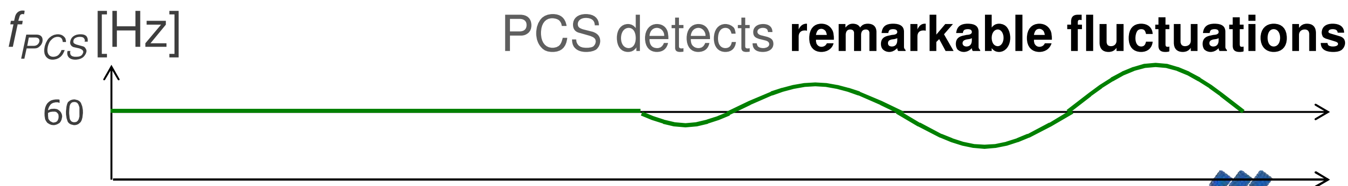


Active method





PCS detects **remarkable fluctuations**



New Active Method causes Voltage Flicker

- With **increase of PV**, the detection of isolated operation will be more difficult, because the disturbance signal of PCS may interfere with each other.
- ***"New Active Method"*** that surely detects islanding has been introduced into low voltage PCS.

- **Voltage flicker** occurs due to reactive power from the PCS.

  - Especially, Kyushu EPCO experienced voltage fluctuations throughout Kyushu twice in 2017.

- As a countermeasure, we introduced **STATCOM** and got results.

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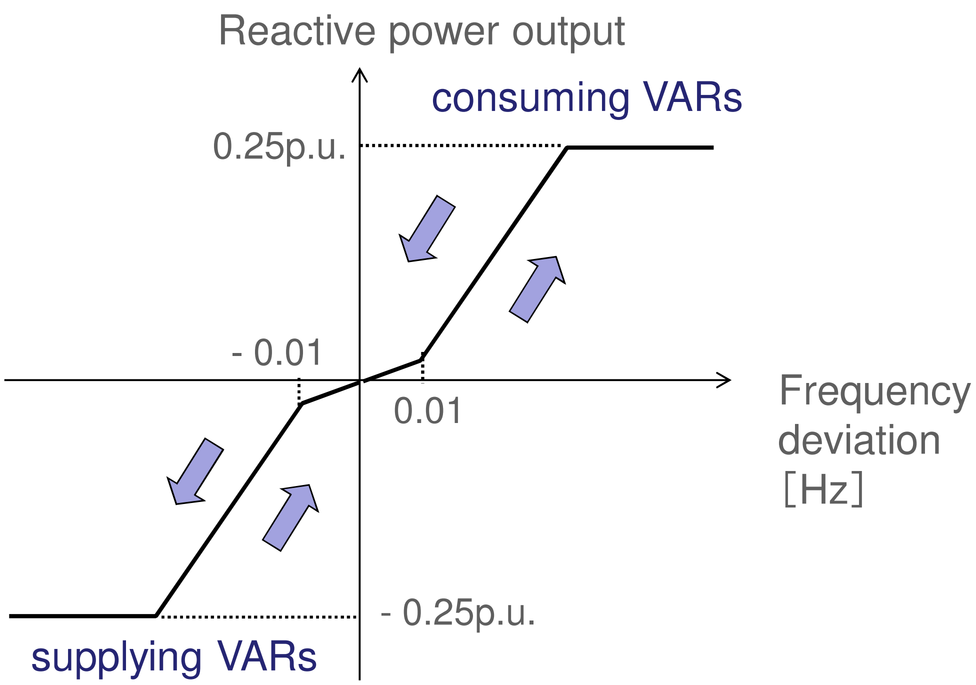
Details of New Method

- The specifications of the new method are regulated in JEM 1498.
- Each PCS consumes or supplies **reactive power** according to the **frequency deviation** synchronously.



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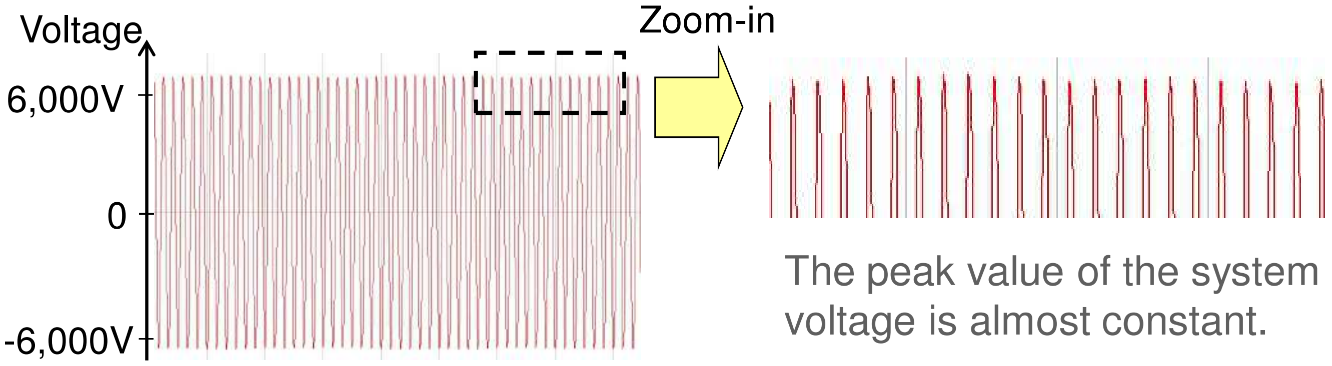
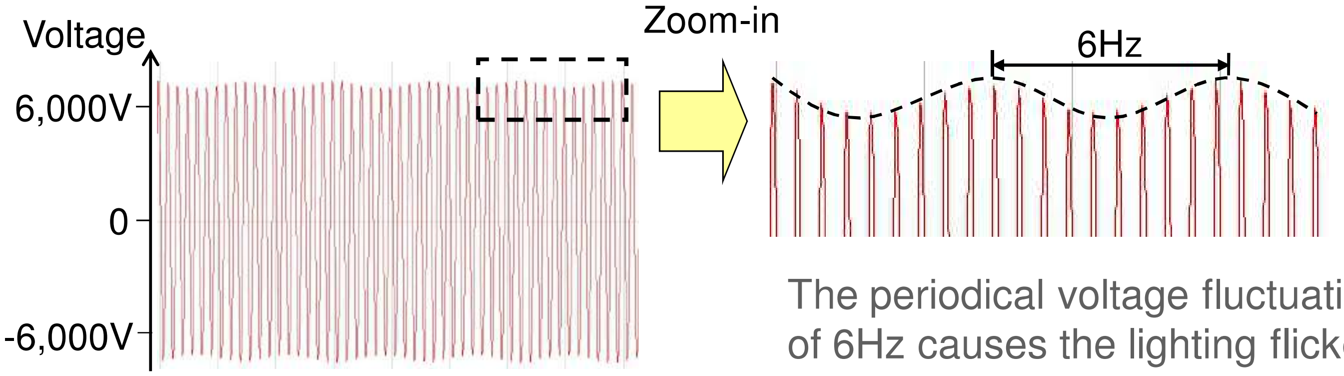
Voltage Waveform with / without Flicker

Without Flicker



The peak value of the system voltage is almost constant.

With Flicker



The periodical voltage fluctuation of 6Hz causes the lighting flicker.

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A measure to Estimate Voltage Flicker

- In Japan, flicker level has been estimated by $\boldsymbol{\Delta V_{10}}$.
- That is used for the influence of load fluctuation due to ark melting furnace (not IEC flicker meter defined by IEC61000-3-3) .

$$\Delta V_{10} = \sqrt{\sum_{n=1}^{\infty} (\alpha_n \times \Delta V_n)^2}$$

α_n : luminosity factor
ΔV_n : **rate of voltage fluctuation** of each order [%]

- The value of ΔV_{10} should not exceed 0.45 .
- However, **ΔV_{10} tends be higher** with increasing the quantity of reactive power.

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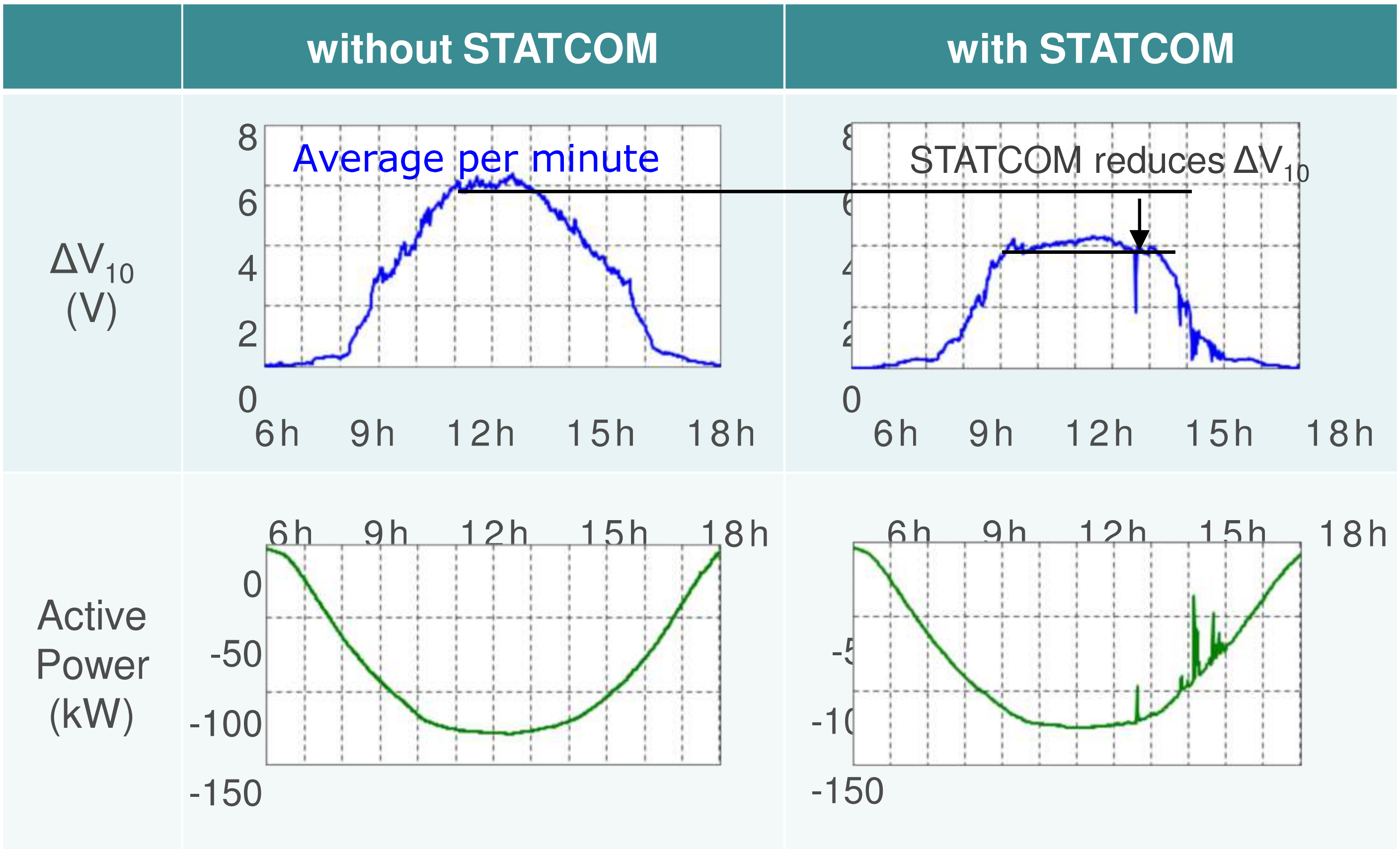
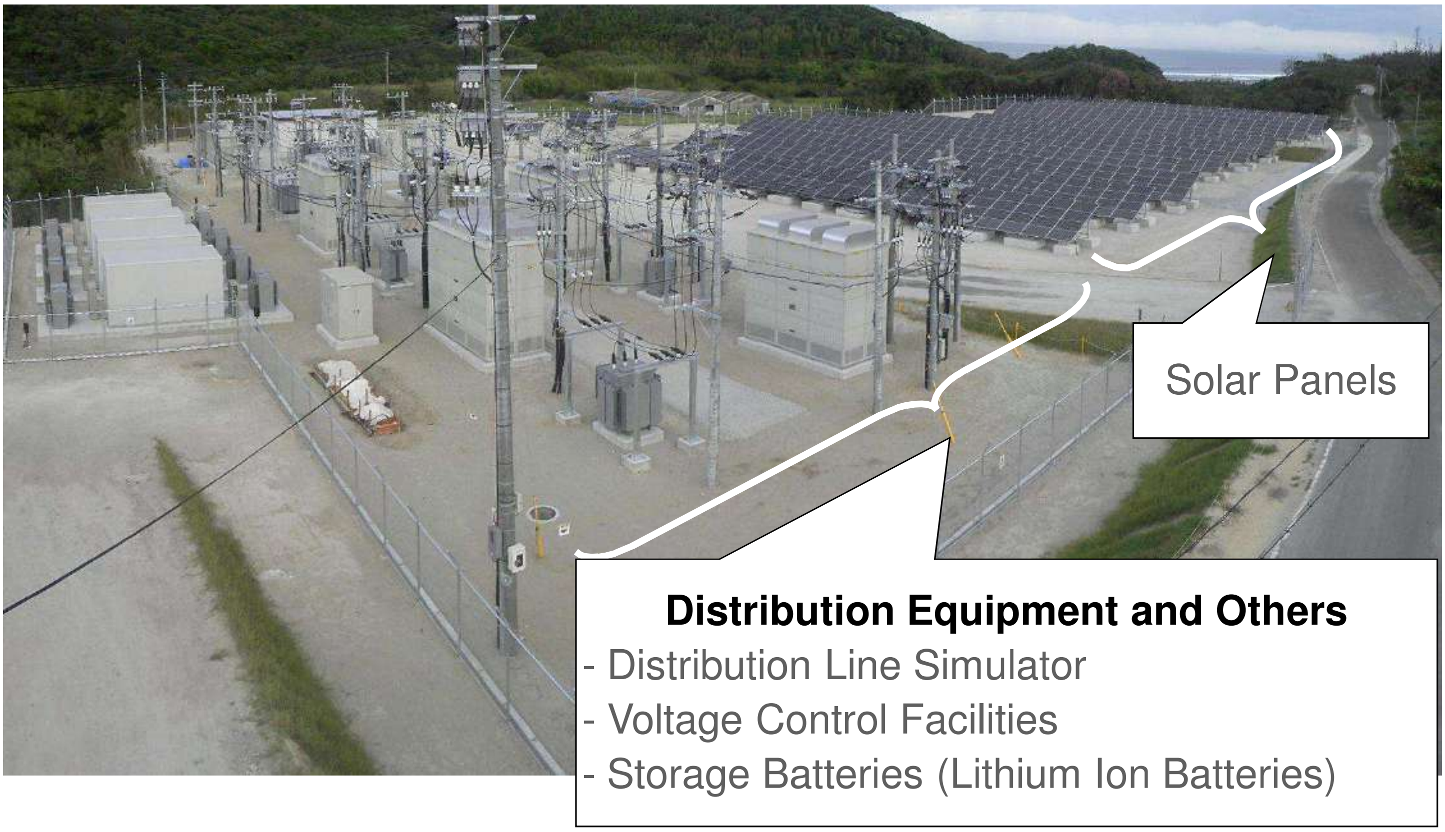
STATCOM as Countermeasure of Flicker

STATCOM can effectively suppress the voltage flicker.



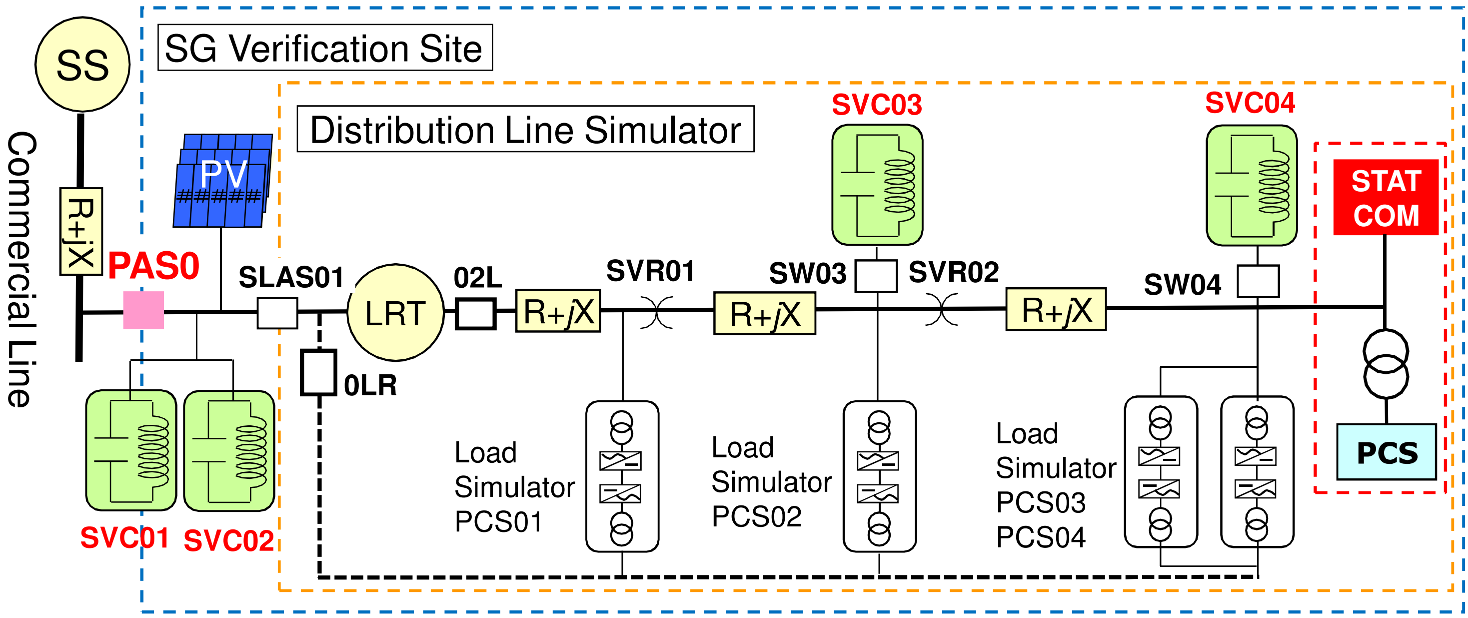
Kyushu EPCO's Challenge

Kyushu EPCO's Distribution Line Simulator



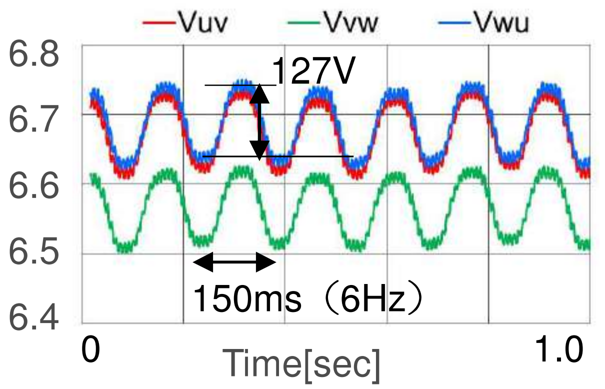
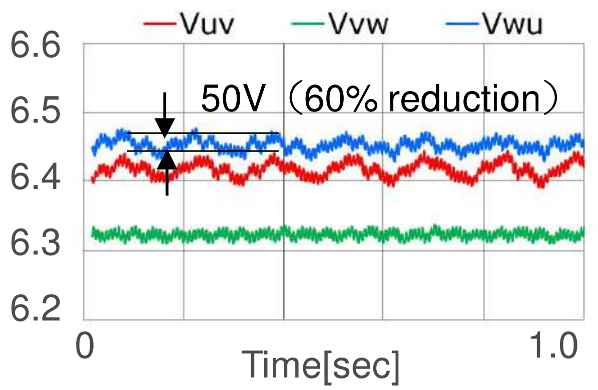
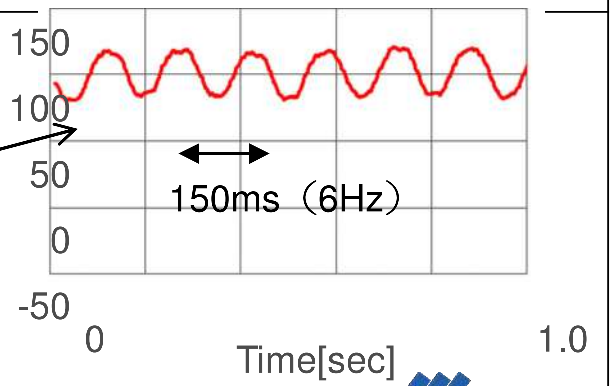
Schematic Diagram of Test Facilities

- Adjusting **line impedance** can simulate distribution line between 3 and 40km length.
- **Load simulator** is capable of being simulated both load and generator.



