11TH INTERNATIONAL EXHIBITION OF ELECTRICAL AND INDUSTRIAL ELECTRONICS INDUSTRY
ELECRAMA-2014
8-12 JANUARY 2014, BIEC, BANGALORE, INDIA

Distribution Systems and Dispersed Generation

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Chairman of CIGRE SC C6

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9 January 2014
Bangalore, India

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CIGRE Study Committees

A: Equipment

A1 Rotating electrical machines
E. Figueiredo (Brazil)

A2 Transformers
C. Rajotte (Canada)

A3 High voltage equipment
H. Ito (Japan)

B: Sub-system

B1 Insulated cables
P. Argaut (France)

B2 Overhead lines
K. Papailiou (Switzerland)

B3 Substations
T. Krieg (Australia)

B4 HVDC and Power electronics
B. Andersen (United Kingdom)

B5 Protection and Automation
I. Patriota de Siqueira (Brazil)

C: System

C1 System development & economics
P. Southwell (Australia)

C2 System operation & control
J. Vanzetta (Germany)

C3 System environmental performance
F. Parada (Portugal)

C4 System technical performance
P. Pourbeik (USA)

C5 Electricity markets & regulations
O. Fosso (Norway)

C6 Distribution systems & dispersed generation
N. Hatziargyriou (Greese)

Technical committee

Chairman: Mark Waldron (UK)
Secretary: Yves Maugain (France)

D: Common technology

D 1 Materials and emerging test technique
J. Kindersberger (Germany)

D 2 Information systems and telecommunication
C. Samitier (Spain)

SC C6 - Distribution Systems and Dispersed Generation

Chair: Nikos Hatziargyriou
Secretary: Christine Schwaegerl

Main Technical directions

- To study the connection and the integration of distributed energy resources (DER), including small size generators, storage and relevant power electronic devices
- To study the application of the DER concept as a part of the medium-long term evolution of distribution systems (Microgrids and Active Distribution Networks)
- To study actions and processes for demand management and customers integration
- To study the subject of rural electrification

… to cover all aspects of Smart Distribution Grids

THE NETWORK OF THE FUTURE

Pillars of Modern Power Systems strategy

- High reliability and security of supply
- Most economic solution
- Best environmental protection

10 Technical Issues

1. Active Distribution Networks

2. Massive Exchange of Information

3. Integration of HVDC / Power Electronics

4. Massive Installation of Storage

5. New Systems Operations / Controls

6. New Concepts for Protection

7. New Concepts in Planning

8. New Tools for Technical Performance

9. Increase of Underground Infrastructure

10. Need for Stakeholder Awareness

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Active Distribution Networks

SC-C6

SC-C3

SC-C4

Massive Installation of Storage

New Tools for Technical Performance

10 Technical Issues

Increase of Underground Infrastructure

Need for Stakeholder Awareness

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Active Distribution Networks

Increase of Underground Infrastructure

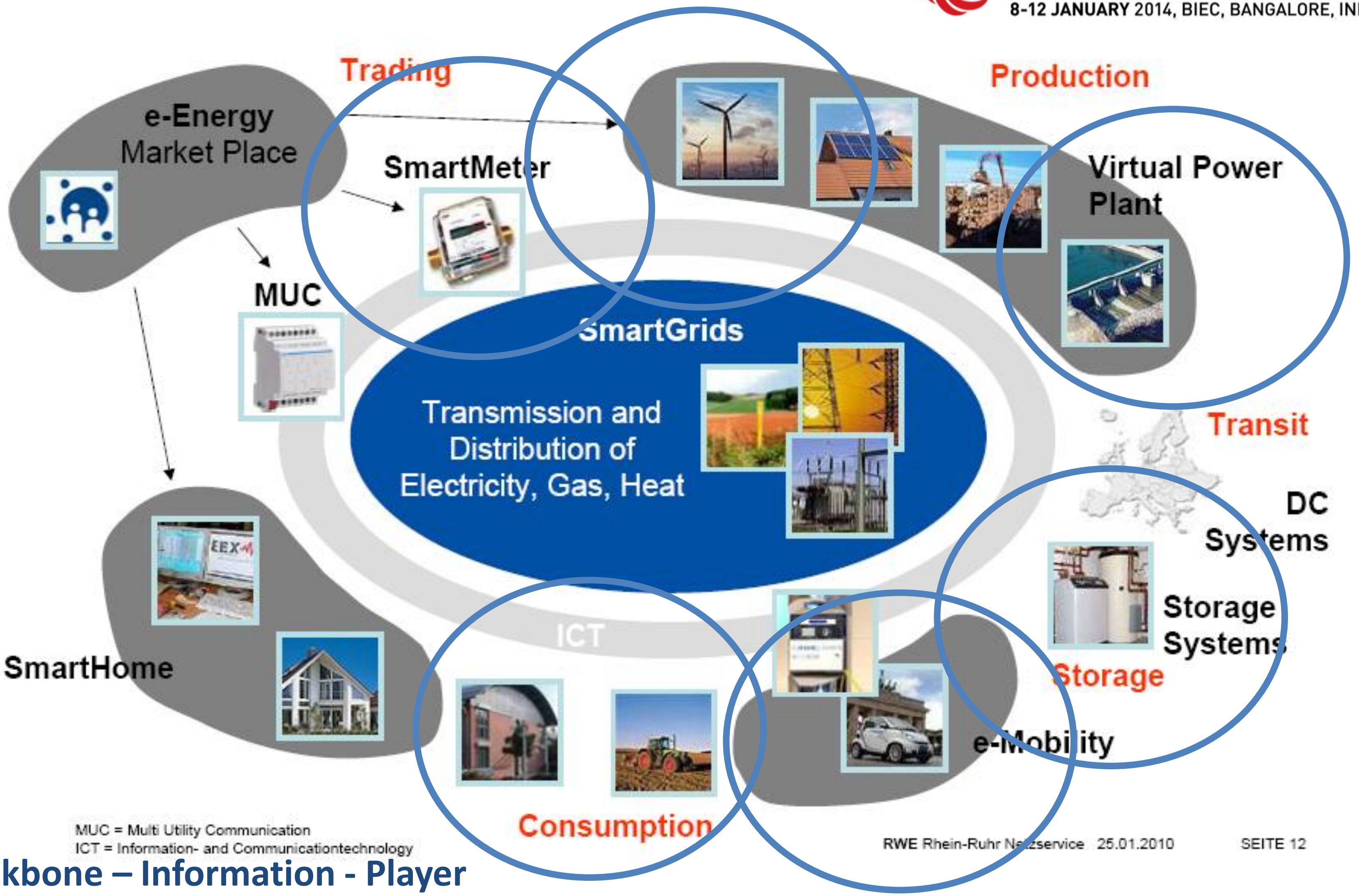
Need for Stakeholder Awareness

Key Challenges

- Distribution level needs more ‘smartness’.
- Massive penetration of smaller units imposes the need for their control and coordination.
- Coordination of millions of small resources poses huge technical challenge, requires application of decentralized, intelligent control techniques.
- Smart metering massive implementation.
- Novel distribution network architectures Microgrids and Virtual Power Plants

Network of the future

Areas currently covered by CIGRE SC C6



Backbone – Information - Player

Source: Peter Birkner, "Subgroup on Smart Grids", www.ec.europa.eu/energy

SC C6 Organisation

SC Chairman **Nikos Hatziargyriou**

Secretary **Christine Schwaegerl**

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DER Connection and Integration

AG C6-01 Strategic Planning Nikos Hatziargyriou

AG C6-12 Tutorials Trevor Gaunt

AG C6-17 Rural Electrification Adriaan Zomers

AG C6-23 Terminology Alex Baitch

JWG C3.05/C6.14 Environmental impact of DG, Liaison Erkki Lakervi

JWG C1/C2/C6.18 Coping with limits for very high penetrations of RE Wil Kling

WG C6.09 Demand Side response Alex Baitch

WG C6.11 Develop. & operation of active distribution networks D'Adamo

WG C6.15 Electric Energy Storage Systems Zbigniew Styczynski

WG C6.16 Technologies employed in rural electrification Trevor Gaunt

WG C6.19 Planning & optimization for active distribution systems Fabr. Pilo

WG C6.20 Integration of electric vehicles Joao Pecas Lopes

WG C6.21 Smart Metering Eduardo Navarro

WG C6.22 Microgrids Evolution Roadmap Chris Marnay

WG C6.24 Capacity of Distribution Feeders for Hosting DER, St. Papathanassiou

WG C6.11
Active Distribution Networks

Completer in 2011

Convener: D'Adamo (Italy)

Scope:

- Assessment of network requirements for the operation of DER
- Identification of enabling technologies and review the most relevant features of ADN
- Definition of limits/barriers
- Evolution in regulatory aspects

WG C6.11 - Active Distribution Networks (ADN) Definitions

- Active distribution networks have systems in place to control a combination of distributed energy resources (DERs), defined as generators, loads and storage.
- Distribution system operators (DSOs) have the possibility of managing the electricity flows using a flexible network topology.
- DERs take some degree of responsibility for system support, which will depend on a suitable regulatory environment and connection agreement.