Example of Test Results

STATCOM reduced the voltage fluctuation from 127V to 50V.

	Without STATCOM	With STATCOM
RMS Voltage (kV)		
Reactive Power of STATCOM (kVar)	STATCOM outputs reactive power in response to change in cyclic voltage fluctuation of 6Hz.	

KYUSHU ELECTRIC POWER CO.,INC.

Kyushu EPCO will further pursue the improvement of power quality for expanding the introduction of renewable energy.

KYUSHU ELECTRIC POWER CO.,INC.

The Situation and Future of the Technology for IEC 61850 based Substation Automation System in Korea

SEOK-KON KIM

KEPCO Research Institute

KOREA

Contents

◆ TC 57 Scope and Working Group

Background of TC 57

- **TC 57 was established in 1964**
  - **Urgent need to produce international standards in the field of communications**
- **TC57 changed the title and scope in 1994 and again in 2003**
  - **Need to take into consideration not only equipment aspects, but also growing need for standardization between IT systems**

Scope of TC 57

- Title : Power systems management and associated information exchange
- Scope : To prepare international standards for power systems control equipment and systems
  - SAS, EMS, SCADA, DA, Remote-protection

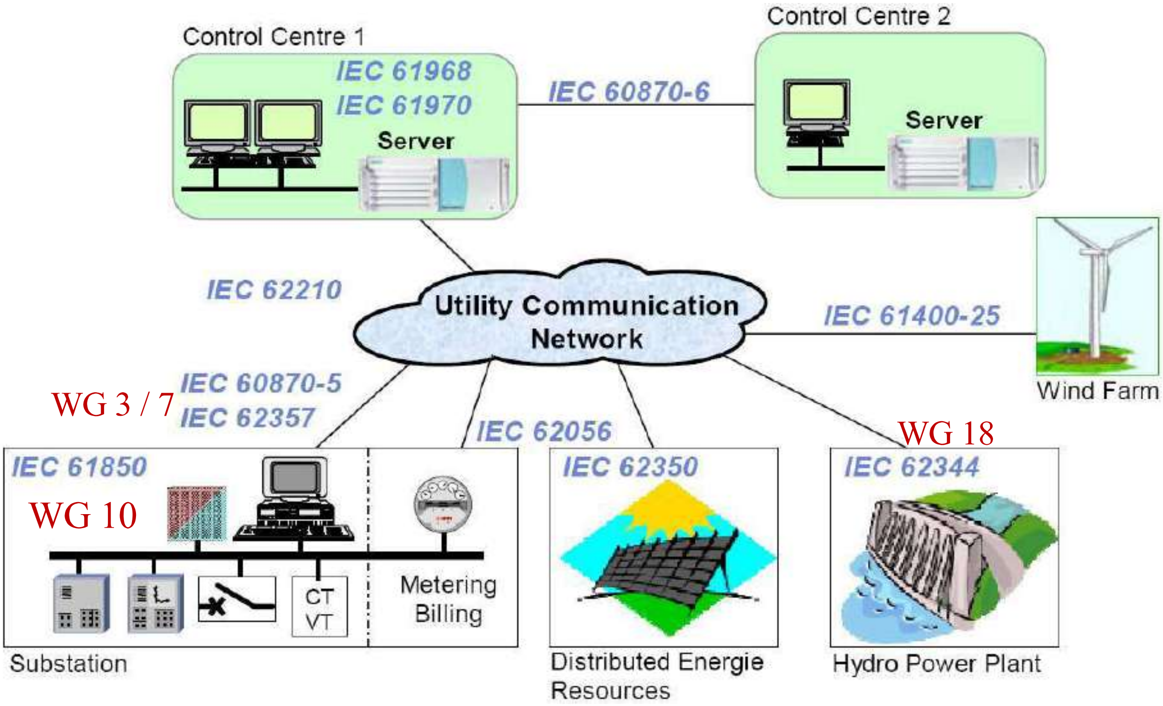
◆ TC 57 Scope and Working Group

Composition of Working Groups of TC 57

- WG 03 : Telecontrol equipment and systems – telecontrol protocols
- WG 07 : Telecontrol protocols compatible with ISO and ITU-T standards
- WG 09 : Distribution automation using distribution line carrier
- WG 10(~WG 12) : Power system IED communication and associated data
- WG 13 : Energy management system application program interface(EMS-API)
- WG14 : System interfaces for distribution management(SIDM)
- WG15 : Power system control and associated communications
  - Data and communication security
- WG 16 : Framework for energy market communication
- WG 17 : Communication systems for distributed energy resources(DER)
- WG 18 : Hydroelectric power plants – Communication for Monitoring and Control
- WG 19 : Harmonization of TC57 standards

TC57 Introduction - IEC Committees

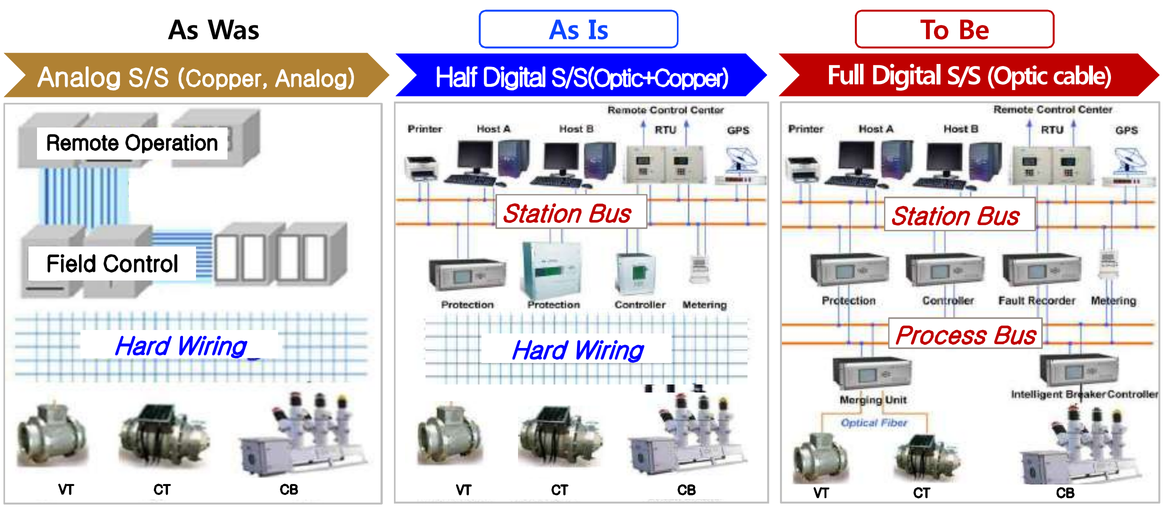
Organization of IEC Committees



IEC 61850 Std. - Optimized Substation with IED Standar

Substation Automation System with IEC 61850

: global standard for 'Communication Networks and Systems for Power Utility Automation'

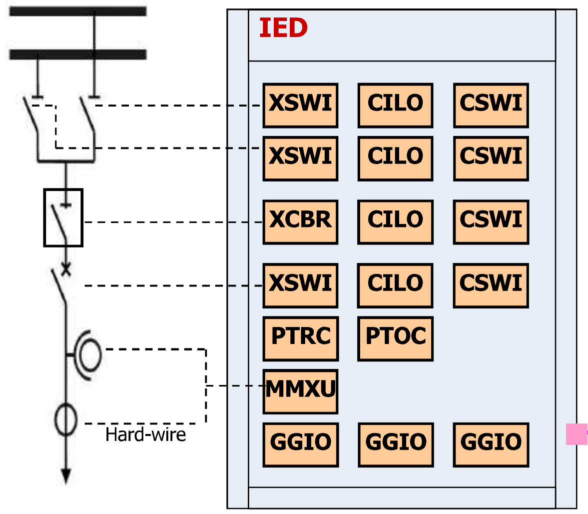


- It specifies an expandable data model and services
- It does not block future development of functions
- It supports free allocation of functions to devices
- It provides the Substation Configuration description Language (SCL)

IEC 61850 Std - Definition of IEC 61850

IEC 61850 define and describe ?

- Logical node on substation facilities(measurement/control/status)
- Communication services(MMS, GOOSE, SV) for data exchange
- Engineering process of substation automation with SCL
- International standard for communication system of digital substation



- ❑ XCBR : LN for circuit breaker
- ❑ XSWI : LN(DS, ES) for switch except CB
- ❑ CILO : LN for interlock condition for switch control
- ❑ CSWI : LN for control of switch like CB, DS etc
- ❑ GGIO : LN for general status data related to other IEDs
- ❑ MMXU : LN for Measuring (Voltage, current, frequency etc)
- ❑ PTOC : LN for over current relay
- ❑ PTRC : LN for trip command
- ❑ GGIO : LN for general input/output

MMS : Read/Write , Report , Log …

Ethernet : GOOSE

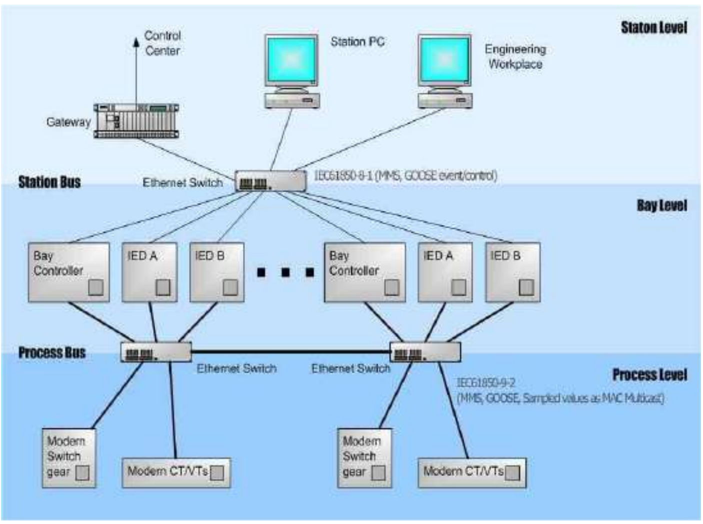
Ethernet Switch

IEC 61850 Std - Optimized Substation with IED Std

Composition of IEC61850 Standards

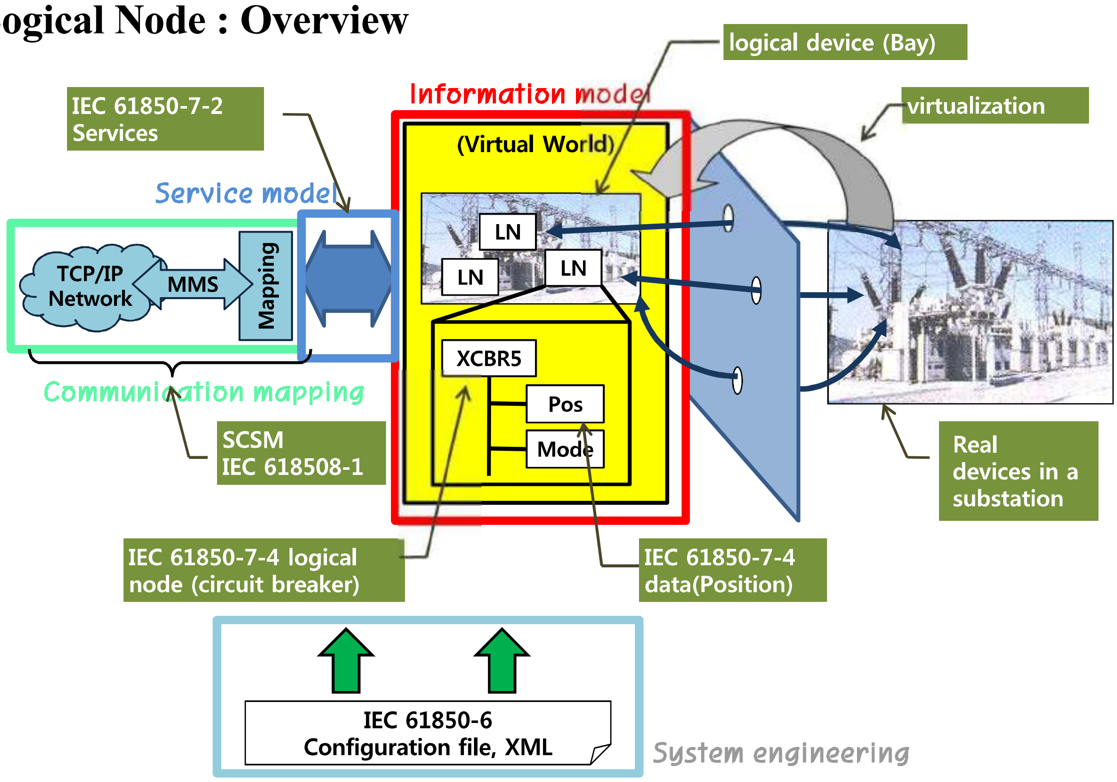
1. Parts 1 to 3 - Overview and Guide of the standard
2. Part 4 - Project management of products and tenders of IEC 61850
3. Part 5 & 6 - Communication requirements and Language
4. Part 7 - Data models and Transactions
5. Parts 8 & 9 - Required mappings for the network
6. Part 10 - Conformance Testing

- Basic principles / Glossary
- General Requirements
- System and project management
- Communication requirements
- S/S Configuration description Language
- Basic Communication Structure
  - Principles and models
  - ACSI
  - Common Data Classes
  - Logical Nodes
- Mapping to MMS and Ethernet
  - Sampled Measured Values
  - Mapping to Ethernet
- Conformance testing



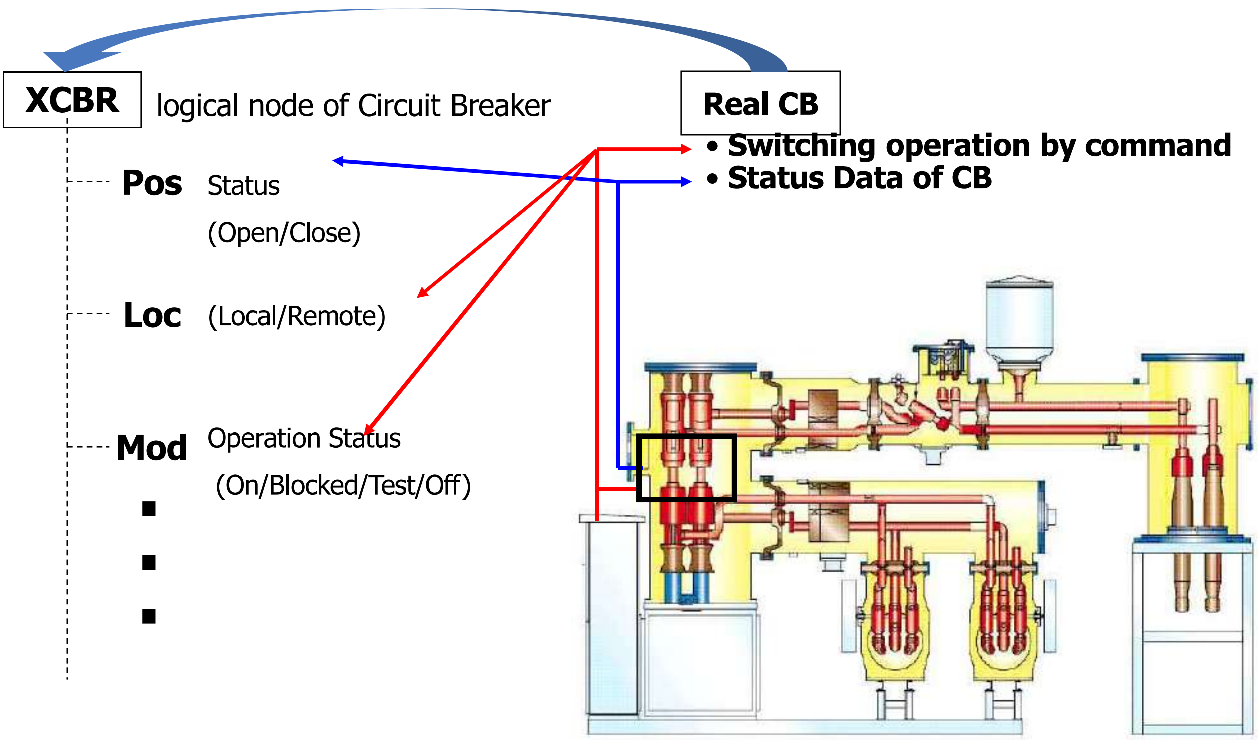
IEC 61850 Std - Logical Node

■ Logical Node : Overview



IEC 61850 Std - Data Model

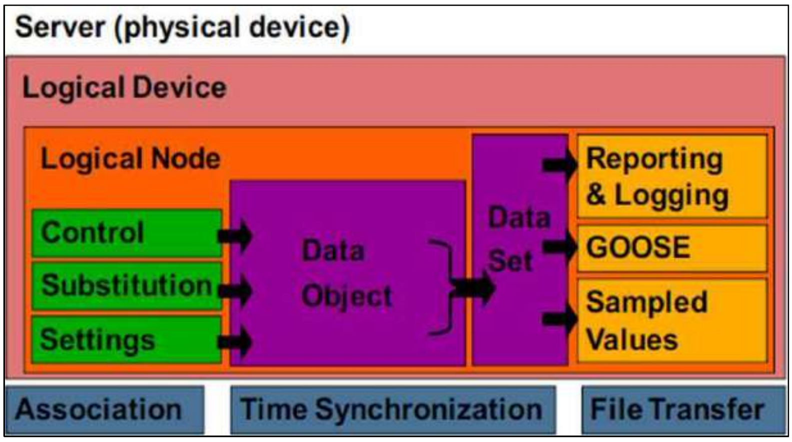
■ Data Model : Example



IEC 61850 Std - APPLICATION LAYER

Application Layer

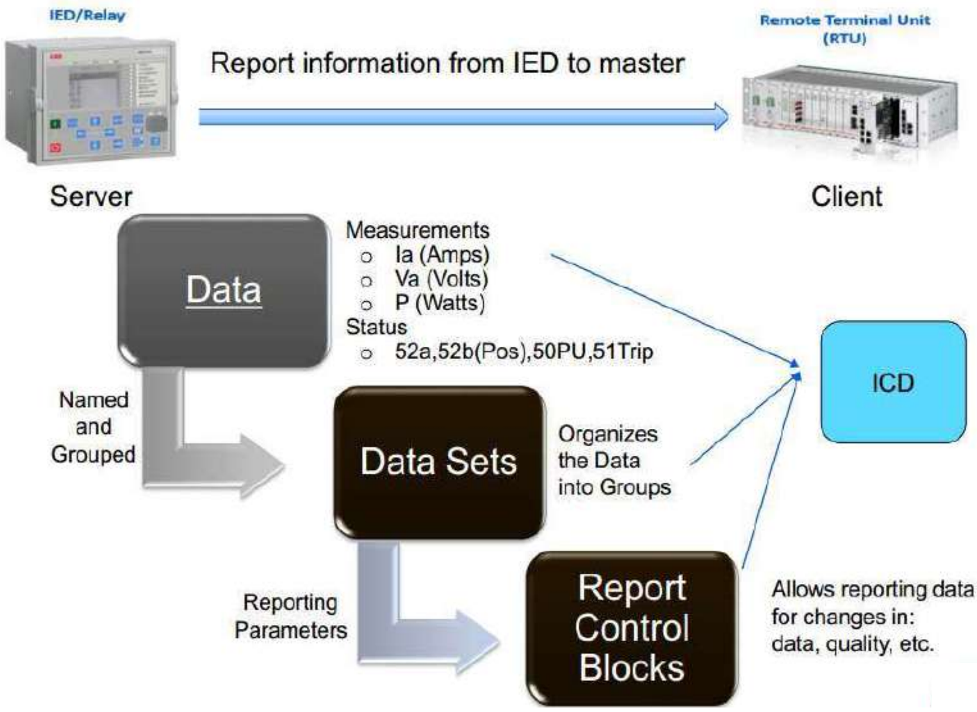
- Services : What can you do with IEC 61850?
  - Naming
  - Read/Write
  - Self-Description
  - Reporting
  - Controls
  - Logging
  - Files



- Object Model : What data can you operate on?
  - Logical Nodes
  - Common Data Classes (CDC)

IEC 61850 Std - Data Exchange Strategy

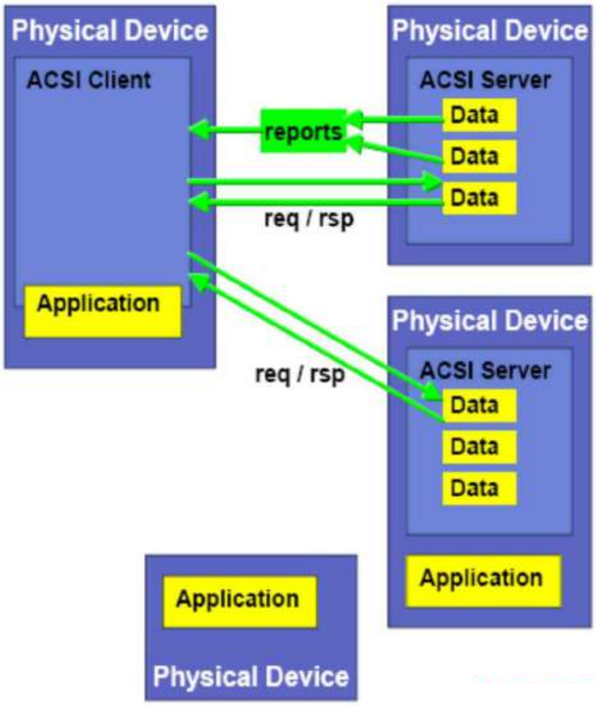
Data Exchange



IEC 61850 Std - ACSI : Service Models : IEC 61850-7-2

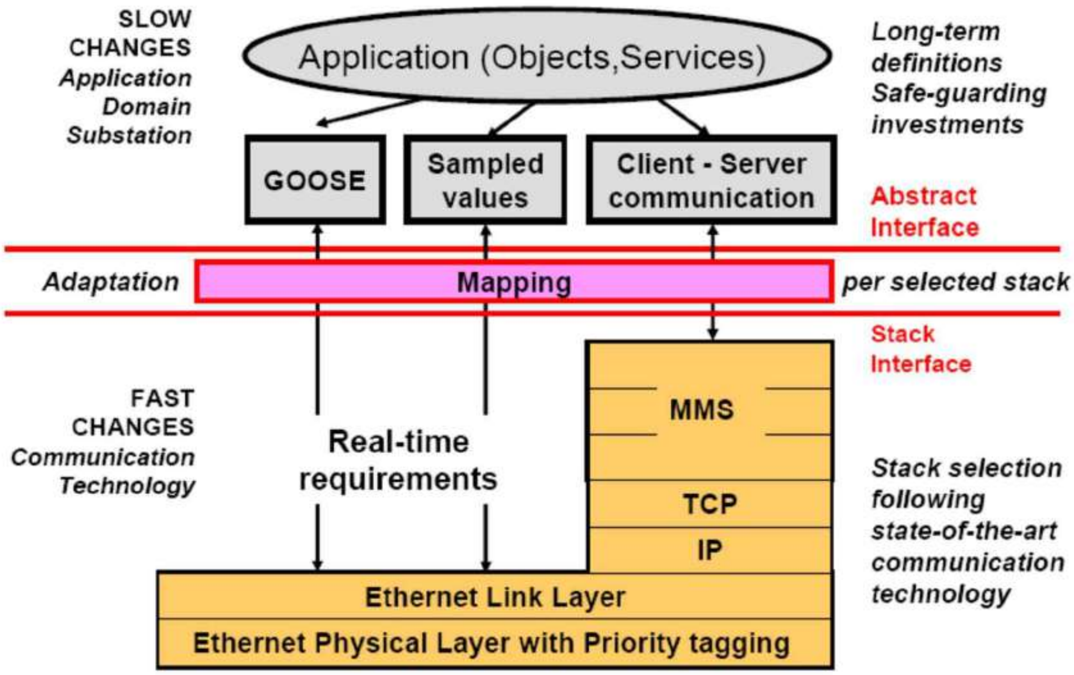
Service Interface

- **Client-Server Relation (HMI ⇔ IED)**
- **Define ACSI (Abstract Communication Service Interface) for monitoring and requesting data on power facilities and function operation**
  - status and measurement values
  - Setting values
  - Read/Write , Report , Logging etc



IEC 61850 Std - Communication Profiles

Communication Profiles



The Situation of SA in Korea

◆ The Situation of Substation Automation in KEPCO

■ Situation of Operation

※ Ref. date : 2017.12

Division	765 kV	345 kV	154 kV	66 kV	23 kV	Subtotal	Total
Legacy	7	111	681	3	4	806	836
Digital	-	-	30	-	-	30	

The Situation of SA in Korea

◆ The Situation of Substation Automation in KEPCO

■ Annual Construction Plan (Digitalization included)

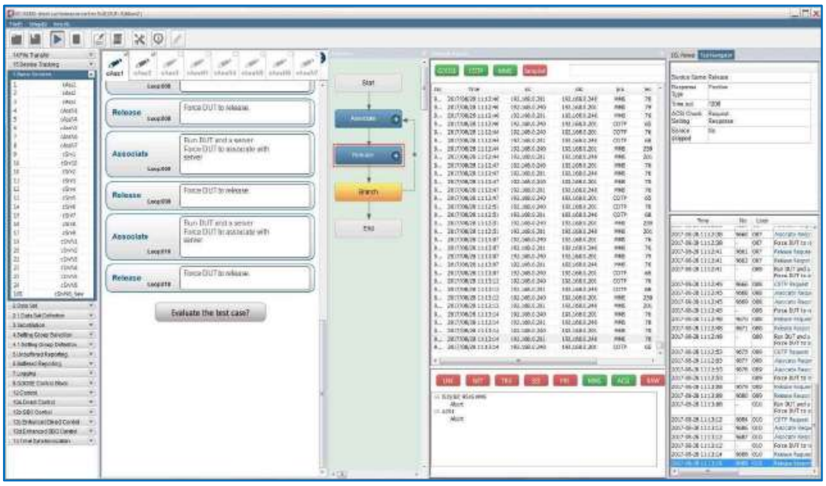
Year	'13	'14	'15	'16	'17	'18	'19	'20	'21	Total
Conversion					1	(13)	(8)	(4)	(4)	(30)
New Const.	11	5	6	4	8	16	20	13	-	83+
Cum. total	11	16	22	26	35	(64)	(92)	(109)	(113+)	

(Estimated quantity)

The Situation of SA in Korea

◆ Test & Engineering Tool Development in KEPCO

■ Conformance Verifier



Verifier testing tool for client

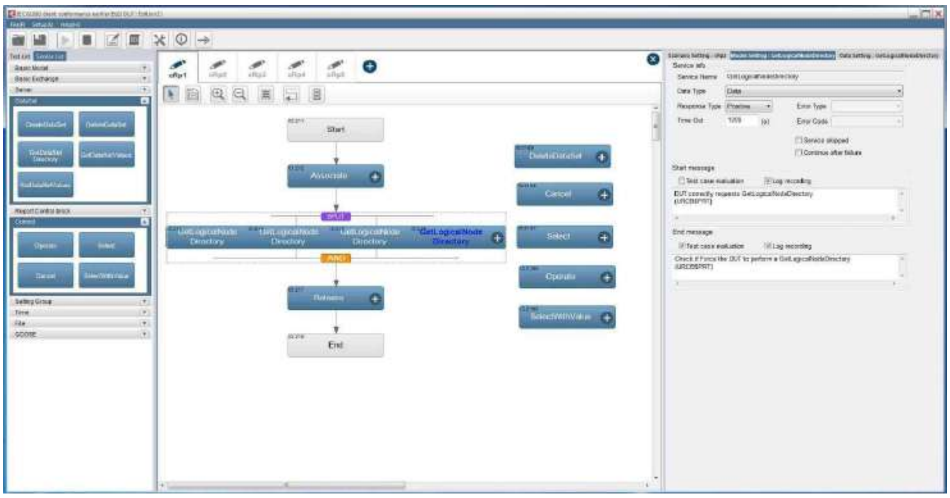
- Addresses conformance testing of IEC 61850 client including HMI, G/W using object model, the test cases defined in by this UCAIug
- Can Edit IUG test procedures
- Supports assessment result to check fail or pass each step of test case automatically

The Situation of SA in Korea

◆ Test & Engineering Tool Development in KEPCO

■ Specification of Conformance Verifier

- Sequential Execution of Conformance Test Procedures
- Model based Editing of Conformance Test Case

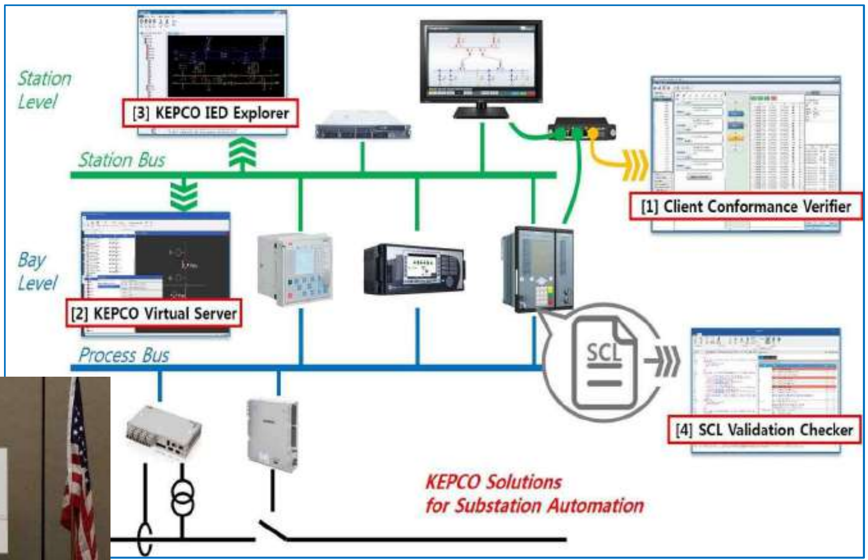


- Analyzing Network Traffic, Supporting ACSI Layer

The Situation of SA in Korea

◆ The Situation of Substation Automation in KEPCO

- Applications – KEPCO Solutions for S/S Automation

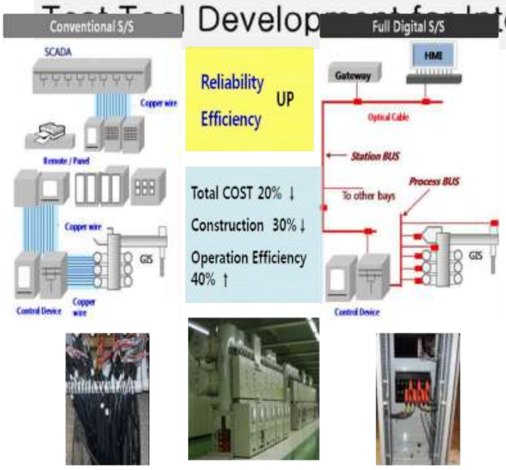


R&D Plan for IEC61850 SAS in Korea

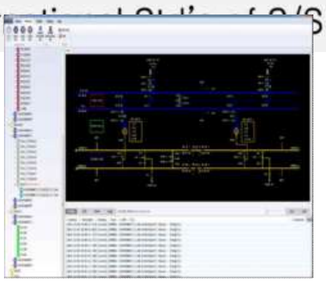
◆ Future Substation Platform in KEPCO

- **Engineering Tool and Test System for IEC 61850 Ed 2**

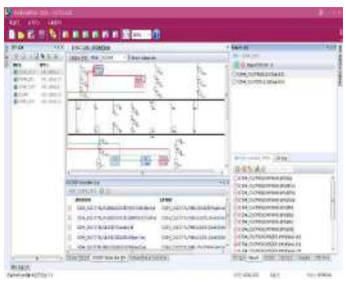
Test Tool Development for International Study of S/S Digital Communication



< Over view of Technology>



< Virtual Server >



< Engineering Tool >

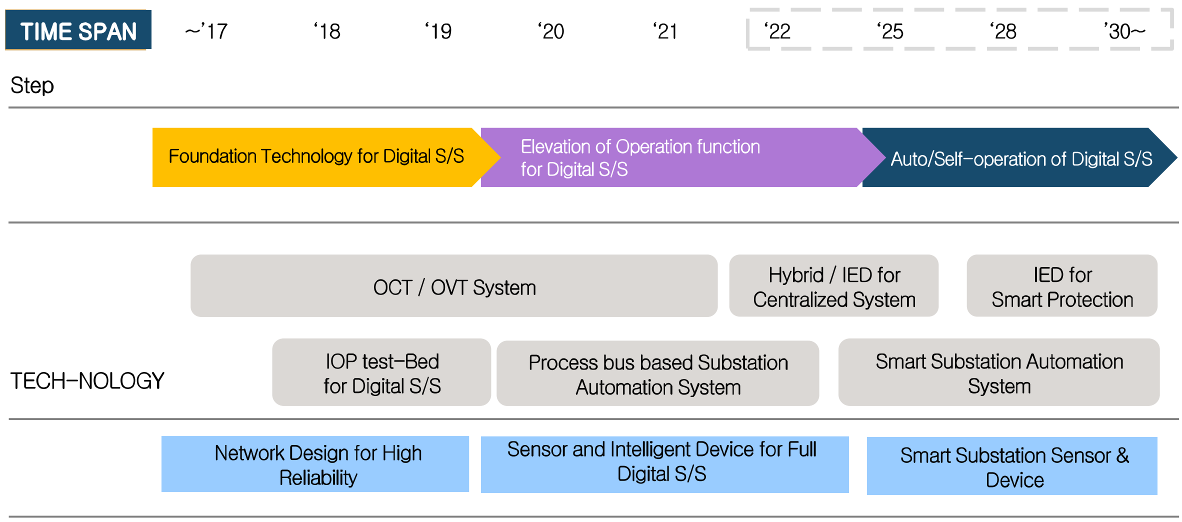
Core Technology

- Engineering Tool for Verification
- Virtual Server for Protection and Control
- HMI, S/W package, Communication Device, Test tool

R&D Plan for IEC61850 SAS in Korea

◆ Future R&D Plan for SAS in KEPCO

■ Business & Product Roadmap



2018 IEEE Japan Forum

THANK YOU

Application of Wearable Devices for Efficient Maintenance Work of Transmission Lines