WG C6.11- ADN Operation

Operation rules

- **Different regulations**
- **No islanding** permitted in most cases
- **Automatic DG disconnection** in case of main network faults
- General rule: no worsening of Power Quality (voltage level, fault current, …) admitted but not clear definition of what Power Quality means (!)
- No rules for **reactive power**

Remote control

- **Only 41% of the interviewed DNO have possibility to remote control the DG** at MV and LV
- **Limited capability** to manage the "active grid"
- **No operational procedures in case of fault**

WG C6.11- ADN Operation

Voltage control

- Voltage variations admitted according to National or International Standards
- **No "active" voltage control** performed
- Adjustable setting of tap changer of MV/LV transformers

Fault clearing procedures

- **60% of DNO don't have dedicated fault clearing procedures for feeders with DG** (same as without DG)

Intentional islanding

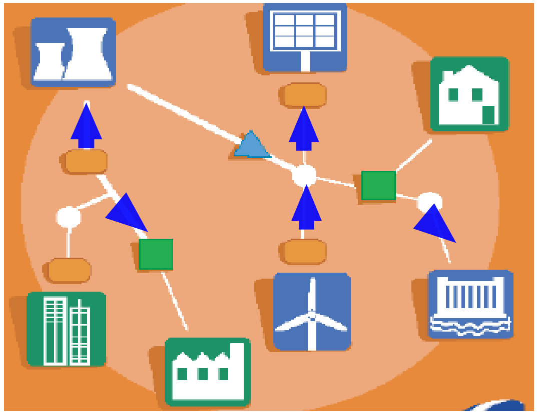
- Very limited intentional islanding in performed
- 22% of DNO may perform DG intentional islanding, mainly in **self-generation customers**
- 14% of DNO may perform intentional islanding **only in emergency cases**
- **Concerns for safety** of network operators

WG C6.11- ADN Operation

- Selection and analysis of 24 innovative pilot projects (sources: ANM database, WG members, workshops)
- Classification of enabling technologies, applications, benefits and research needs
- Presentation of ADN functionalities, specific applications and with required analysis tools
- Provides a snapshot of the industry and a basis for the development of recommendations

Common features and priorities for ADN (scale 1 to 5):

- PROTECTIONS 4,50
- SAFETY 4,42
- FAULT MANAGEMENT 4,27
- COMMUNICATIONS4,15
- ISLANDING 4
- ANCILLARY SERVICES 3,85



WG C6.11 Key Recommendations

Grid operation

- **Review protection systems and safety** measured in the context of ADNs
- **Grid codes should be updated** to reflect the fact that DER owners need to **share responsibility** with DNOs for the application of ADN
- **Communication systems** to support data exchange for ADNs **should integrate industry standards**
- Put mechanisms in place for grid users to **provide ancillary services and receive remuneration** for this service

WG C6.15
Electric Energy Storage Systems

Completed in 2010

Convener: Zbigniew A. Styczynski (Germany)

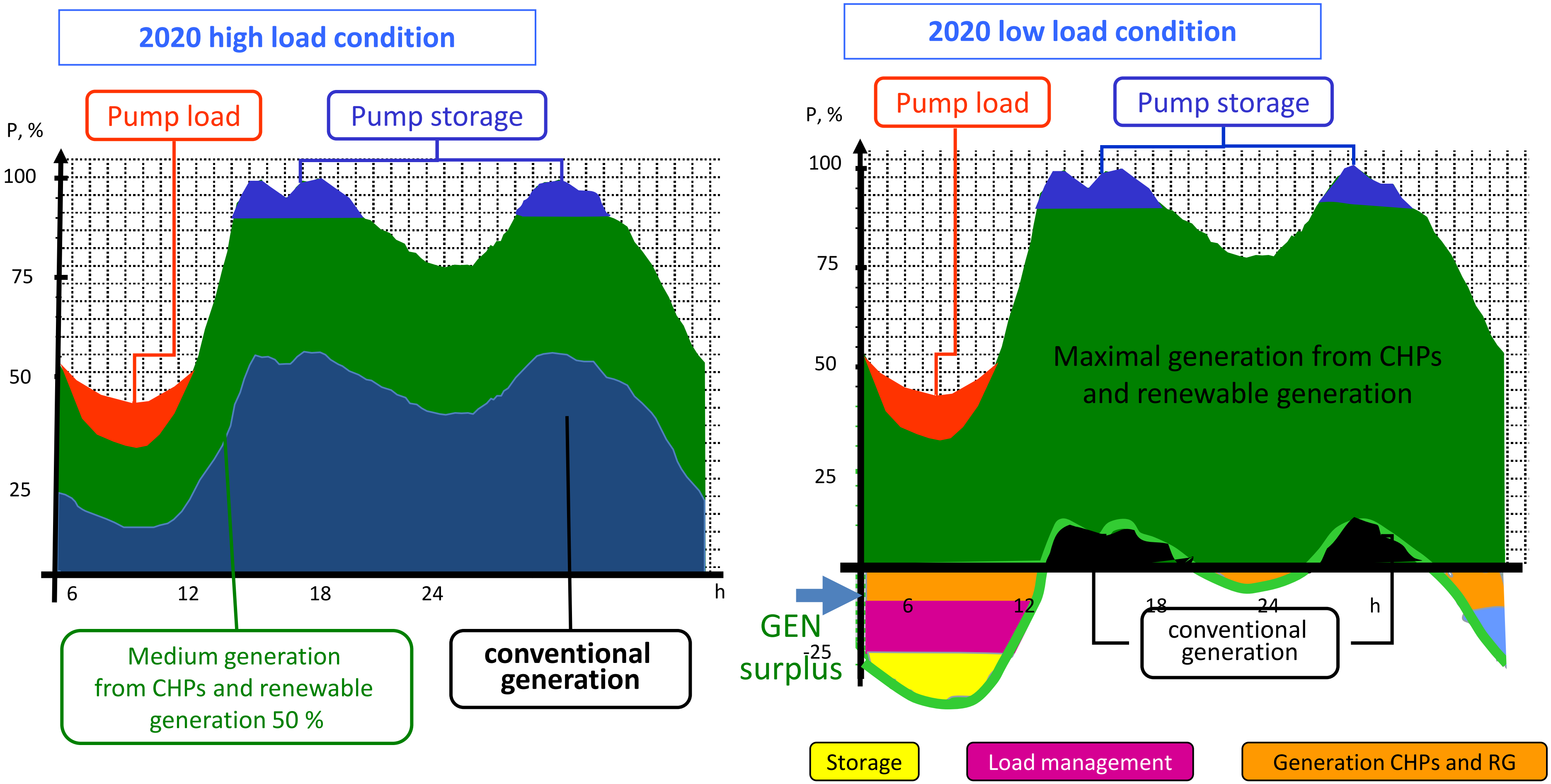
Membership
*N° of full members:**26***
*N° of involved countries:**16***

Scope:

The aim of the WG was to evaluate different storage technologies and their commercial backgrounds, therefore great emphasis was given to the integration and support of power networks which have a high penetration of dispersed generation (DG) and renewable based generation (RES).

European Scenario for Renewables

SET – Plan for Europe – 2020 – 635 GW in RG+CHP



The overflow of renewable & CHP generation power during low load condition has to be managed in future!

European Scenario for Renewable Generation

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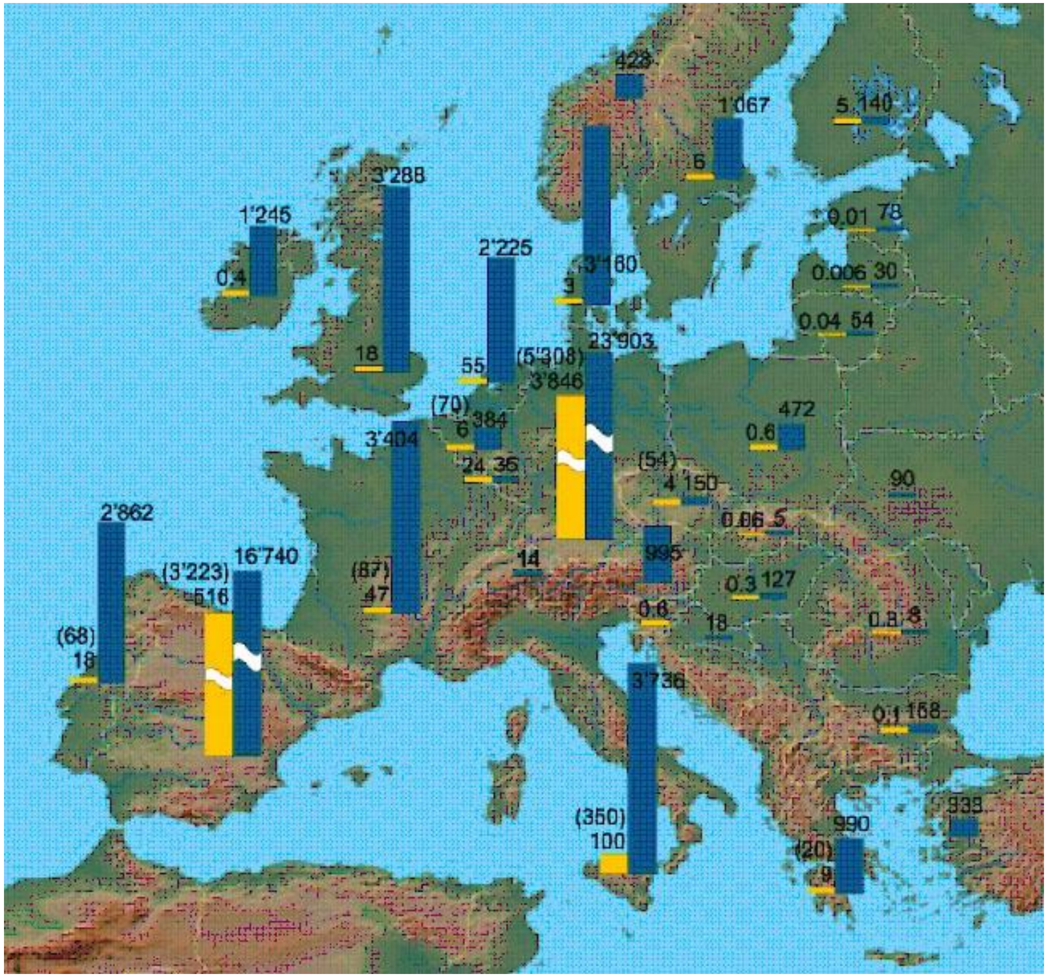

2008

Wind power: 66 [GW]

PV power: 9 [GW]

EU Targets (SET Plan):

-2020 *Reduce greenhouse gas emissions by 20% and ensure 20% of renewable energy sources in the EU energy mix by 2020*