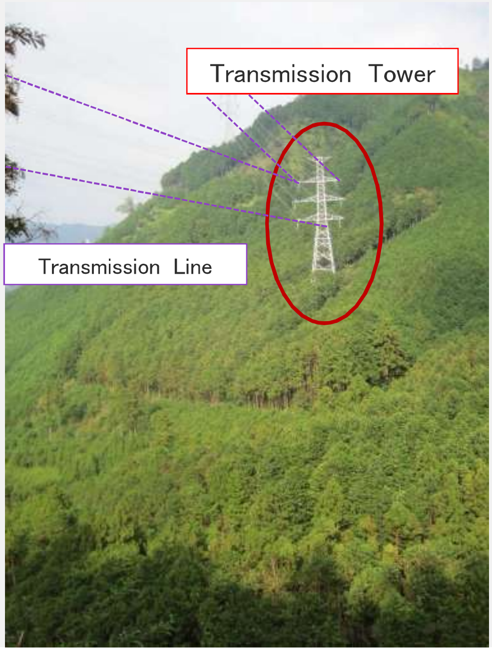
Kenichiro YAO

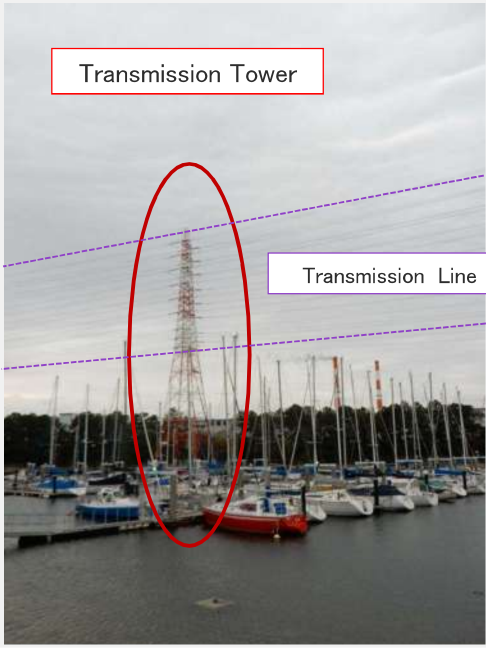
CHUBU Electric Power

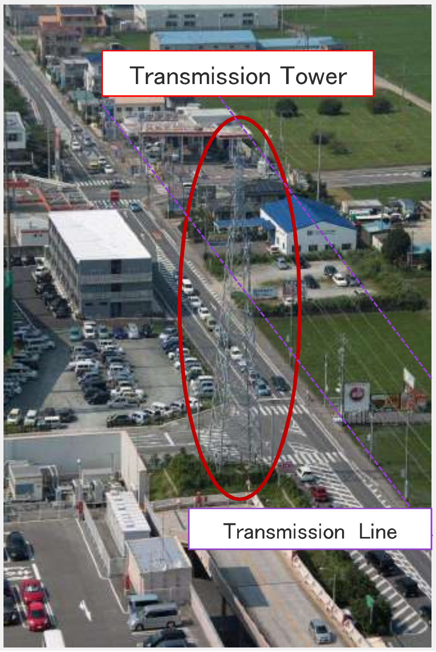
CHUBU Electric Power

The towers of power transmission line built in various places.

Mountainous Area	Coastal Area	Urban Area







Each of them has its own characteristics. There are various kind of problems in maintenance.

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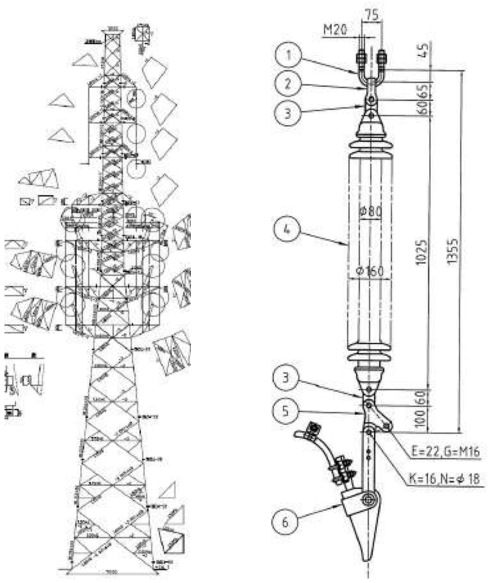
1. A lot of Data is necessary for Maintenance Work.

Design books and documents



Specification of Equipment

Item	Spec
Tower	○○line №.4
Construct year	1988/5
Voltage	77KV
Insulation Area	C
Height	53m
Weight	21.8t
Foundation	Pile
Foundation Size	1078N
Latitude	136° 56′ 54″ 400
Longitude	35° 03′ 26″ 100

Past maintenance data

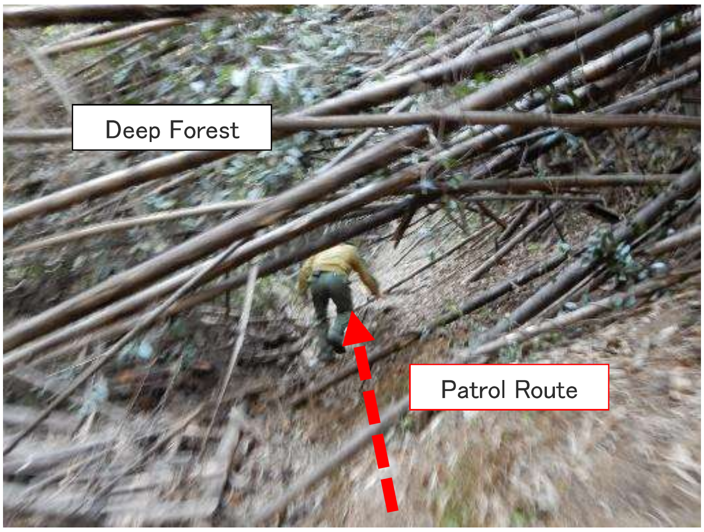
Check Date	Facility trouble data	Corresponding Date
1996/06/01	AAAAAAAA	1997/10/05
2015/11/08	BBBBBBB	2016/05/20
2015/05/18	CCCCCCC	2015/11/20
2014/06/08	DDDDDDD	2015/02/02
2009/11/24		2010/05/18
2009/04/24		2009/04/24
2004/07/04		2004/07/22
2003/08/08		2003/08/12

The maintenance worker can not bring all the documents on an mountainous patrol route.

01 | Background and Objective (3)

2. Maintenance Work in Mountainous area.

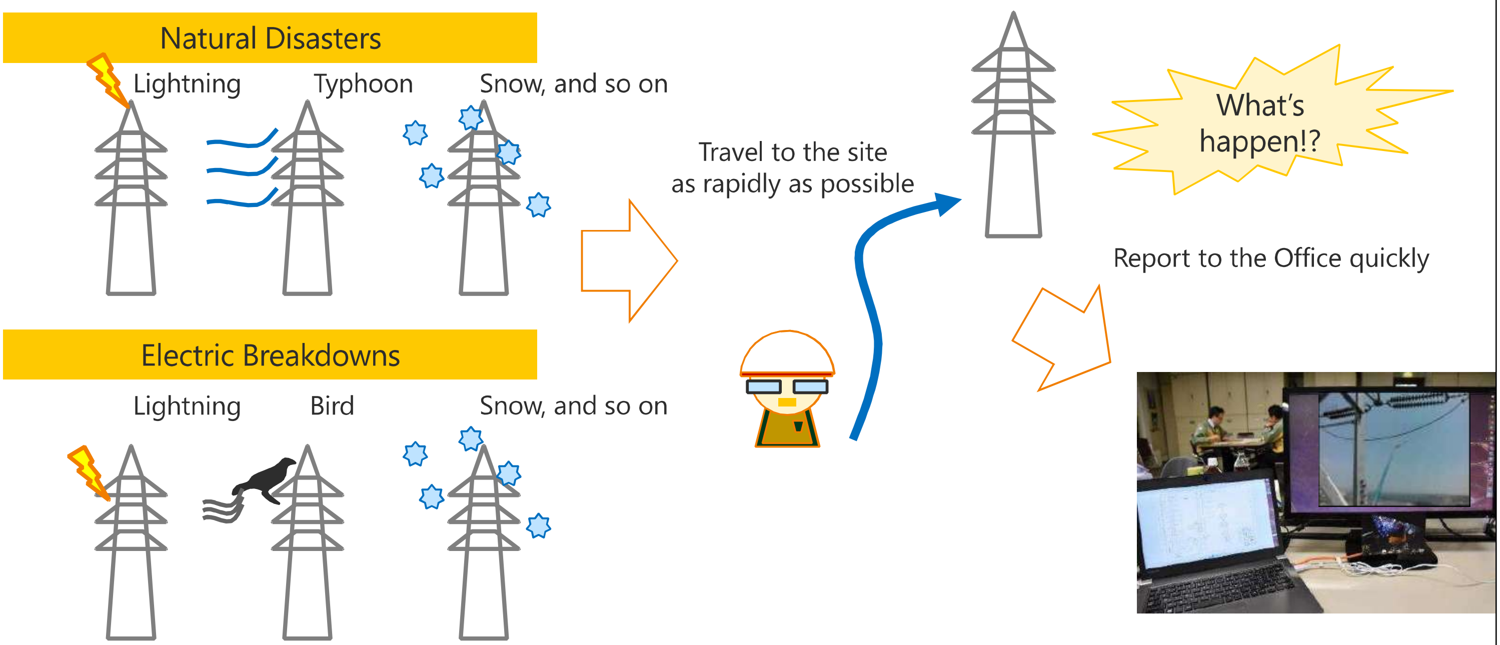
Patrol Route



The worker want a good tool to avoid losing their way in mountainous areas.

01 | Background and Objective (4)

3. Natural Disaster and Electric Breakdown.



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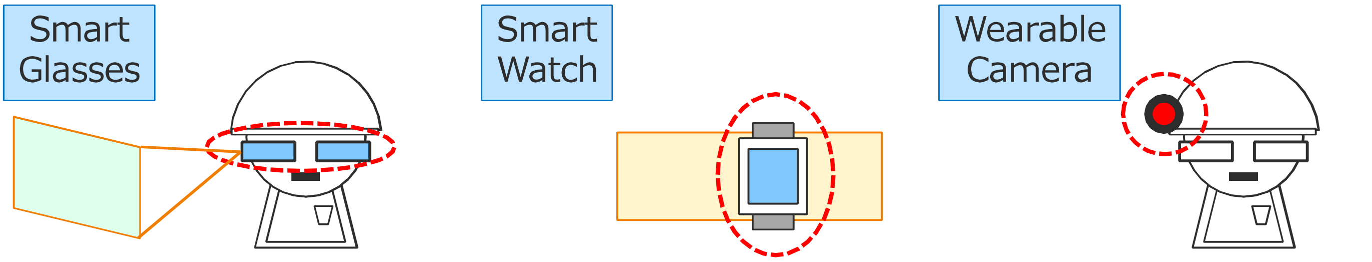
Wearable Devices are Useful

We need to solve these problems for efficient maintenance.

Wearable devices are useful.



Wearable devices realize the **hands-free** operation and has the feature that can handle a **large amount of data**.

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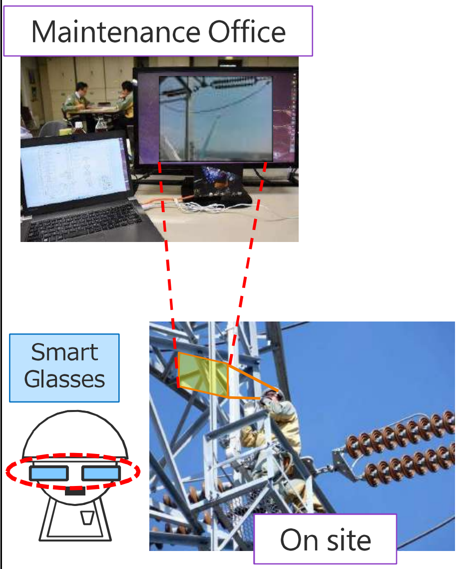
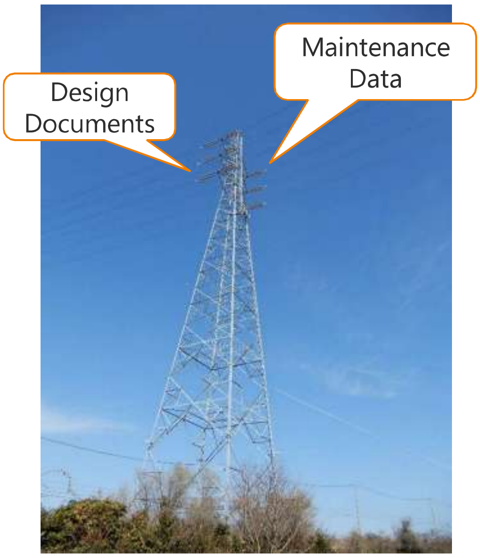
Three types of System with Wearable Devices.

① Real-time communication



② Maintenance Assist



③ Mountain Walk Navigation

※AR=Augmented Reality

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Real-time Communication System.

Report (video and voice)

On-site

Smart Glasses (BT-300) ⇔ Wi-Fi ⇔ Mobile Router

Cloud Server

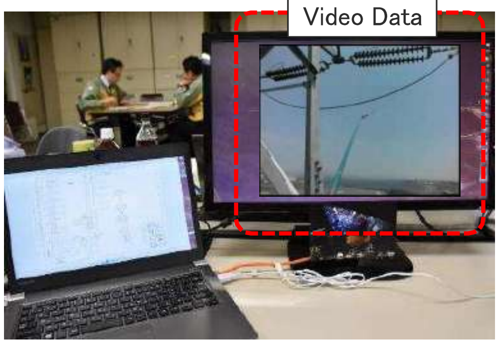
Mobile Network ← Network → Mobile Network

	Wearable Device Specs
Device type	Eye glasses type Smart Glasses
Maker/Model	EPSON/BT-300
Display type	See-through over the glasses
Sensor	GPS･Gyroscope Accelerometer･Compass
Weight	Headset：69g

Maintenance Office

Mobile Router ⇔ Wi-Fi ⇔ PC

Video Data



Advice

The Administrator wants to check the site in real time.

- Natural disaster and electrical breakdown.
- Monitoring construction site.
- Inspection and operation.

Check Points

- Communication quality of voice and video between the worker on site and the maintenance office.
- Influence of induction from voltage applied conductor. (Transmission line and substation)
- Communication quality in underground manhole.

Result of Verification test On-site

Video data Image

Tower of Transmission line	In Manhole	Substation
		

Advantage Point

- Communication quality is good
- Influence of voltage application has no problem for data communication

Problem

- Noise of the wind sound
- In manhole, Network was torn down and sometimes Interrupted
- Time Lag

The Improvement points of the System.

Time Lag

Previous System

Time Lag : 1 ~ 6 second

Danger (Near High voltage)

Improved System
(Data compression and Bandwidth adjustment)

Time Lag : 1 second

Multiple Communication

Tower

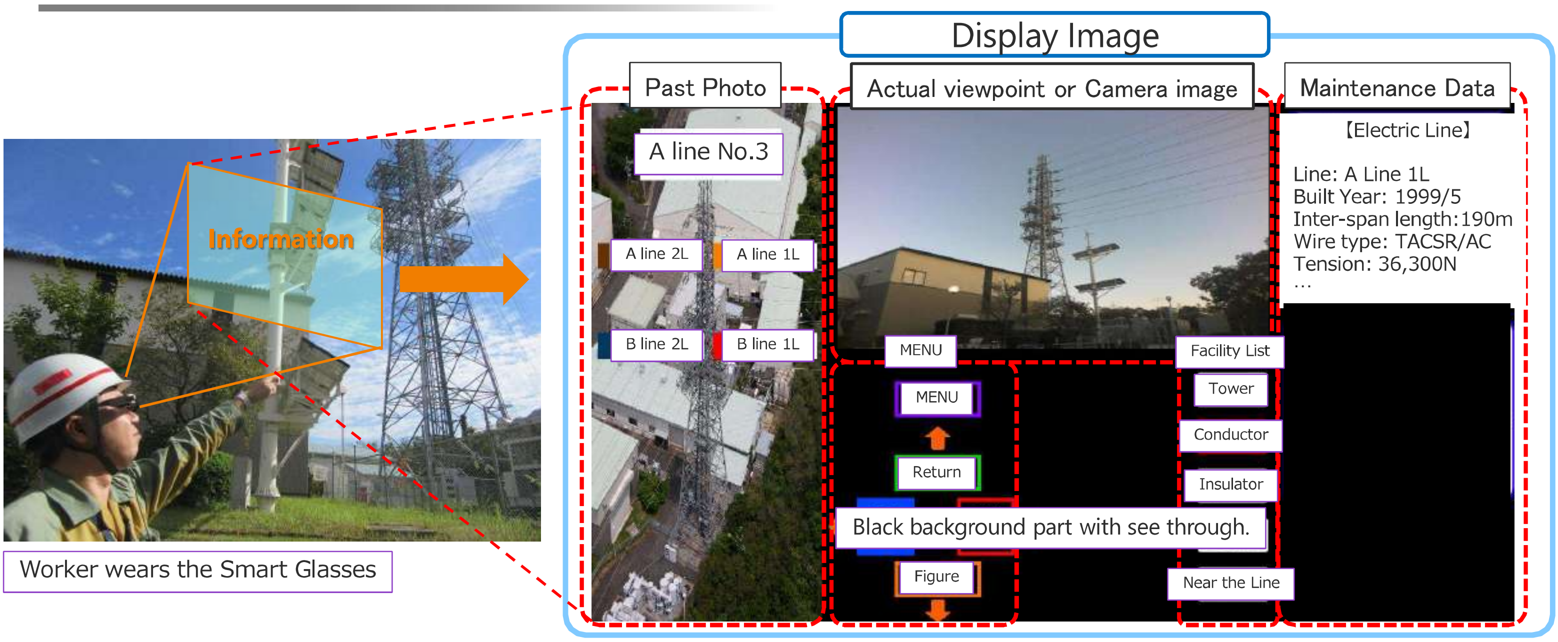
Office

Ground

INDEX

Application of Wearable Devices for Efficient Maintenance Work of Transmission Lines

Display Image about Maintenance Assist System



Advantage Point

- Hands−free
- Paperless in on-site work
- Efficient Maintenance

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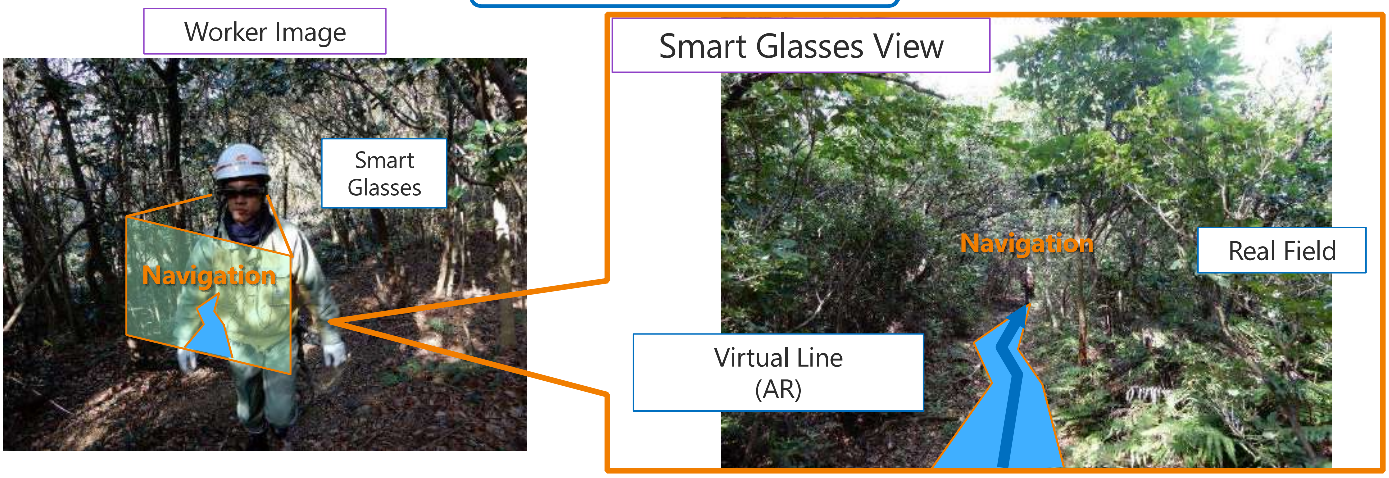
Application of Wearable Devices for Efficient Maintenance Work of Transmission Lines

CHUBU Electric Power

Mountain Walk Navigation System

System Image

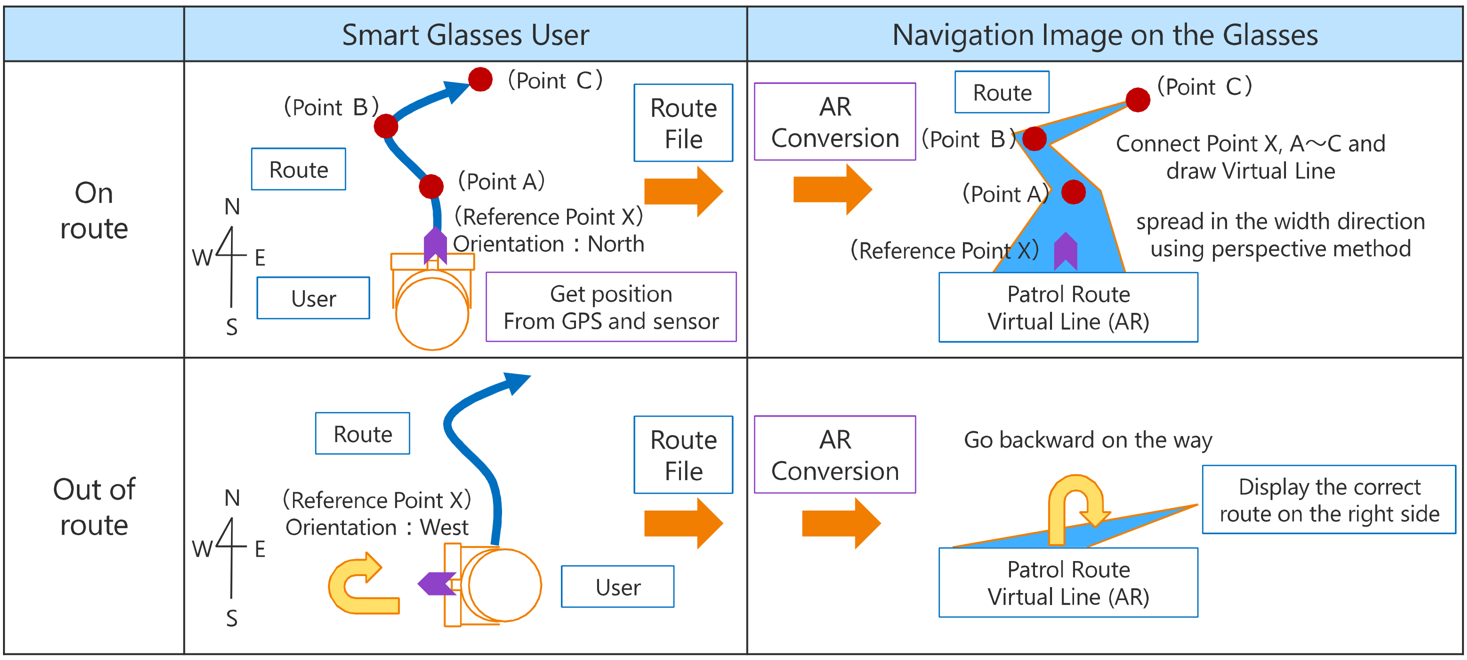


	Wearable Device Specs
Device type	Eye glasses type Smart Glasses
Maker/Model	EPSON/BT-300
Display type	See-through over the glasses
Sensor	GPS・Gyroscope・Accelerometer・Compass
Weight	Headset ：69g

※AR=Augmented Reality

CHUBU Electric Power

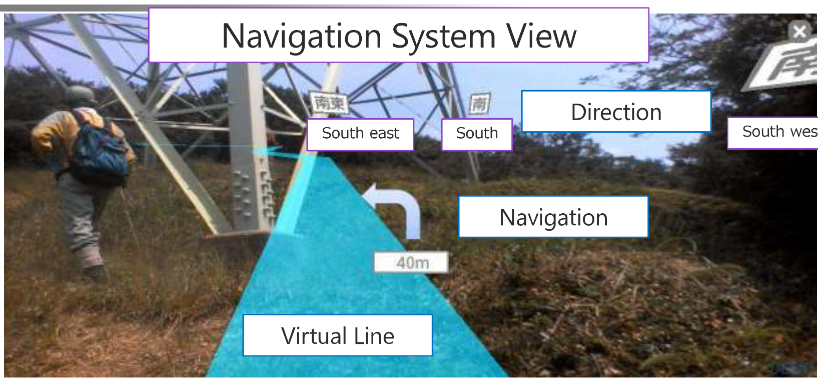
Draw the Navigation Image



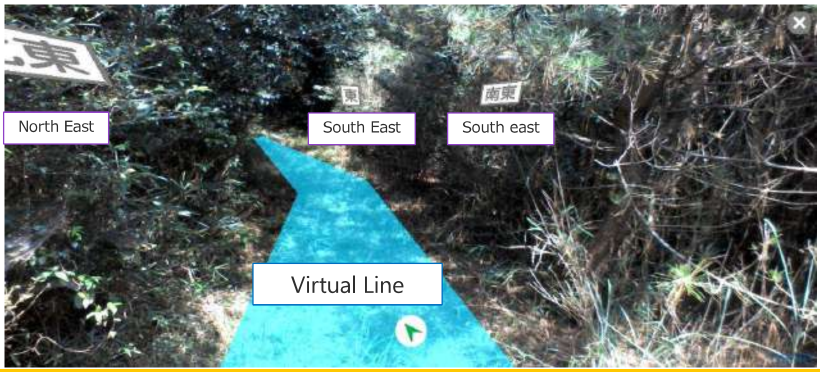
Result of Verification test On-site

Navigation System View

① Tower



② Forest Patrol Route



Worker Image

Actually See-through Real Viewpoint and AR image can be overlapped.

we can investigate the patrol route for two hours, whose distance is about 1.5 km

INDEX

Application of Wearable Devices for Efficient Maintenance Work of Transmission Lines

● Conclusion

○From the results of a variety of verification test on-site, it is confirmed that smart glasses are useful for the maintenance work of transmission lines.

① Real-Time Communication System

- The worker easily communicate to maintenance office for the transmission line tower and substation while using both hands.
- The system improved to decrease time lag and realize multiple communication.

② Maintenance Assist System

- The system easily enables a large amount of data by hands-free operation to verify the necessary facility data, past photo data, maintenance data, and so on.

③ Mountain Walk Navigation System

- The system can guide the patrol route on a long distance using AR technique .

Thank you for your kind attention

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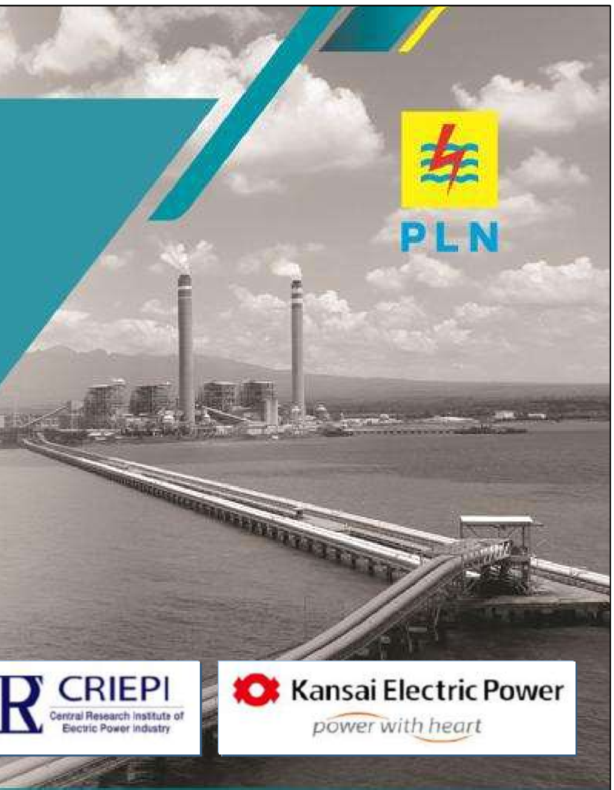
(at)→@

The feasibility of PV for Distributed Power Generation; an assessment of PV Farms for replacing Diesel in Indonesia



Dr. Zainal Arifin
PT. PLN (Persero) – Indonesia

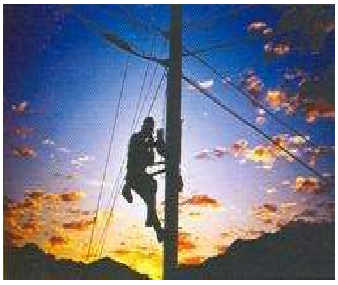
The 18th IERE General Meeting & Japan Forum
Kyoto - Japan, 21 - 24 May 2018

IERE | CRIEPI Central Research Institute of Electric Power Industry | Kansai Electric Power power with heart

www.pln.co.id

Who we are ...

One of the largest Indonesia's state owned company within USD 90.9 billion assets and revenue USD 18.2 billion (2015)
PLN is 477 of 500 FORTUNE (2014)



Power Generation

Total capacity 52.9 GW:
- 42 GW (80%) PLN
- 10.9 GW (20%) IPP

Source : PLN, September 2016

Transmission

- 41.600 kms Transmission line
- 92,600 MVA Power transformers

Distribution

- 809,090 kms Distribution lines
- 50,150 MVA Distribution transformers
- Over 62 million customers (more than 22.2 million using pre-paid meter)

BACKGROUND

1. Based on REN21's 2017 report, renewables contributed 19.3% to humans' global energy consumption in 2015 and 24.5% to their generation of electricity in 2016.
2. As of 2016, solar power provided just 1% of total worldwide electricity production but was growing at 33% per annum.
3. Indonesia has an aggressive goal to increase the share of renewable energy in the country's energy mix to 23 percent by 2025.
4. Yet Indonesia still operates Diesel station within 4.665 units and capacity 3.534 MW as Distributed power generation for electrifying rural areas especially in some isolated islands.
5. The development of Solar power (PV farm) as Distributed power generation in Indonesia still have some drawbacks due to some determinant factors; technical, financial, human resources, policy etc.

RESEARCH OBJECTIVES

RESEARCH QUESTION:

1.How feasible the PV (photo voltaic farm) as Distributed power generation replacing Diesel station for electrifying some rural areas Indonesia?

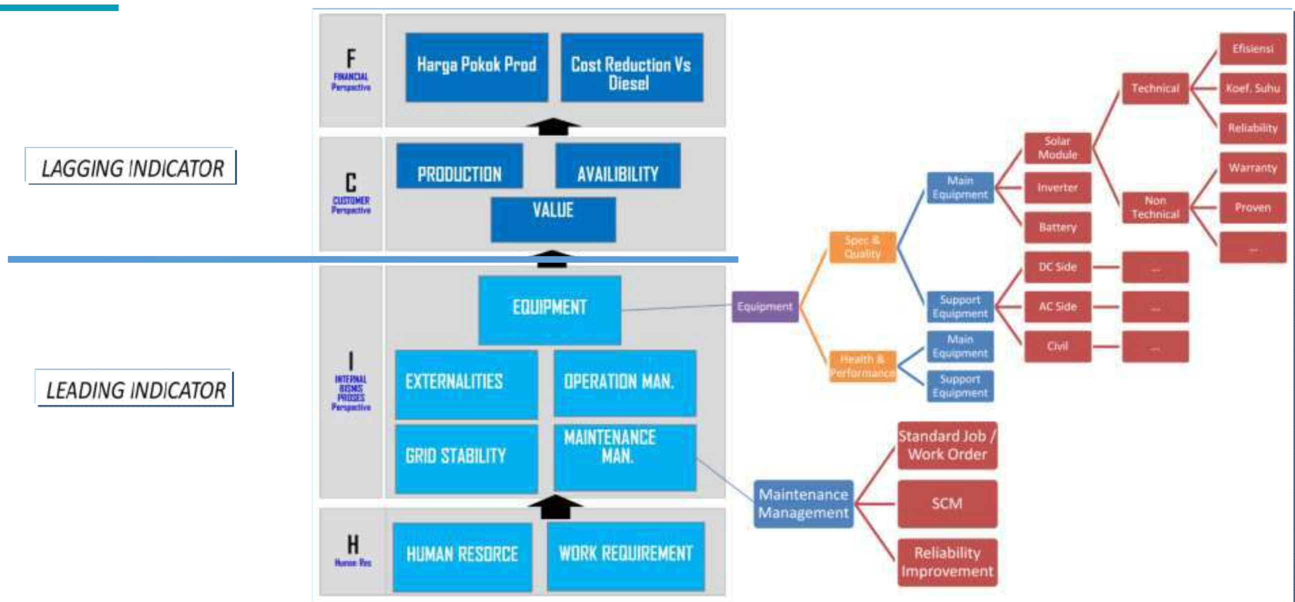
2.Is PV farm technically feasible, economically viable, sustainable, and socially equitable solution to the future of society's energy requirements?

RESEARCH GOAL:

1.To set-up a guideline assessment for PV evaluation and implementation process based on asset management approach.

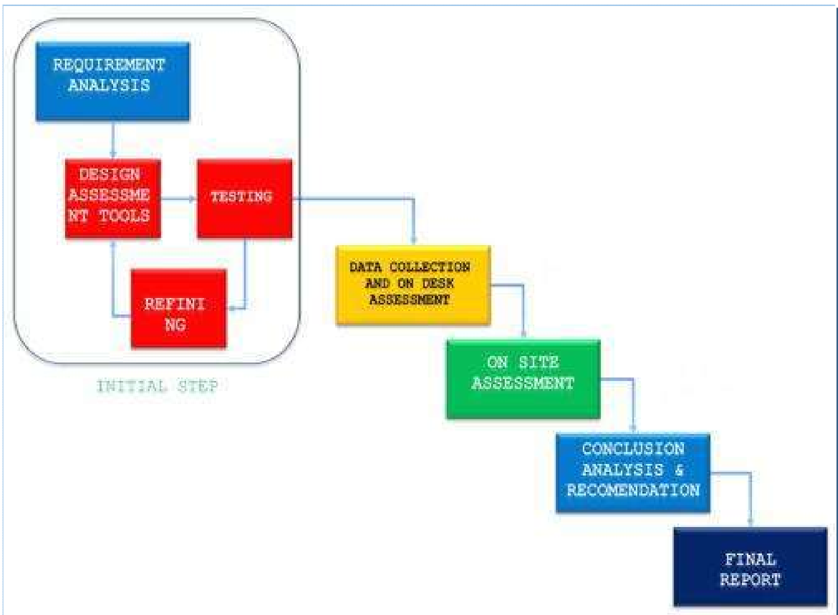
2.To provide an overview of PV farms existing conditions as well as doing portraits gap analysis assessment of PLN's PV projects viewed from various perspectives.