-2050 (Vision) *Complete decarbonisation*

Sources:

World Wind Energy Report 2008

Photovoltaic Energy Barometer

Overview of Storage Technologies

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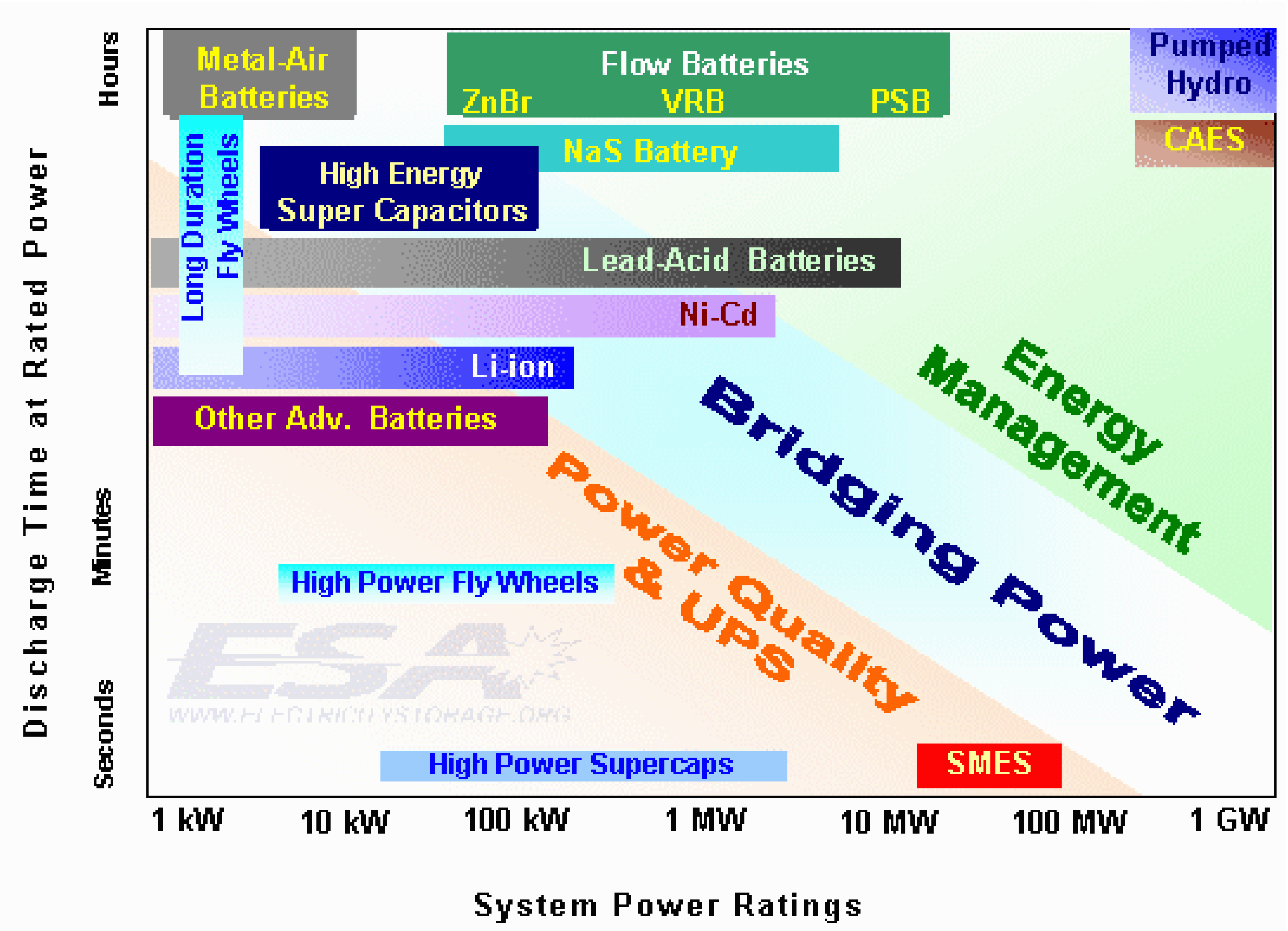


Source: Electricitystorage.org: "Technologies and applications". 2003

Total Installed Storage Capacity Worldwide

Technology		Total installed	Size ranges	Potential application
Pumped Hydro		110 GW	Up to 2.1 GW	• load levelling • spinning reserve
CAES		477 MW	25 MW - 350 MW	• peak shaving • spinning reserve
Batteries			100 W - 20 MW	• integration with renewables • load leveling • peak shaving • spinning reserve • power quality
	Lead Acid	125 MW		
	Na-S	~ 200 MW		
	Redox	38 MW		
	Ni-Cd	26 MW		
Flywheels			kW scale	• Power Quality
SMES			10 - 100 MW	• Power Quality
Supercapacitors			7 - 10 MW	• Power Quality

Source: Energy Information Administration (EIA)

Vehicles to Grid: *pros and cons*

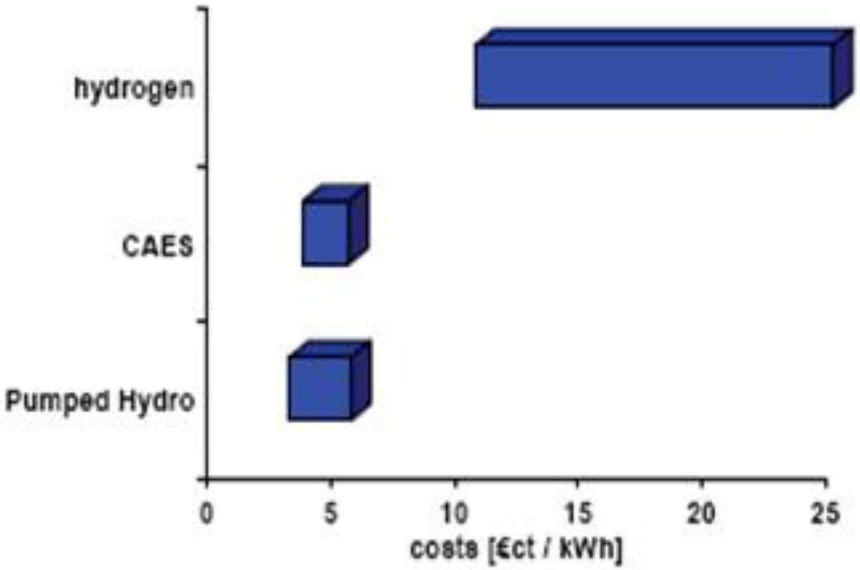
+	-
Pollution reduction	Reinforcement of the grid
Primary and secondary reserve	Life time of the battery
Ancillary service	Limitation due to the rise of temperature of battery
Load shifting	Vehicle autonomy
Peak shaving	

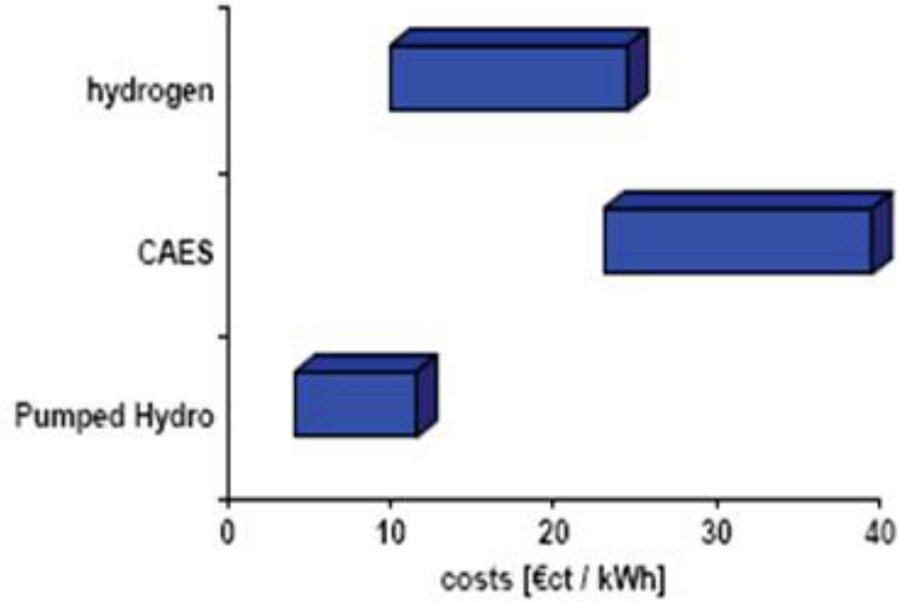
- Nickel-Metal Hydride (NiMH)
- Litium-ion family (Li-ion)
- Sodium Nikel Chloride (ZEBRA)

Economical Aspects

Load-levelling applications

Long term applications





Source: German Power Engineering Society (VDE-ETG)

Economical Aspects

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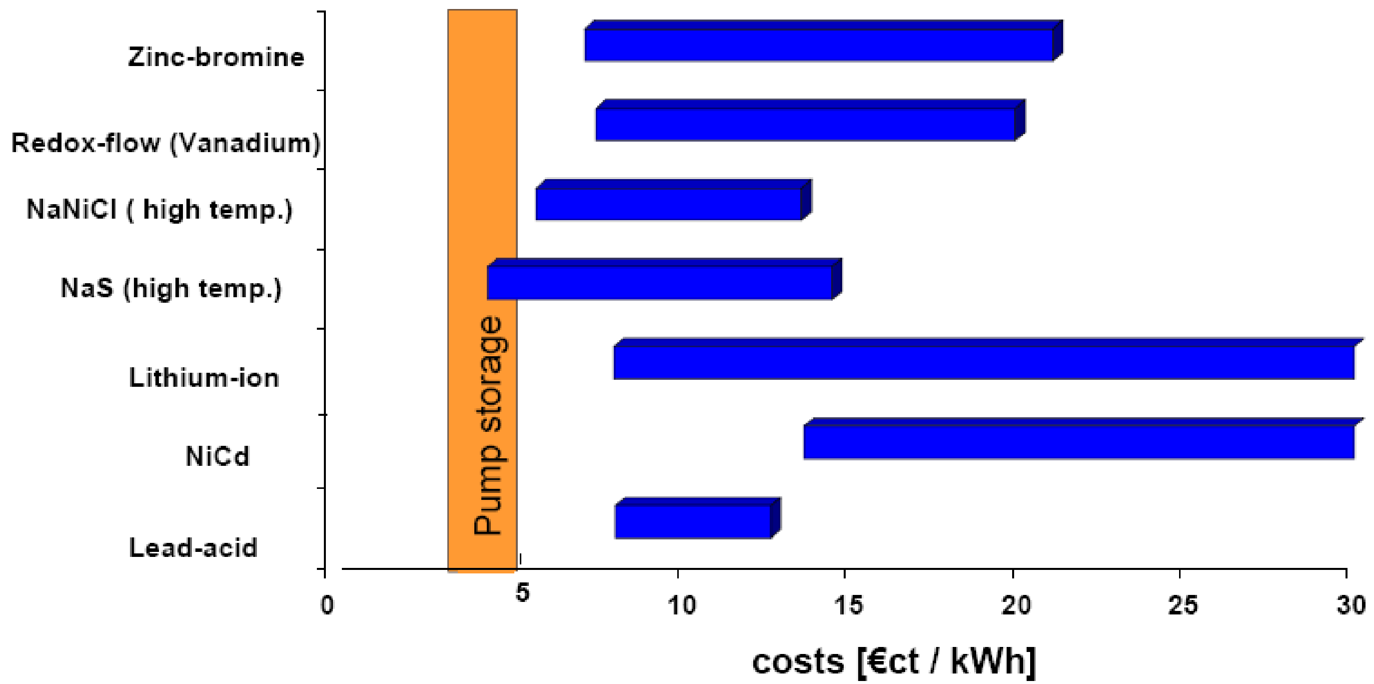
Comparison of storage systems for peak shaving at distribution level



Source: German Power Engineering Society (VDE-ETG)

Pilot installation: Rokkasho, Japan

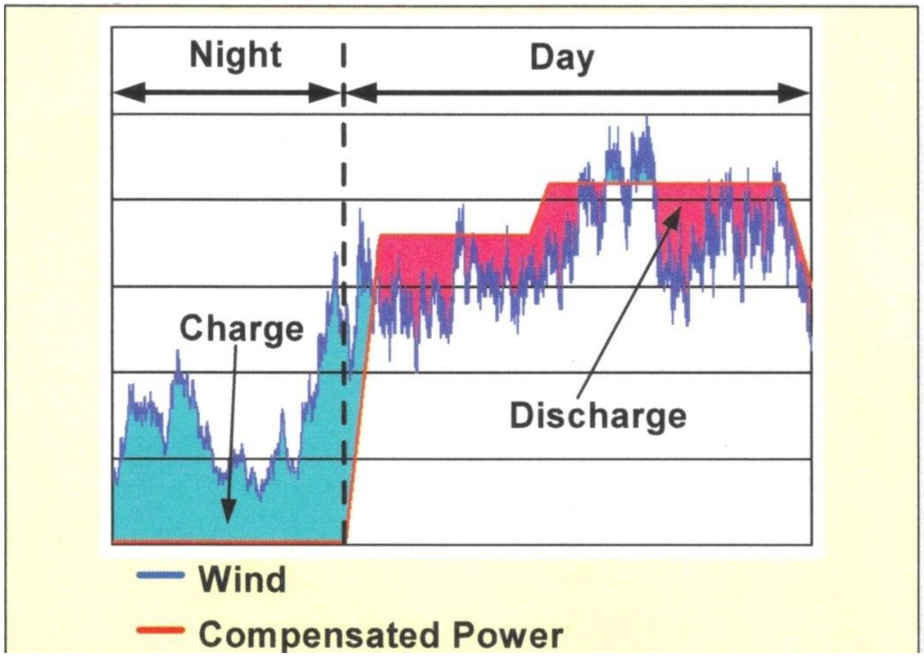
Wind farm combined with NaS battery

-Wind farm: 51 [MW]

-NaS battery power: 34 [MW]

-NaS battery capacity 238 [MWh]

-Life time expected: up to 15 years, 300 cycles per year



Source: NGK

Pilot installation: Wakkanai, Japan

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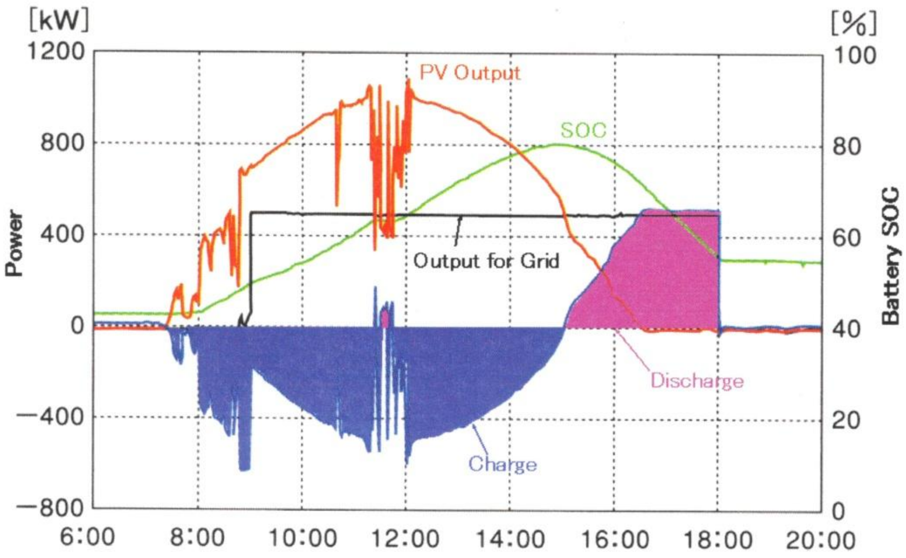
Photovoltaic plant combined with NaS battery

-Photovoltaic plant: 5 [MW]
-NaS battery power: 1.5 [MW]
-Nas Capacity:13.5 [MWh]



Source: NEDO

WG C6.20: Integration of EVs in Electric Power Systems

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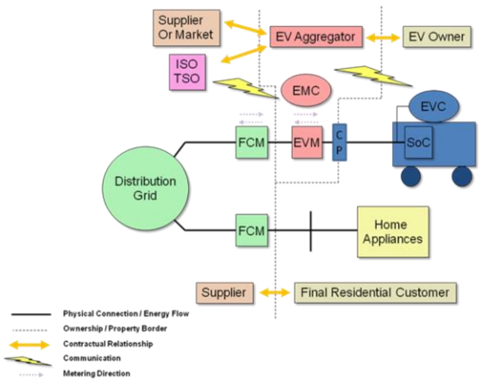
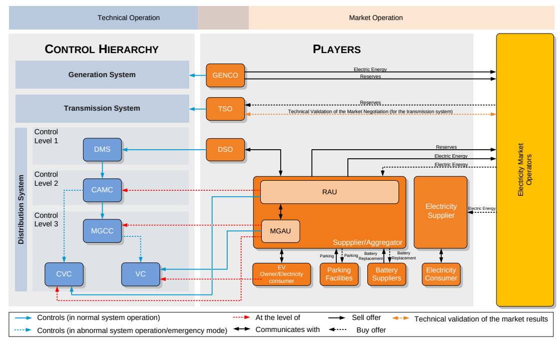
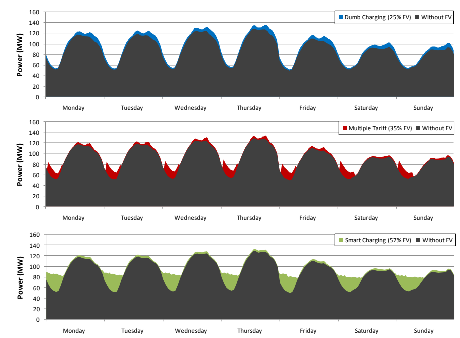


EV aggregator providing with home connected EV



Technical management and market operation framework for EV integration



Load profiles with different EV charging strategies

CHAdeMO Connector

Convener: **Joao Abel Pecas Lopes (Portugal)**

Completed in 2013

- Key Drivers: Social behavior of EV drivers, CO_2 emissions, RES integration
- EV deployment scenarios and business models
- Identification of management and control solutions to accommodate large scale deployment of EV taking into account drivers interaction
- System impacts resulting from the presence of EV
- Standardization of technologies and technical requirements
- The effects of EV into electricity markets and the need for regulatory and support mechanisms

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Key Drivers for Electric Mobility

- Sustainability and environmental awareness,
- Economic and policy aspects,
- Consumer/driver acceptance,
- Evolution of technologies and concepts.