METHODOLOGY



"Balance Score Card within Tree Data Structure"

PROCESS AND PERSON



TEAM QUALIFICATION:

1.Finance Expert
2.Operation & Maintenance Expert
3.Asset Management Expert
4.PV Expert
5.Electrical Engineer
6.Control & Communication Network Engineer
7.Civil & Construction Engineer
8.Environment & CSR Analyst
9.IT Engineer

MEASUREMENT

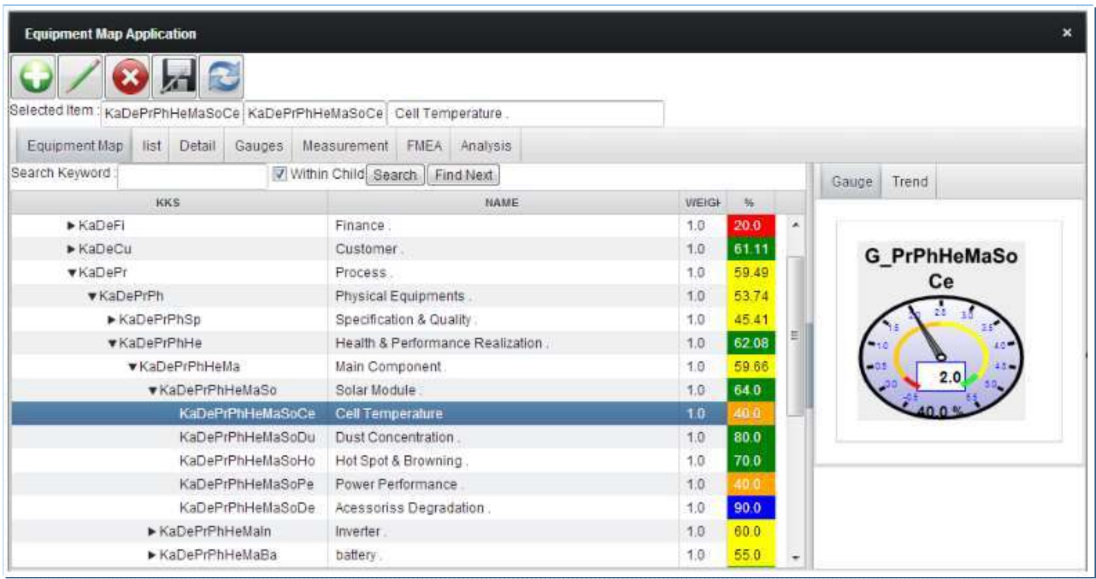
Variabel Proses :

Index *Level*	% Skor	Kategori skala	Keterangan skala	Estimasi umur PLTS
0	0	*Unsustainable*	Keberlangsungan tidak bisa terjadi	< 3 Tahun
1	20	*Minimum*	Minimal agar mampu bertahan / *sustain*	5 Tahun
2	40	*Corrective*	bersifat reaktif & mulai ada perencanaan	10 Tahun
3	60	*Improvement*	Terdapat peningkatan berkesinambungan	20 Tahun
4	80	*Best Practice*	Telah matang dan telah berkembang	25 Tahun
5	100	*World class*	Standar kelas dunia atau melebihi	> 25 Tahun

Variable Equipment :

Index *Level*	% Skor	Kategori skala	Keterangan skala	Estimasi umur PLTS
0	0	*Unsustainable*	Spesifikasi Teknis tidak bisa berlangsung	< 3 Tahun
1	20	*Unreliable*	Spesifikasi Teknis tidak handal	5 Tahun
2	40	*Just Enough*	Spesifikasi Teknis cukup	10 Tahun
3	60	*Reliable*	Spesifikasi Teknis handal	20 Tahun
4	80	*High Reliability*	Spesifikasi Teknis sangat handal	25 Tahun
5	100	*World class*	Spesifikasi Teknis Kelas dunia atau melebihi	> 25 Tahun

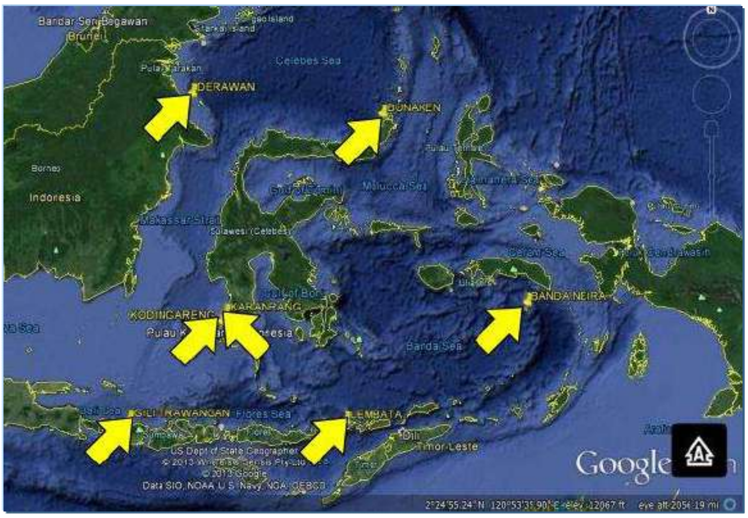
SCORING



The research defined 12 KPAs with 34 KPIs which has at least 108 point variables scoring based on description for each KPIs.

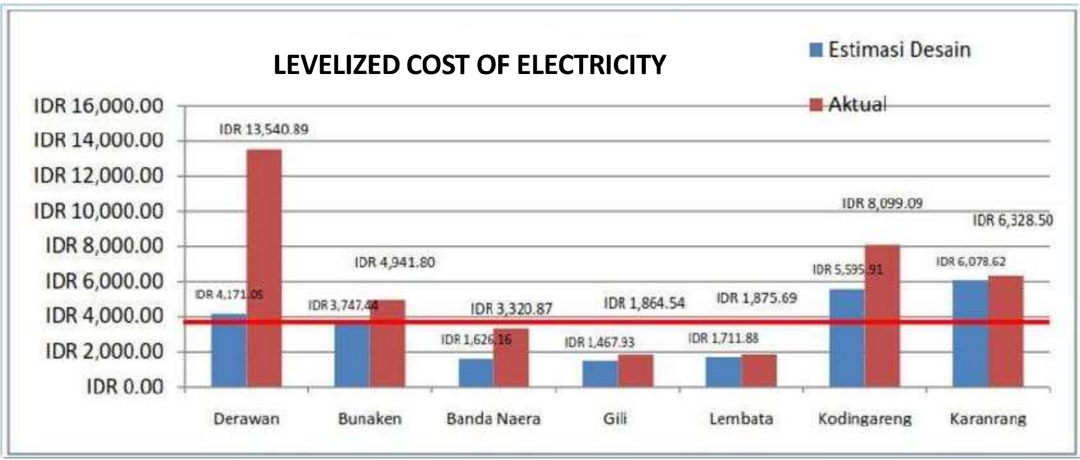
UNIT ANALYSIS

No	PV power station	Capacity (kWp)	Operation
1	Gili: -Gili Trawangan -Gili Air -Gili Meno	 600 160 60	Day – On Grid
2	Derawan	170	Day – Off Grid
3	Bunaken	335	Day – Off Grid
4	Lembata	200	Day – On Grid
5	Banda Neira	100	Day – On Grid
6	Kodingareng	150	Night – Off Grid
7	Karanrang	200	Night – Off Grid



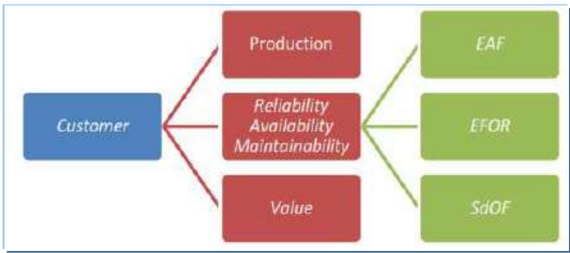
- *Day - On Grid,* the solar power operate only at the day for 8-12 hours supplies to the existing small grid within other power supply.
- *Day - Off Grid,* the solar power operate only at the day for 8-12 hours, independence and isolated; not connected to the grid.
- *Night - Off Grid,* the solar power supply electricity only at night for 8-12 hours independently and isolated.

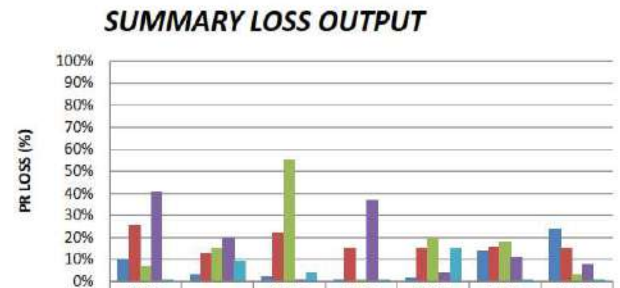
ANALYSIS - FINANCIAL



Based on the study, the LCOE of PV is following;
•*Day - On Grid* : Rp 1,200 – 1,800 / kWh (0.1 – 0.15 US$/kWh)
•*Day - Off Grid* : Rp 3,200 – 3,600 / kWh (0.27 – 0.3 US$/kWh)
•*Night - Off Grid* : Rp 5,900 – 6,500 / kWh (0.5 – 0.54 US$/kWh)
On the other hand the LCOE of Diesel station at the same or near location of PV is on average Rp 3,900 – 4,500 / kWh (0.3 25 – 0.375 US$/kWh).

ANALYSIS - COSTUMER



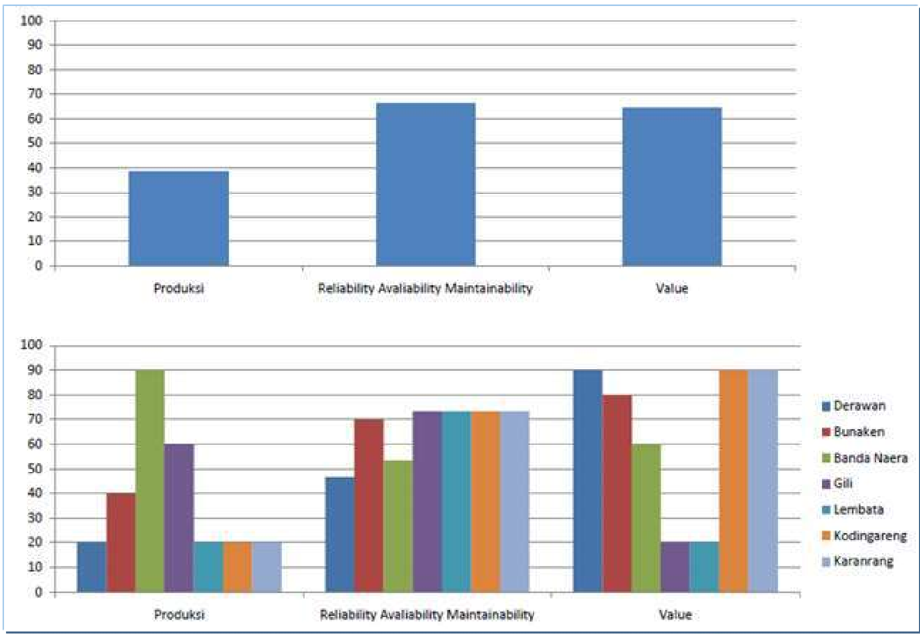


	PLTS DERAWAN	PLTS 3 GILI	PLTS BUNAKEN	PLTS LEMBATA	PLTS BANDA NAERA	PLTS KODING ARENG	PLTS KARAN RANG
ENG, DESIGN, CONSTR.	10%	3%	2%	1%	2%	14%	24%
EQPMNT. CHAR	25%	13%	22%	15%	15%	16%	15%
MAINT / EQ. FAIL	7%	15%	55%	1%	20.00%	18%	3%
OPERATIONAL	41%	20%	1%	37%	4%	11%	8%
EXTERNALITIES	1%	9%	4%	1%	15%	1%	1%

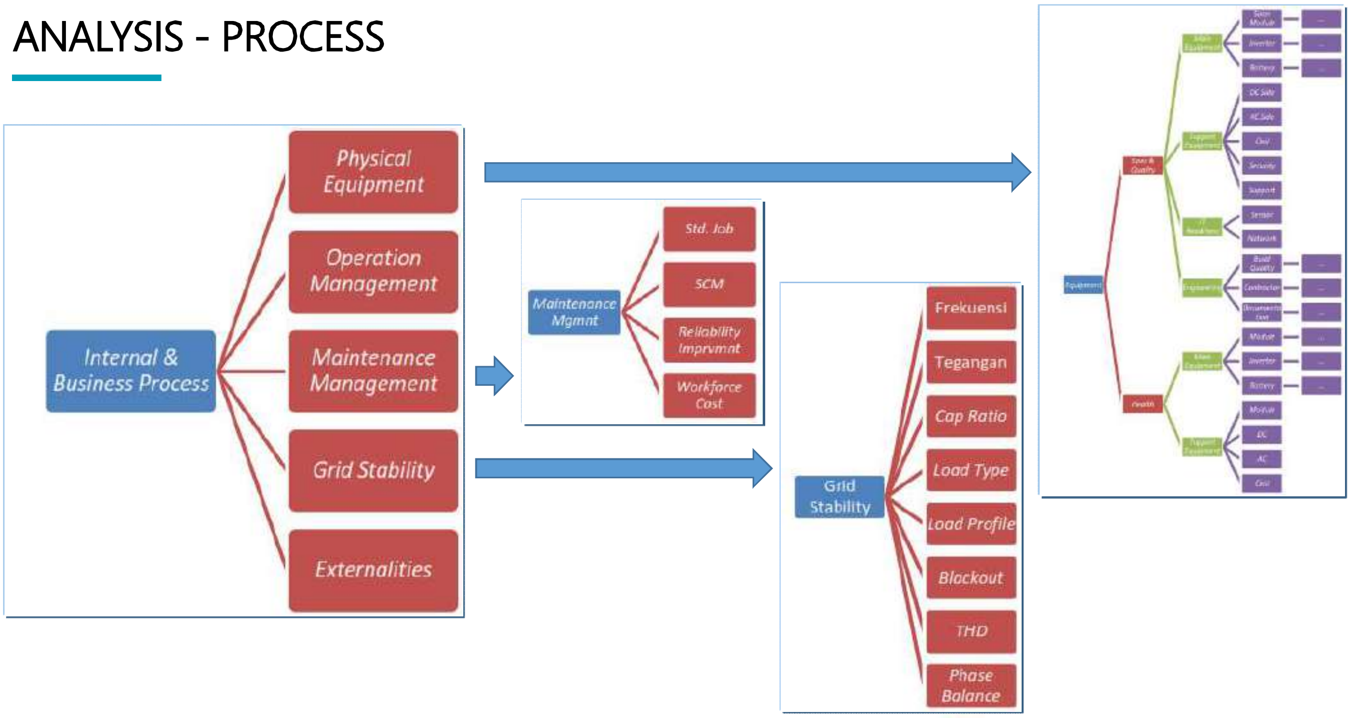
Based on field assessment and measurements, the all PV farm production is relatively low within kWh production is below than 50% of its installed capacity on average.

Meanwhile the availability (EAF) of all PV farm is relatively good but the SdOF (Sudden Outage Factor) is poor affected by the grid quality or other externality factors.

ANALYSIS - COSTUMER

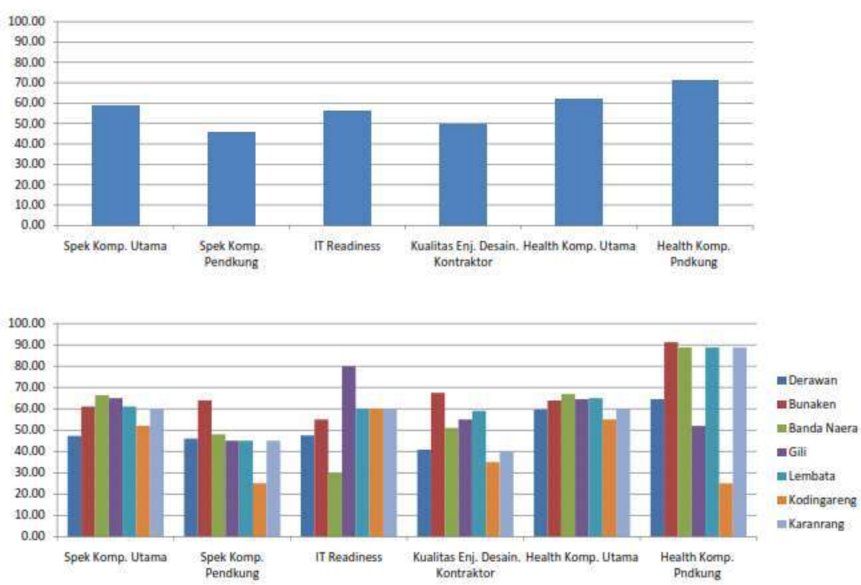


ANALYSIS - PROCESS



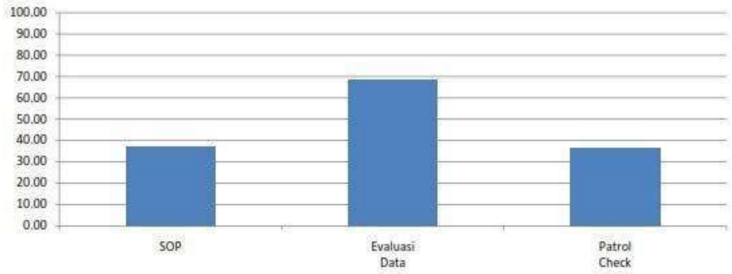
ANALYSIS – PROCESS → EQUIPMENT

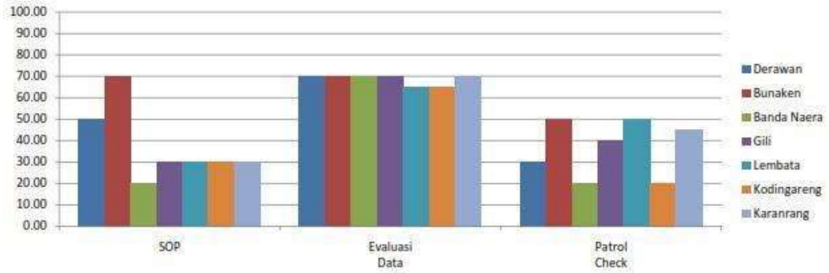
1. The majority of equipment specifications → median range of quality.
2. Their performance and condition → healthy range category with some note.
3. Whereas "Build Quality" PV contractor's work of most equipment → median-good quality category.



ANALYSIS – PROCESS → OPERATION

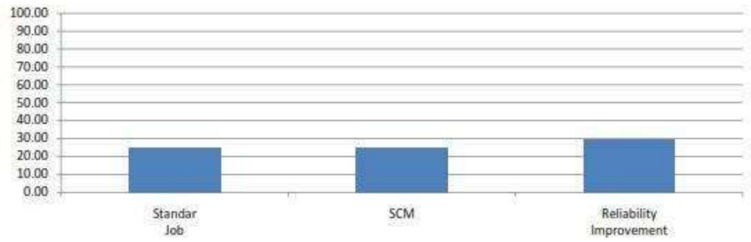
1. The maturity level of SOP and Patrol check status is still low which the sore is only 38% of the world class level.
2. No data analysis yet to evaluate the PV performance regularly.

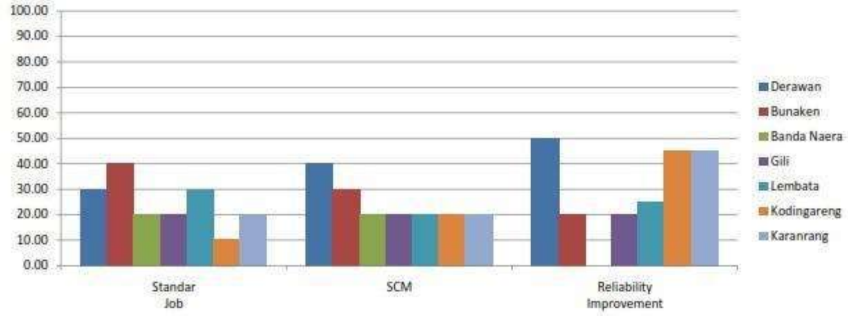




ANALYSIS – PROCESS → MAINTENANCE

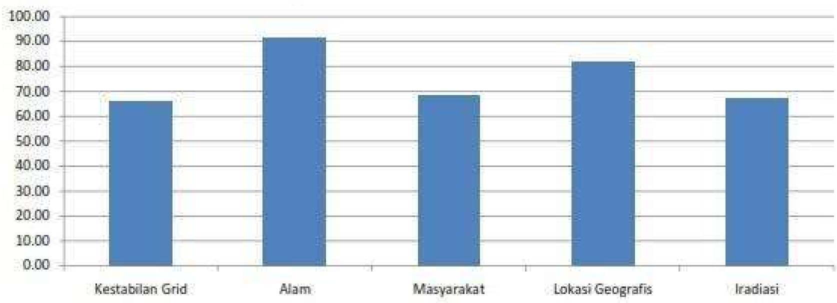
1. Overall, all of three indicators (standard job, supply chain and improvement) are low level which score is below 30.
2. The score of job standard is very poor which is only 25, the supply chain is also 25 and reliability. improvement is about 30.
3. While the PV inventory system is still poor and not supports an effective maintenance process.