EV Deployment Scenarios, Market and Business Models

Several EV deployment scenarios, market and business models are described

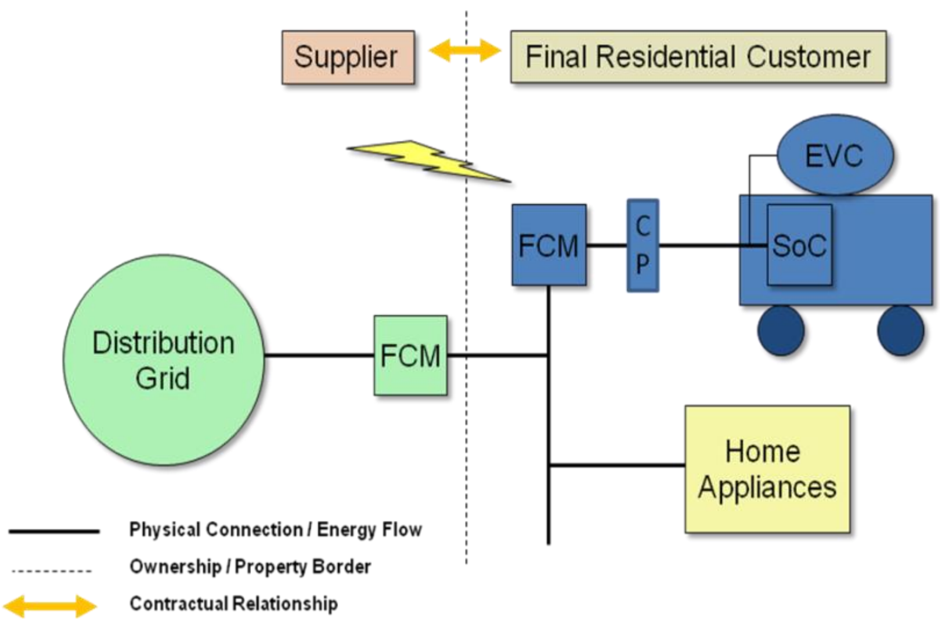


Figure - EV charged at home with separate meter

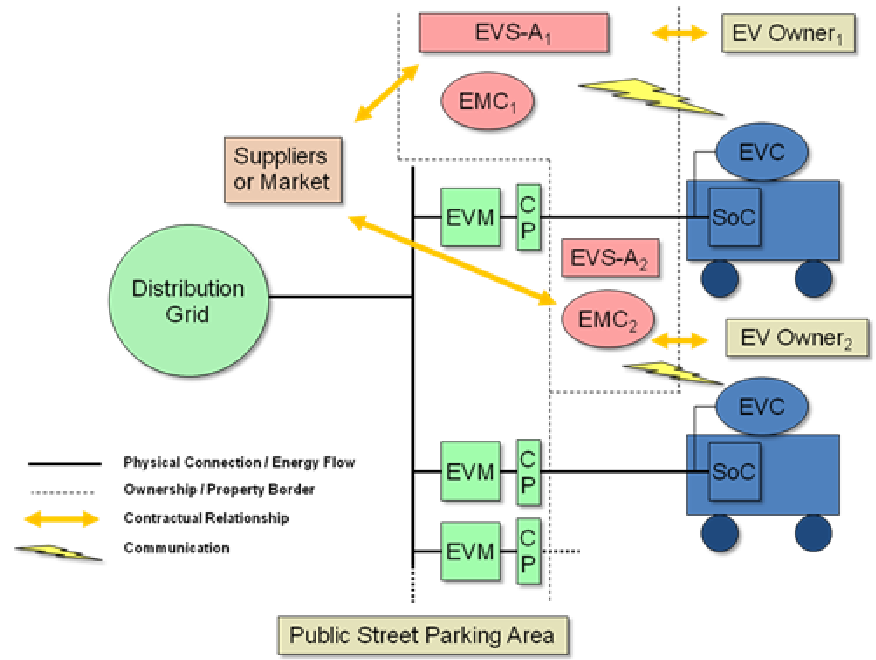


Figure - EVS-As, EV owners, and DSO

EV Deployment Scenarios, Market and Business Models

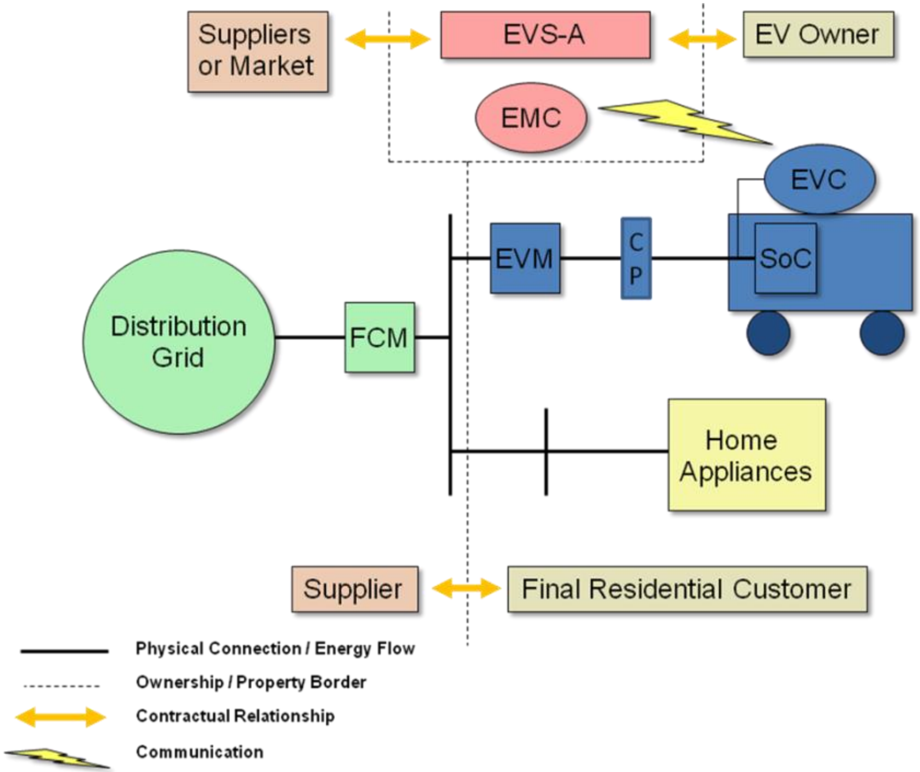


Figure - EV home charge under EVS-A management

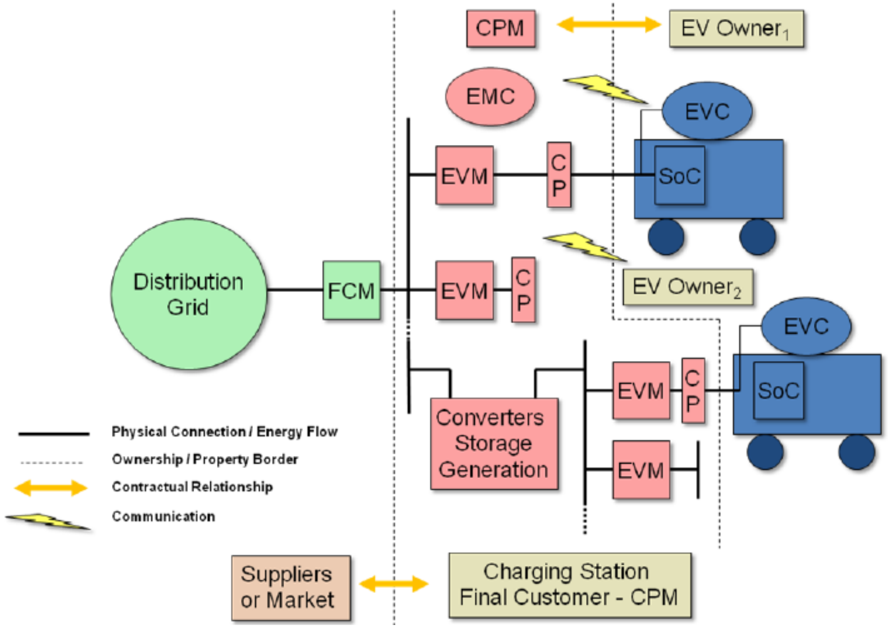
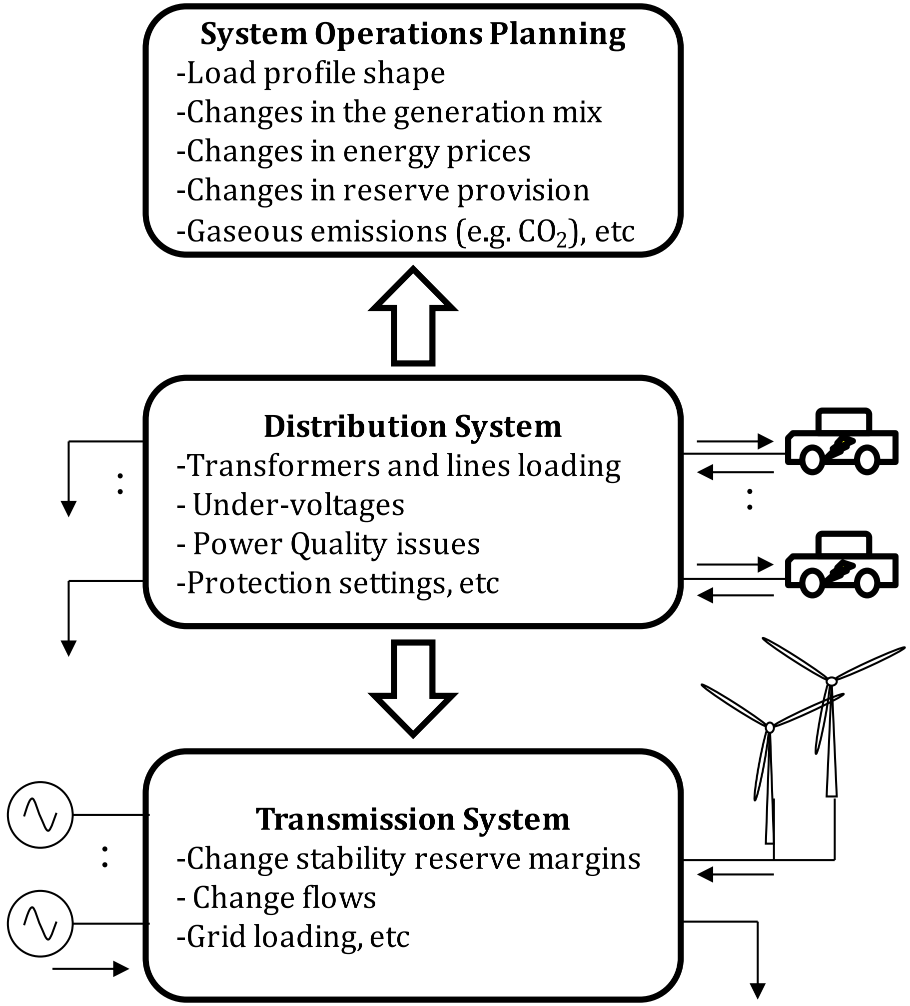