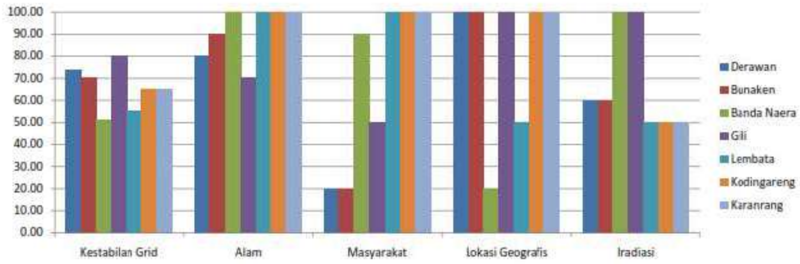




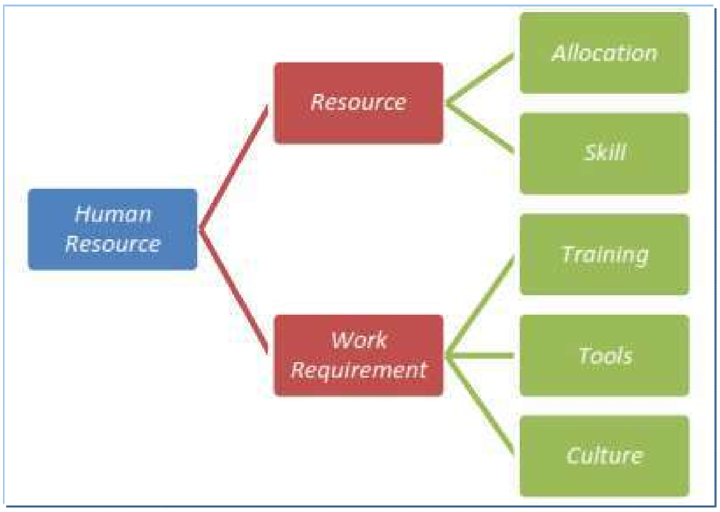
ANALYSIS – PROCESS → GRID STABILITY & EXTERNALITIES

1. The power quality of grid at most PV's are already well performed with some notes .
2. The operation disruption is more affected by human factors rather than externally natural factors.
3. However natural external factors such as irradiation, affects significantly the operational then economical feasibility for all PV farms.





ANALYSIS – HUMAN CAPITAL

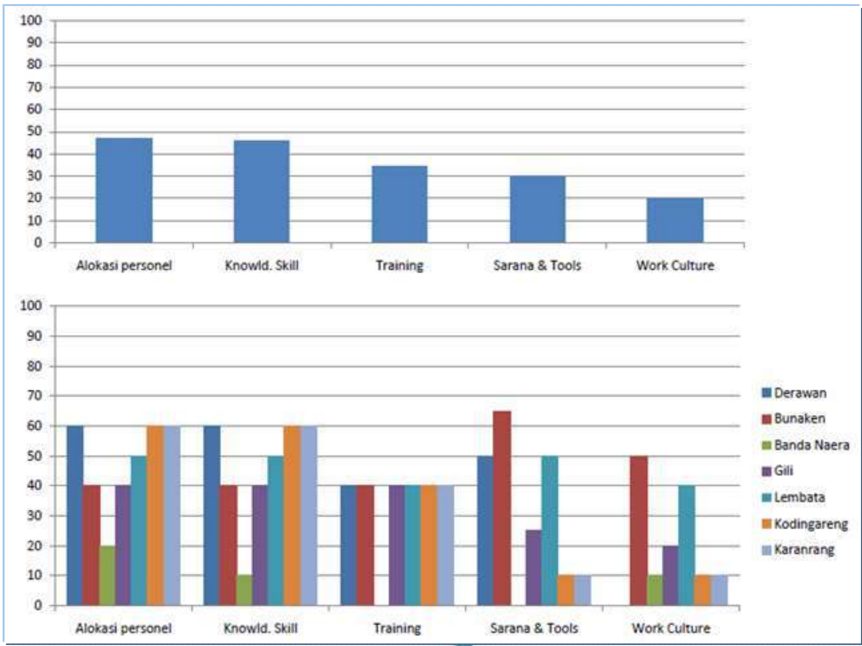


1. Most PV fam have met the minimum standard allocation of personnel and their skill. They have sufficient technical operator who do the patrol check routines. The operators have passed basic training of operational and maintenance periodic.
2. Yet maintenance technician to do repair and junior engineer to perform analysis and evaluation are relatively limited.
3. Tools for the minimum operational requirements and regular maintenance are less available.

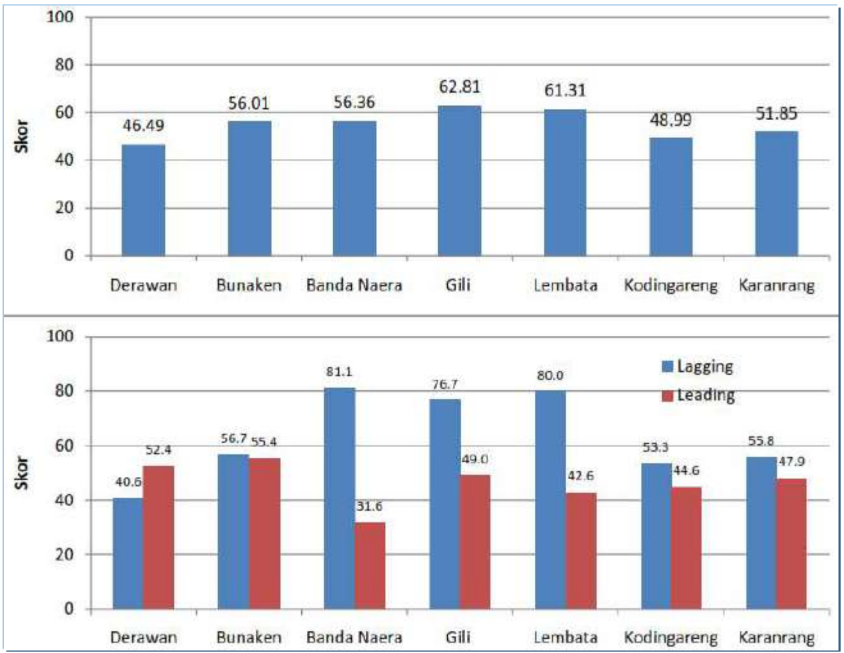
ANALYSIS – HUMAN CAPITAL

Instead of technical matters, there are other factors affecting to human resources altitude such as availability of tools and equipment, limitation of allocated operator for shift working and less attention from stakeholder to PV operational.

In summary, human resources can be seen as the figure.



RESULT



FINDINGS

1. PV is potential to replace Diesel power in Indonesia at these following conditions:
- PV On Grid (without battery) at all places
- PV Off Grid - day time (PV stand alone with sufficient battery as a buffer) at all places
- 24 Hours Off Grid Solar PV (PV stand-alone modules and battery capacity is able to meet the needs of 24 hours) in some areas in Indonesia
2. However PV is not able to compete with Diesel yet for 24 hours Off Grid operation with irradiated below 5 kWh /m^2 /day (5 hours or Equal Sun Hour).
3. Referring to the tree structural data analysis, the cause of PV farms low production is "solvable".
- That causes are a normative technical problems, an incidental occurrence, as well as operational issues.
- Equipment of PV is in a relatively healthy condition and has good specification.
- The majority of low production problems can be solved by increasing awareness of PV and competencies of human resources.

CONCLUSION

1. Empirically PV farm is highly potential and feasible to replacing Diesel station for Distributed power generation at certain condition.
2. Balanced Score card within tree data structure is effective to set-up a guideline assessment for PV farm performance and implementation process.
3. The tool can provide an overview of PV farms existing conditions as well as doing portraits gap analysis of PV projects viewed by comprehensive perspectives.

PLN

THANK YOU

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国家电网公司
STATE GRID CORPORATION OF CHINA

Mobile Sensing and Interactive Diagnosis Technology for Power Cable Lines

China Electric Power Research Institute

May 2018

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Part I: Existent Issues of Operation and Maintenance of Power Cable Lines

Scale of distribution cable and its increasing trend of SGCC

- A total length of nearly **600,000km**;
- Increasing at an average annual growth rate of **15%**.

PROBLEMS

- Difficulties in inspection
- Restrictions for live detection
- Restrictions for online monitoring

Existing difficulties in inspection of power cables

- Method is not varied;
- Utilization rate of inspection data is low;
- Inspection Personnel cannot get condition information in real time;
- Inspection cycle and Inspection effect are difficult to implement;
- Inspection process is not standardized.

➢Restrictions for live detection

Massive devices vs. limited manpower	Along with the all-round promotion of live detection, the contradiction between the **huge** number of devices and the **limited** manpower become increasingly worse.
High demands on testers	Live detection work has high demands on testers, while testing personnel's quality is generally not high.
Huge workload of arranging test data	The workload of arranging test data is huge in an unstandardized and incomplete way.
Safety risk to testing personnel	Great challenges have been posed to the safety of testers, since large number of measure points on site are near the high voltage parts.

Part I: Existent Issues of Operation and Maintenance of Power Cable Lines

➢Restrictions for online monitoring

Unsatisfactory quality of equipment	Equipment are affected by high failure rate, short service life, large maintenance workload, bottleneck of the power supply and difficulty of communication.
Unsatisfactory performance	Data accuracy, stability, and real-time performance of the equipment are unsatisfactory.
Lack of online monitoring means	A complete breakthrough has not yet been achieved in on-line monitoring for important parameters of cable condition.
Low integration of equipment	The measurement data is not comprehensive because of low integration of equipment and sensors.

Part II: Outline of Mobile Sensing and Interactive Diagnostic Technology

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➢The ideas of mobile sensing and interactive dianostic technology

The condition of power cables and decision on power cable maintenance

Historical information

- Cable device quality
- Installation test
- Repairing history

Condition information according to detection

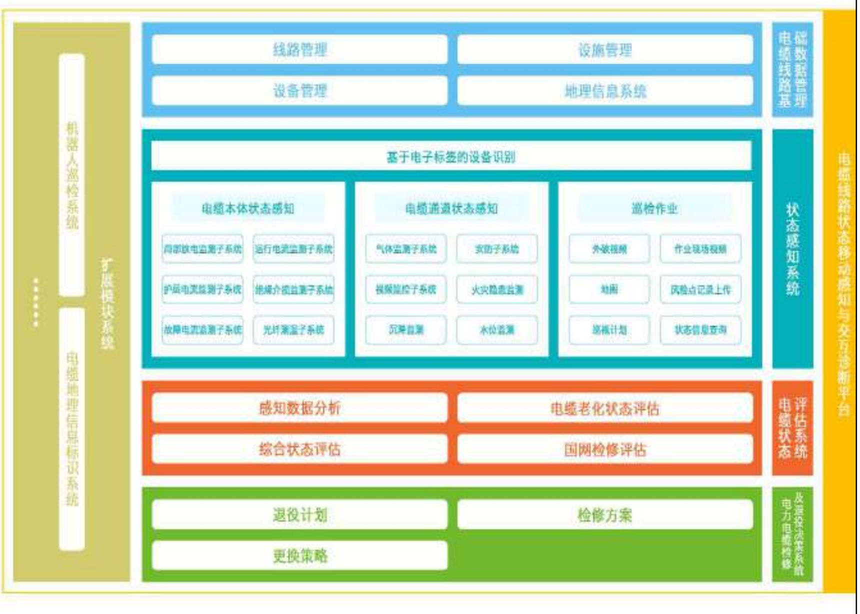
- Electronic tags
- Mobile terminal
- Sensing modules

Part II: Outline of Mobile Sensing and Interactive Diagnostic Technology

Core technologies

Maintenance decision-making	Life assessment
Multi-source heterogeneous data fusion diagnosis	Big data analysis
Mobile database	Operation and maintenance knowledge base
Mobile data synchronization	
Mobile terminal	RFID

Function diagram of mobile sensing and interactive diagnostic system for power cable lines



Part II: Outline of Mobile Sensing and Interactive Diagnostic Technology

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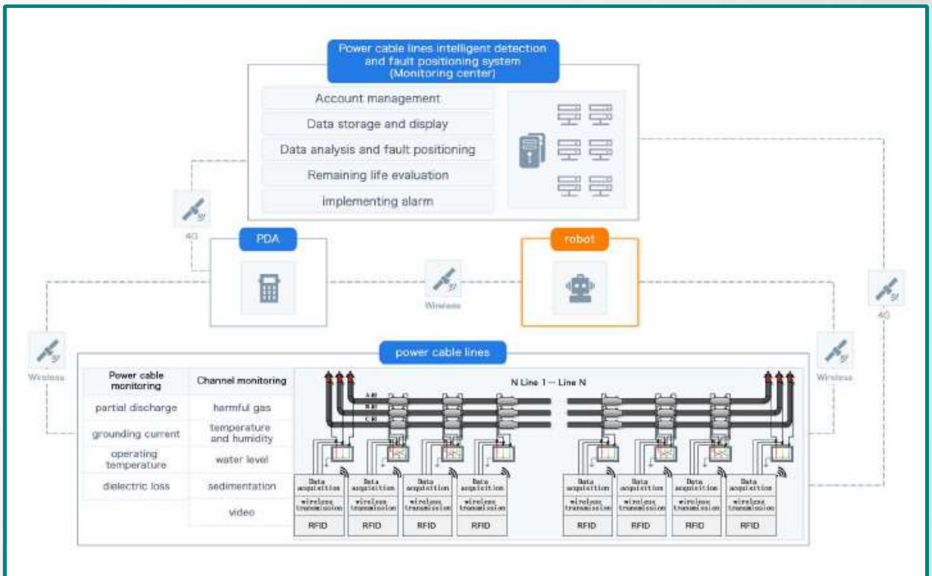
Component architecture

- Cable intelligent identifying tag components
- Detection components of power cable lines in operating state
- Non-contact data sending components for status information
- Intelligent inspection mobile terminal
- State interactive diagnosis and assessment system platform

Structural diagram of mobile sensing and interactive diagnostic system for power cable lines



Part III: Condition Mobile Sensing Components

Cable intelligent identifying tag components

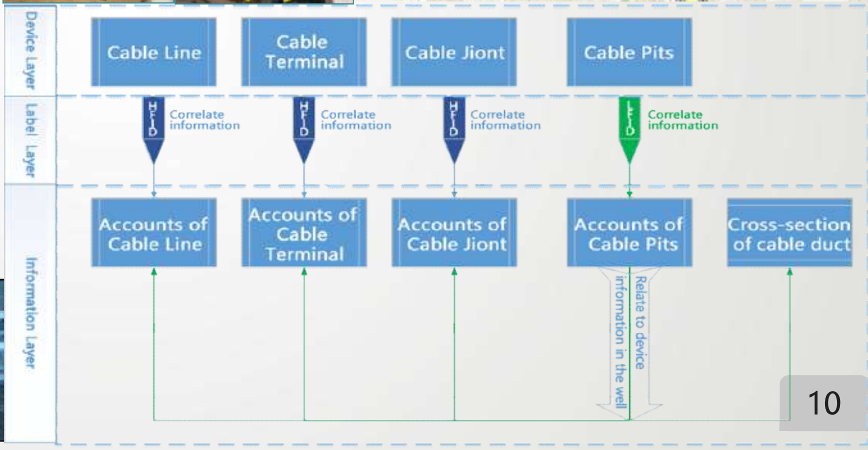
(1) Record basic account information of power cables;

(2) Asset management and identity label;

(3) Automatic linkage of wireless sending and receiving components;

(4) Quick and remote identification;

(5) Passive and high reliability;



Part III: Condition Mobile Sensing Components

Detection components of cable lines

(1) Condition data acquisition of power cable lines.

(2) Caching of operating state data.

(3) Modification of condition detection mode.

(4) Acquisition and push of abnormal data;

(5) Flexible and highly-reliable power supply;

Part III: Condition Mobile Sensing Components

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Non-contact data sending components

(1) Sending condition data of power cables lines.

(2) Self-assessment of operating state.

(3) Networking interaction of failure or risk warning information.

(4) Networking interaction of backstage and diagnostic information.

(5) Inspection record and risk point processing record.

(6) Compatibility with traditional online monitoring devices.