Figure - CPM as commercial or office building with integrated energy management

The effects of EV into Electricity Markets



The effects of EV into Electricity Markets

Effects on markets without controlled charging

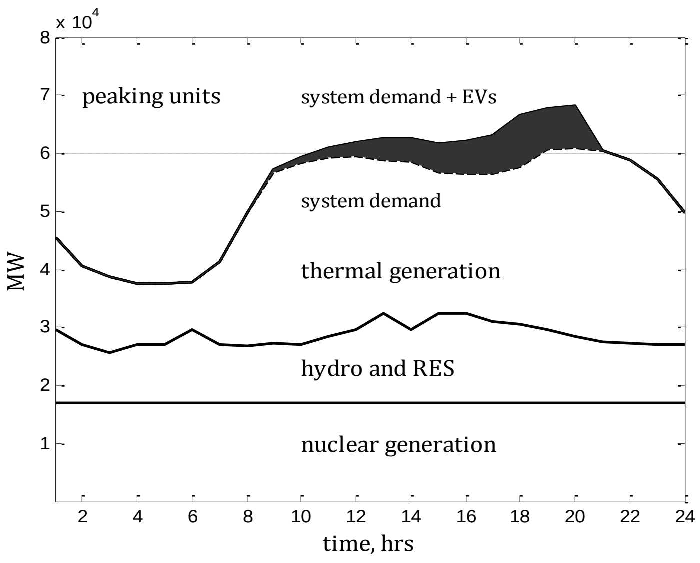


Figure - System with a total EV penetration of a 4.28% of the system total energy consumption

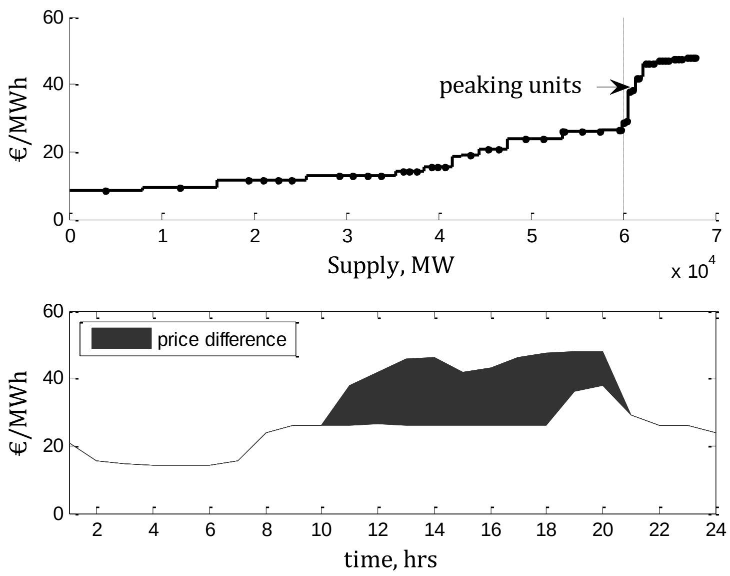


Figure - Bidding curve for the hypothetical system and price difference for the market clearing with EVs and with no EVs

Management and Control of EVs

Control and management architectures for EV integration

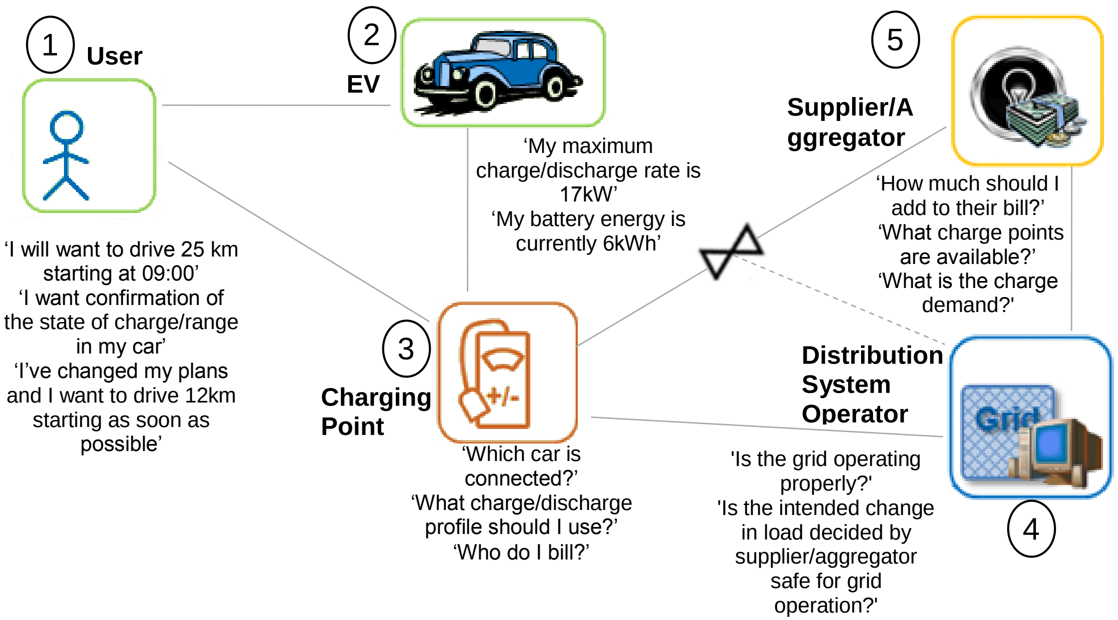


Figure - Examples of reasons behind communication between the different parties involved in the charging process

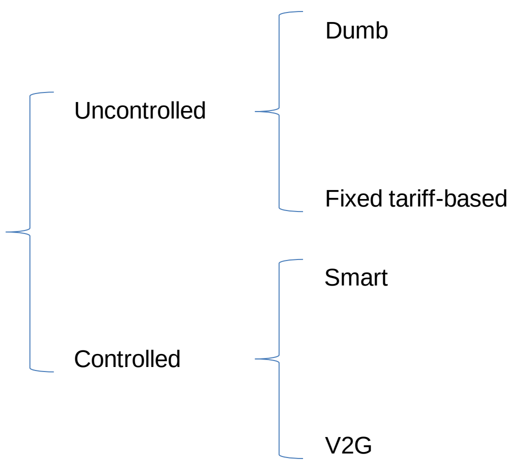


Figure - Charging Modes of Operation

Management and Control of EVs

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Aggregating agents interfacingt EVs with the markets and DSOs