Basic information acquisition

intelligent control

Acquisition of device characteristics

Part III: Condition Mobile Sensing Components

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Intelligent patrol mobile terminal (PDA)

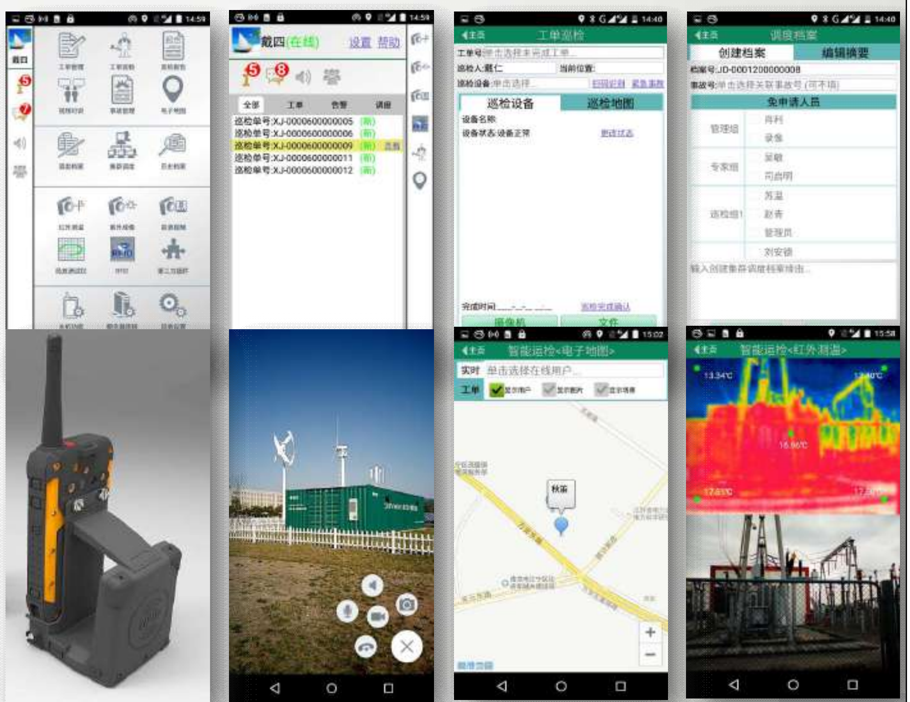
(1) Object information is obtained through sensing the electronic label;

(2) Power cable lines and channel state data are collected;

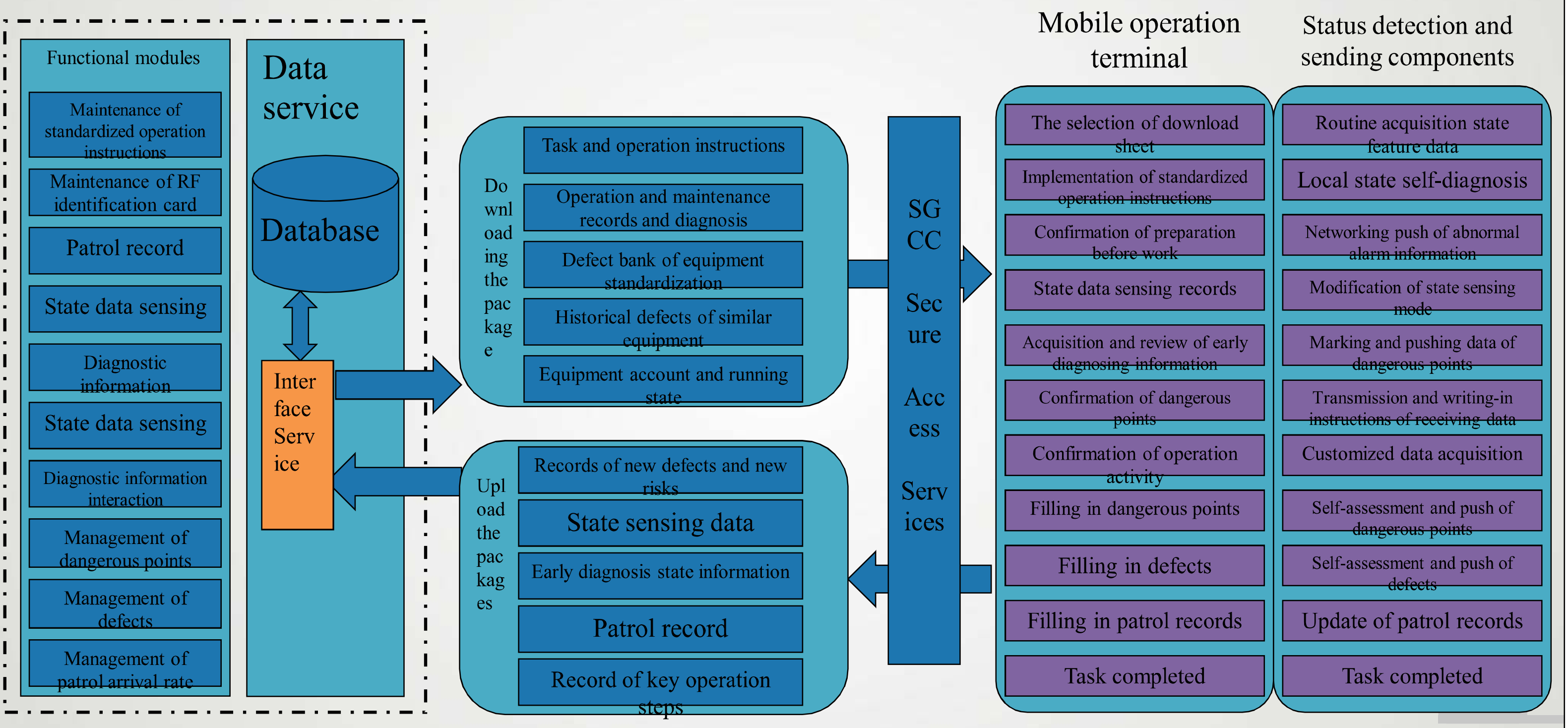
(3) Inspection plans and assistant inspection operations are received;

(4) Devices and facilities defects and hidden dangers are recorded;

(5) Data of the backstage platform are shared;



Part III: Condition Mobile Sensing Components



Part IV: Interactive Diagnosis and Assessment System

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Overview of Interactive Diagnosis and Assessment System

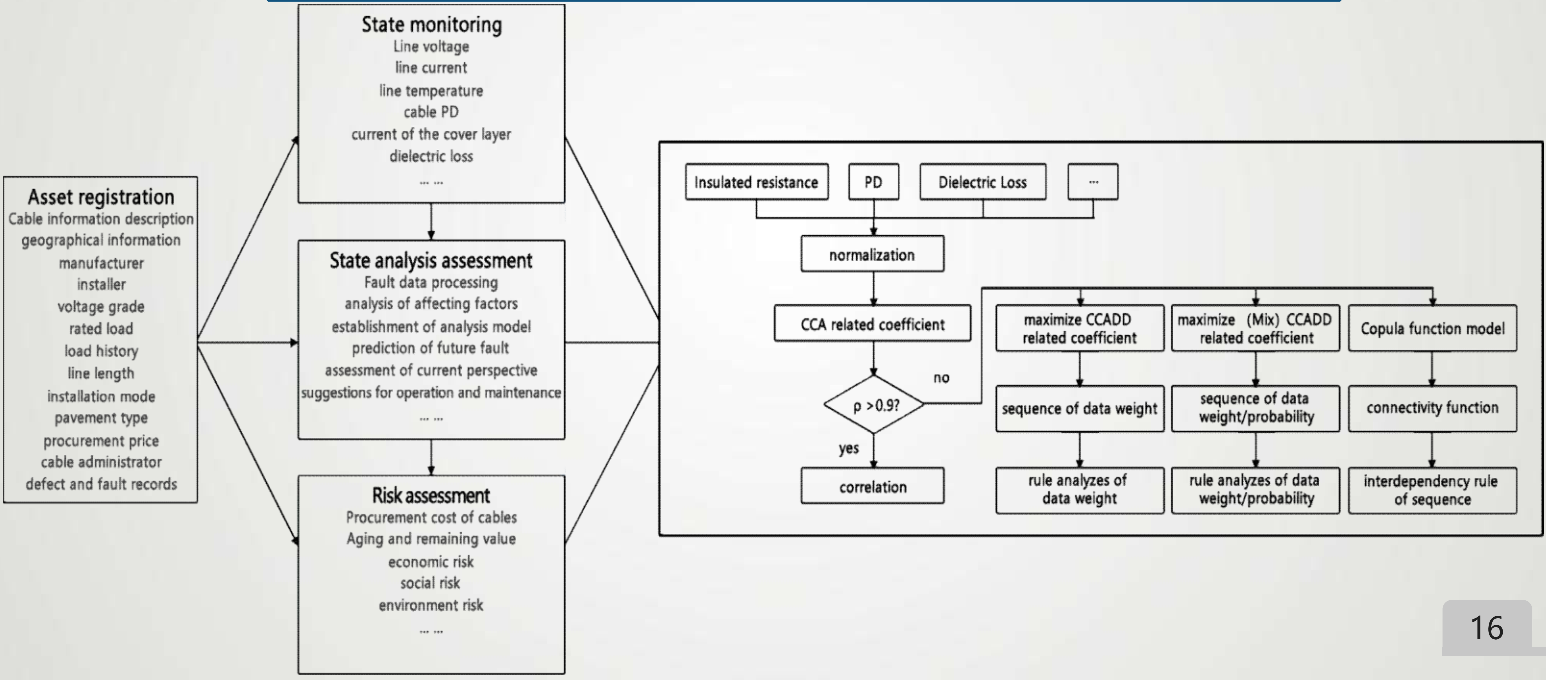
Foundation of technologies and theories + **Source of input data** = **Targets to achieve**

Foundation of technologies and theories
- Aging theory of insulation
- Comprehensive diagnosis
- Evaluation of remaining life
- Expert system by AI

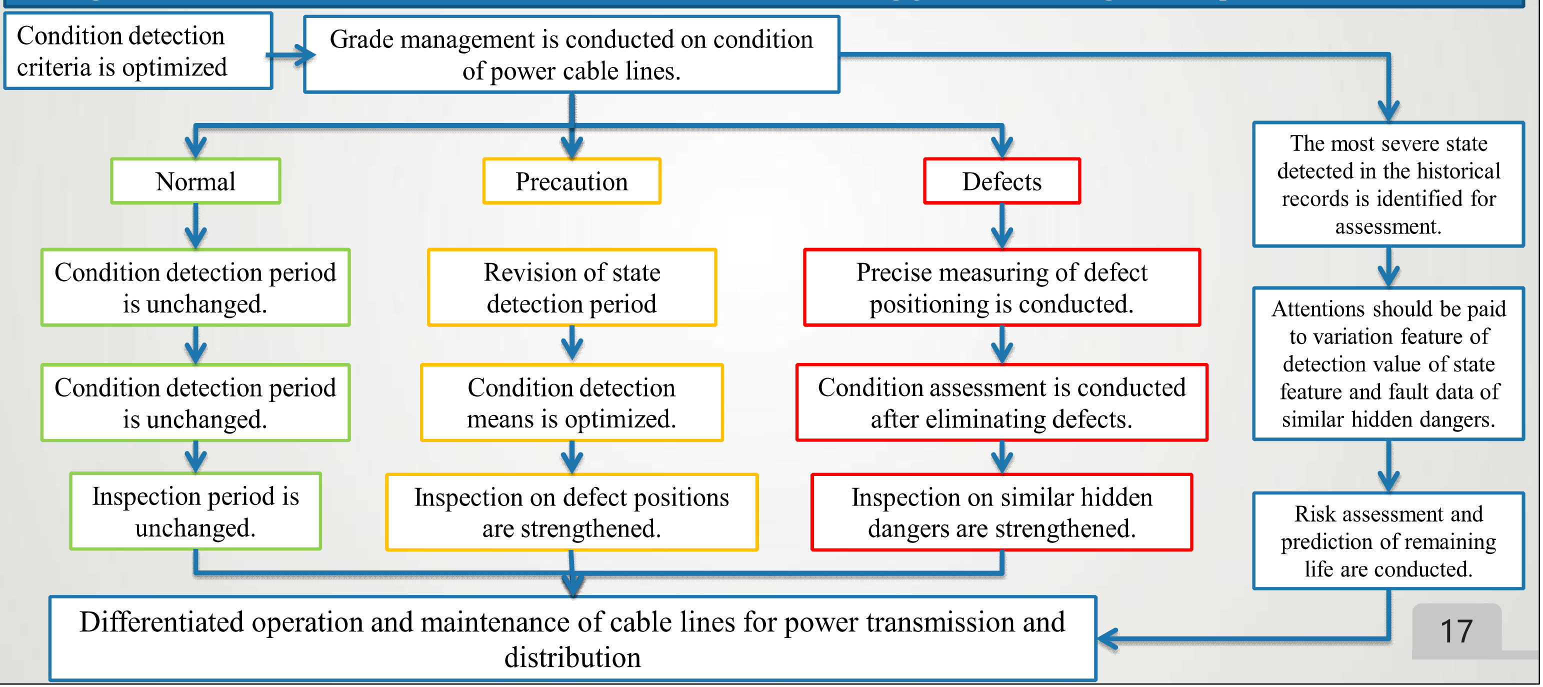
Source of input data
- Mobile sensing
- Offline test and diagnosis
- Analysis of insulation material
- Assessment of equipment and its supplier
- Test information of installation and operation
- Service length and operation environments

Targets to achieve
- To manage the basic records of cable lines
- To manage the operation information of cable lines
- To diagnose the faults and defects of cable lines
- **To assess and diagnose the conditon of cable lines**
- **To decide the strategy of maintenance**

Grading evaluation on power cable lines



Logic structure of differentiated strategy-making for power cables



Part IV: Interactive Diagnosis and Assessment System

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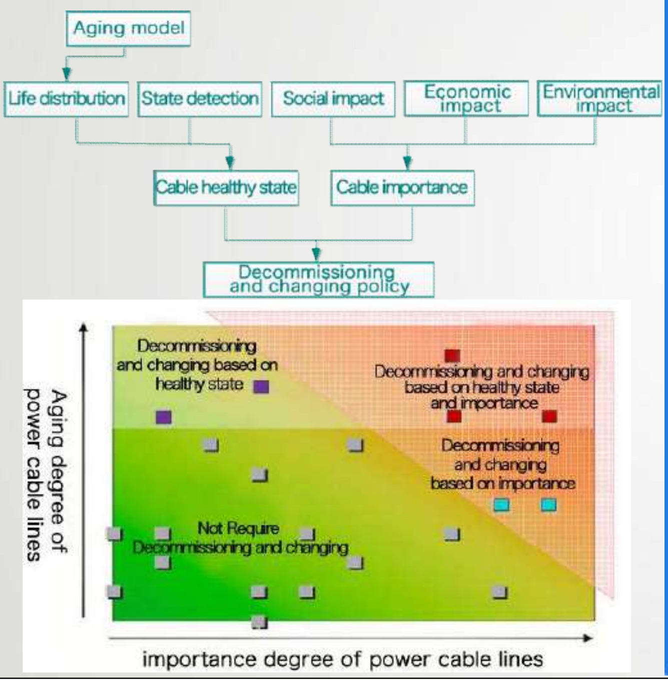
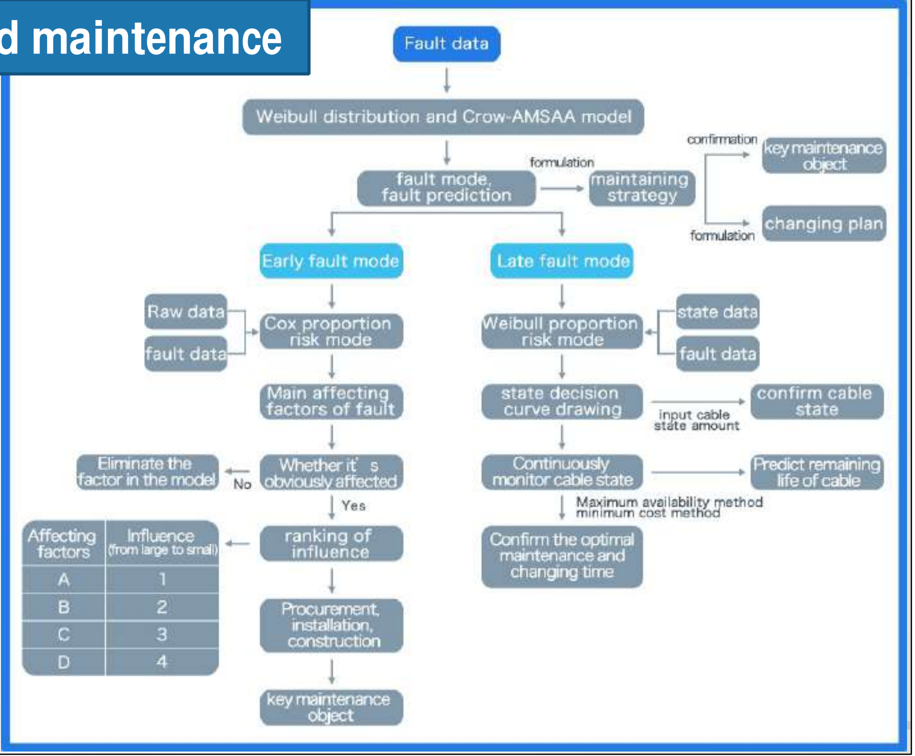
Strategy-making of operation and maintenance





Part V: Technology Development Trend

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To improve the function of mobile sensing terminal

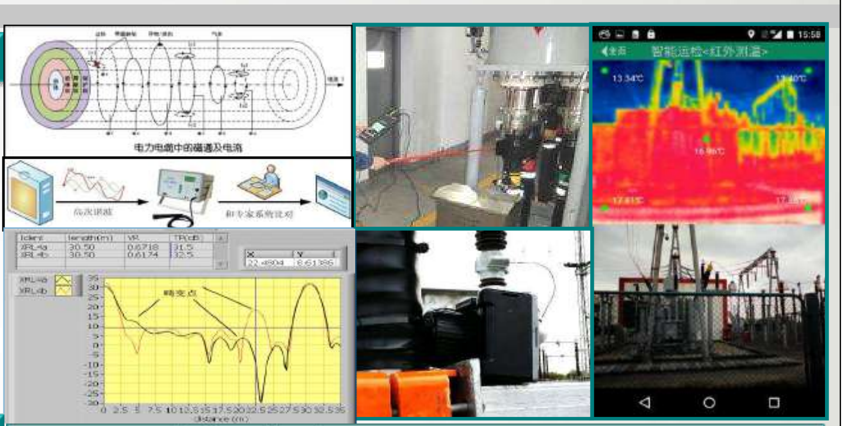
- ➢Multi-state detection and sensing technologies
- ➢Real-time state analysis of cable lines during the inspection.

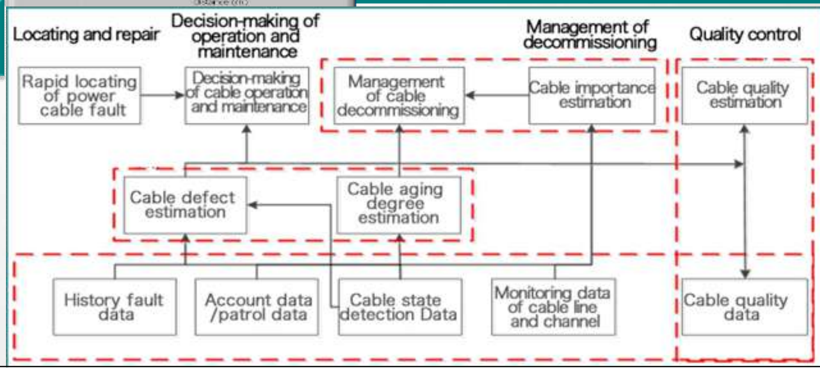
To optimize acquisition and sending components

- ➢Coordination with existing online monitoring systems
- ➢Reliability of acquisition and sending components

To expand the function of interactive diagnosis and assessment system

- ➢Improve fault diagnosis function, similar defect analyzing function, equipment state monitoring and dynamic assessment function, fault map/image understanding and analysis function, and state warning function.





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