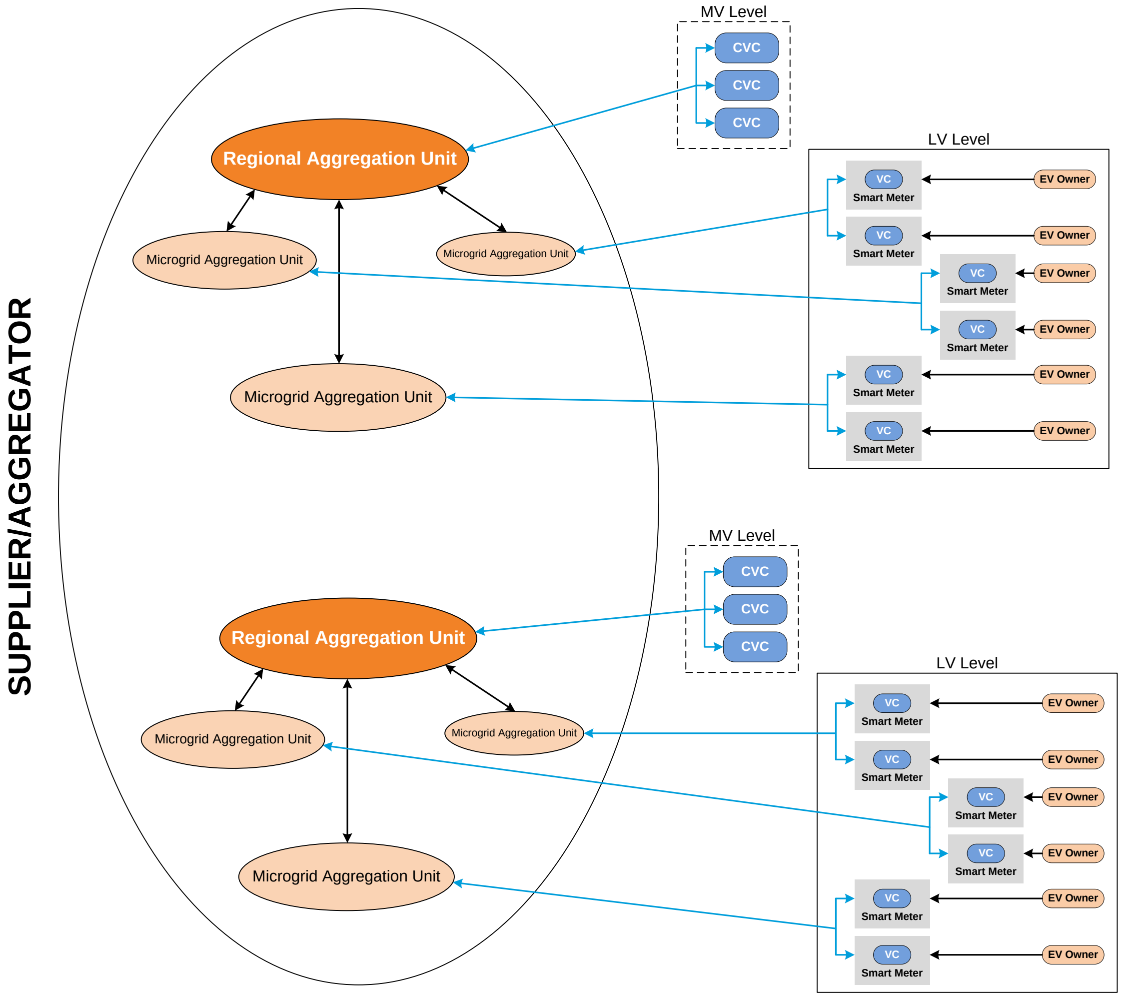

Figure - EVS/A hierarchical management structure

System Impacts resulting from EVs

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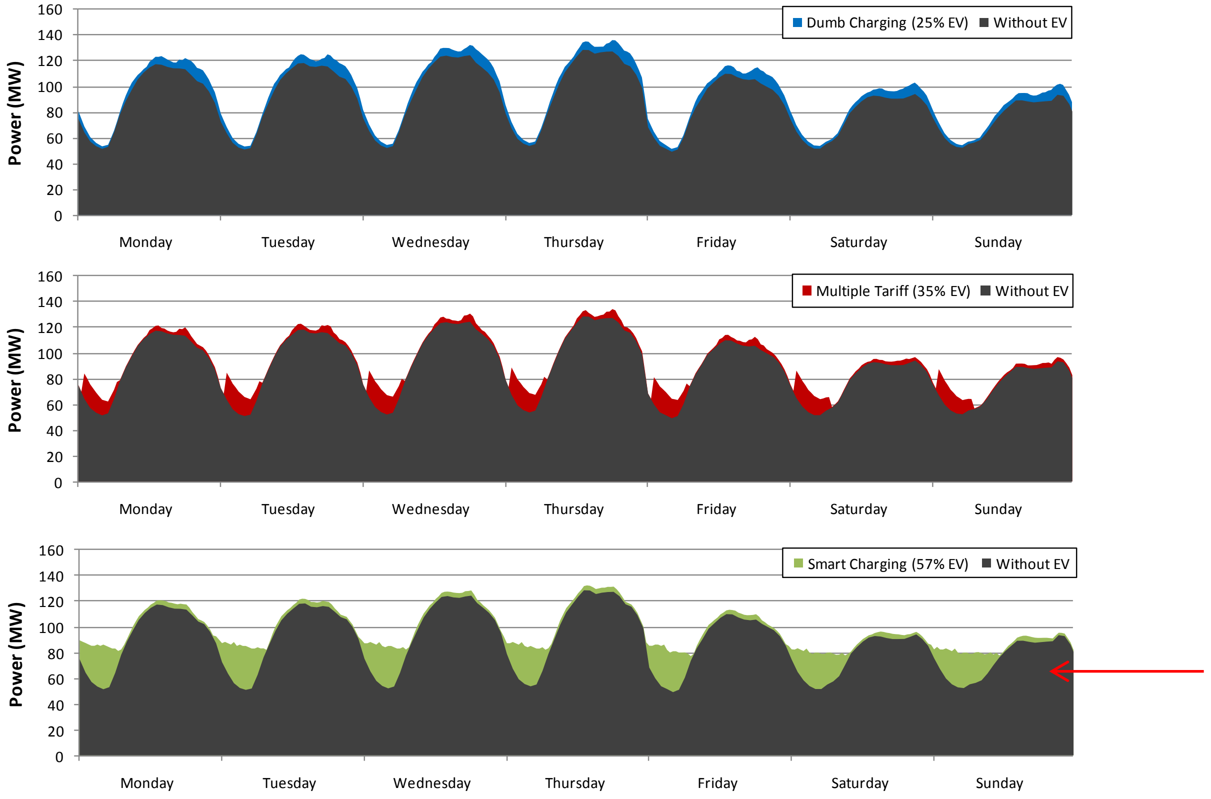
Comparing different control charging strategies: dumb; dual tariffs and smart charging



Smart charging

Figure Load profiles without and with EV

System Impacts resulting from EVs

Participation of EVs of the AGC and on the Dynamic behaviour of the system

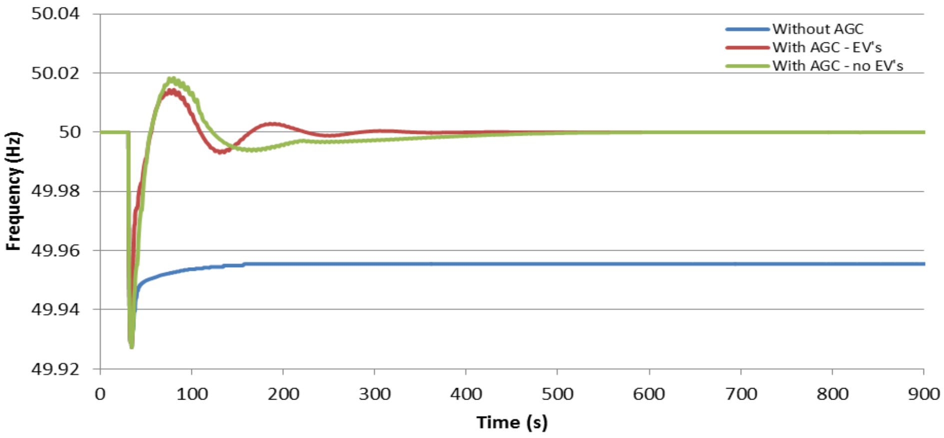


Figure - Frequency in the Spanish control area for the scenario with extra wind power

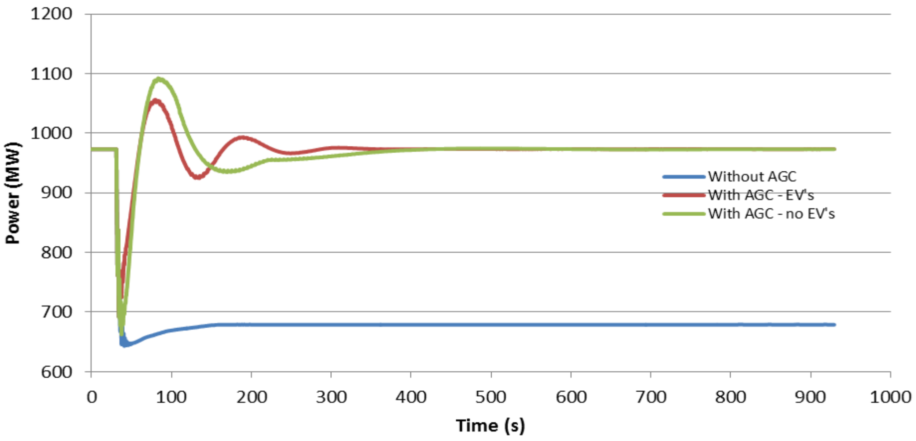


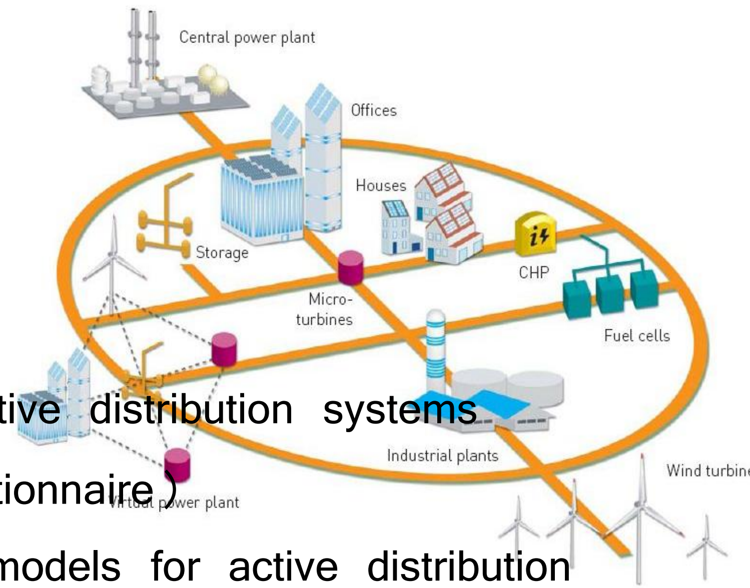
Figure - Interconnection power from Spain to Portugal for the scenario with extra wind power

Standardization of Technologies

- Standards and technologies for slow and fast charging
- Charging methods and communication protocols
- Reference and description of on-going projects

Figure Samples of Installed Fast Charge Points

WG C6.19: Planning and Optimization Methods for Active Distribution



Convener: Fabrizio Pilo (Italy)

To be completed in 2014

Scope

- Survey on state of the art on planning for active distribution systems
- Requirements of planning methodologies (questionnaire)
- Identification of short, medium and long term models for active distribution planning (e.g., technical models, economic and market models)
- Reliability models of active distribution systems
- Algorithms for active distribution system expansion/upgrade planning suitable to different scenarios and regulatory frameworks. Methods and tools allow optimal DES (distributed energy storage) and DG sizing and siting as well design and integration of microgrids and multi-microgrids

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Network Planning

DG Integration challenges with present and future solutions

Challenge	Current solution	Future alternatives
Voltage rise	- Operational p.f. 0.95 lagging - Volt/ VAr control	- Volt/VAr control - Demand side management - Storage
Network Capacity	- Reinforcement	- Non-firm access - Storage - Demand side management
Network Power factor	- Limits / bands for demand and generation	- Constant voltage mode? - Unity power factor generation?
Sources of Reactive Power	- Transmission network	- Storage - SVC - Wind turbines? (no firm supply!)
Network Asset Loss of Life	- Strict connection designs and network asset specifications based on technical and economic analyses	- Constant voltage mode? - Dynamic, coordinated protection settings - Asset condition monitoring

Network Planning

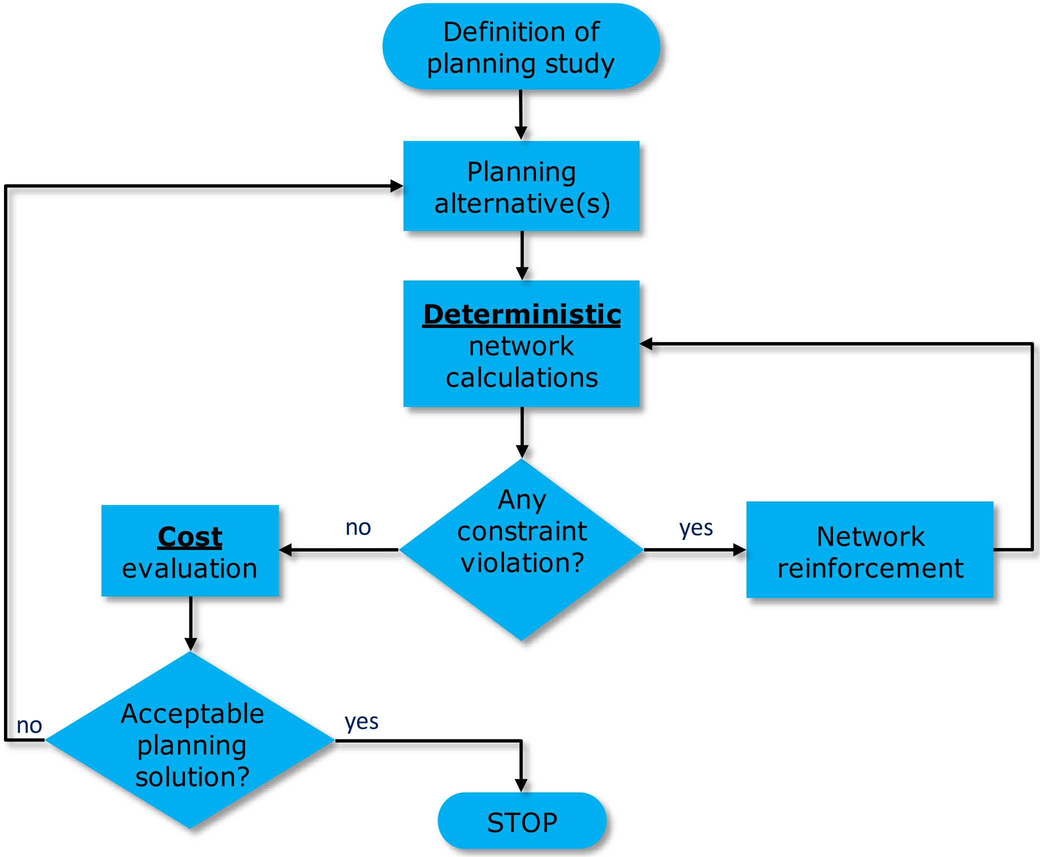
General considerations under the active distribution network paradigm

Consideration	Conventional Network	Active Distribution Network
Degree of automation	- Very little or none	- Ubiquitous
Control philosophy	- Local control	- Integrated - Hierarchical
Planning metrics	- Capacity requirements - System losses - Short-circuit level	- Capacity requirements - System losses - Energy conservation - DG curtailment - Short-circuit levels
Planning options	- Addition of new capacity - Phase balancing	- Addition of new capacity - Phase balancing - Peak load management measures - Addition of storage
Modeling DER	- If relevant, synchronous machine model	- Multiple DG types - Accurate short-circuit model - Energy forecasts - Various control modes

Methods for Active Network Planning

Inadequacy of traditional planning

Distribution networks are, in general, sized to cope with the worst-case scenario of a given load forecast and in a way that minimum or no operation is required (“Fit and Forget” approach).



Methods for Active Network Planning

Incorporating operational aspects into planning

Technical Issue	BAU Distribution Network	Active Distribution Network
Voltage rise/drop	Limits/bands for demand and generation connection/operation Generation tripping Capacitor banks	Coordinated volt-var control Static var compensators Coordinated dispatch of DER On-line reconfiguration
Hosting Capacity	Network reinforcement (e.g., lines/transformers)	Coordinated dispatch of DER On-line reconfiguration
Reactive Power Support	Dependency on transmission network Capacitor banks Limits/bands for demand and generation connection/operation	Coordinated volt-var control Static var compensators Coordinated reactive power dispatch of DER
Protection	Adjustment of protection settings New protection elements Limits for generation connection Fault ride through specifications for generation	On-line reconfiguration Dynamic protection settings
Ageing	Strict network designs specifications based on technical and economic analyses	Asset condition monitoring

Methods for Active Network Planning

Challenges (incorporating operational aspects into planning)

1. To what extent do operational aspects need to be modelled in planning?
2. To what extent are sophisticated tools needed?
3. How can uncertainties be dealt with?
4. How can ICT infrastructure be cost-effectively planned for the long term?
5. How should the huge amount of data in ADNs/Smart Grids be handled?
6. How can the business case for ADNs be correctly assessed?

Reliability of Active Networks

General

- While the evolution of distribution reliability tools has accelerated significantly in the recent years, most of the focus in these tools has been on peak loading capacity.
- While there are now many powerful reliability analysis tools presently being supplied to the utility industry, deficiencies and difficulties in perform reliability analyses remain.
- Further advancement in models, methods, and metrics will be required to assess reliability active distribution network implementations.

Reliability of Active Networks

Reliability Indices

- Standard reliability indices for sustained interruptions, e.g., SAIFI, SAIDI, CAIDI, CTAIDI, CAIFI.
- Other indices, e.g., ASAI, ASIFI, ASIDI,
- Indices for momentary interruptions, e.g., MAIFI, $MAIFI_E$, CEMSMIn
- Power quality indices, e.g., SARFIx.

Reliability of Active Networks

Need for new Reliability Indices

- Active distribution networks will warrant the development of additional indices that reflect new assets and resources as well as changing system operations.
- One such example is distributed generation (DG). Since the reliability indices are average annual values and normalized by large numbers such as number of customers, they are frequently too coarse to quantify the benefit of DG that might improve the reliability for only a small segment of the system.
- Additionally, indicators of curtailment and demand response will have to be developed to account for inconvenience to the end user including extraneous factors such as ambient temperature.
- Identification of communication infrastructure reliability indices and

Reliability of Active Networks

Issues with Reliability Analysis Tools

- Commercially-available reliability analysis tools are designed to address the problems the customers of each software vendor are presently experiencing. This results in tools that are often too inflexible to be adapted to other problems.
- Many utilities are purchasing the reliability analysis modules available in distribution system analysis tools, but finding it difficult to put them into practice. It is not entirely clear why this is happening, but the likely reasons stem from insufficient time for distribution engineers to gather the data to use the tools.

Demand Side Integration

Distribution planning methodologies in a smart grid world :

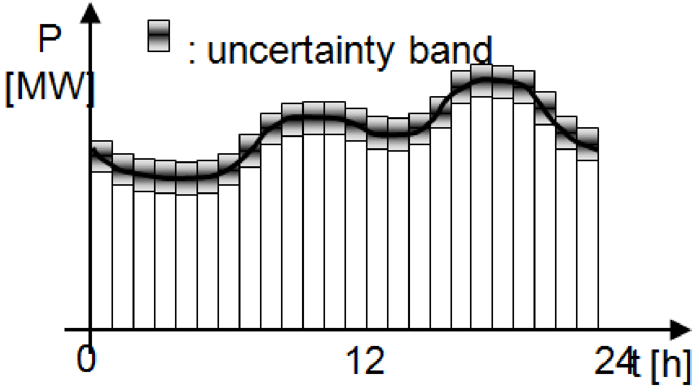
- how different Demand Side Integration （DSI）, Energy Efficiency （EE）, and Time-Of-Use （TOU） rate scenarios will **affect system peaks**
- DSI = deliberate alteration of electrical energy use
  - **Load response**: the end user agrees to be disconnected （with or without notice, if necessary, upon discount in tariffs）.
  - **Price response**: the end user intentionally modify its demand according to its economical purposes

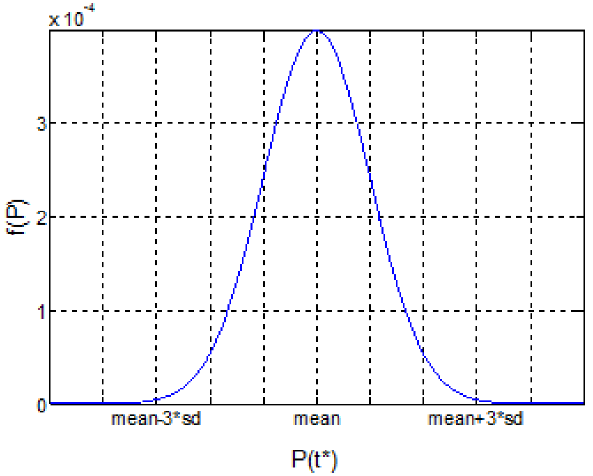
Demand Side Integration

Load modeling

With the evolution of the MV distribution network management (Active networks, Smart grids) there is the need to include operational aspects into the planning process:

- Data from Smart Metering will allow a full load profile
- Daily load profiles can and should be used in modern planning





Necessity to describe the instant load value P(t*) with a normal probability density function

WG C6.22: Microgrid Evolution Roadmap

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8-12 JANUARY 2014, BIEC, BANGALORE, INDIA

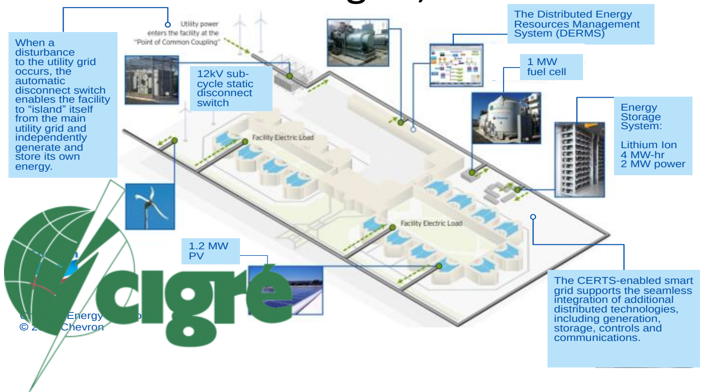
Convener: Chris Marnay (USA) , on-going until 2014

34 members, experts and correspondents:
Europe (13), Americas (11), Australia (2), Asia (7), Africa (1)

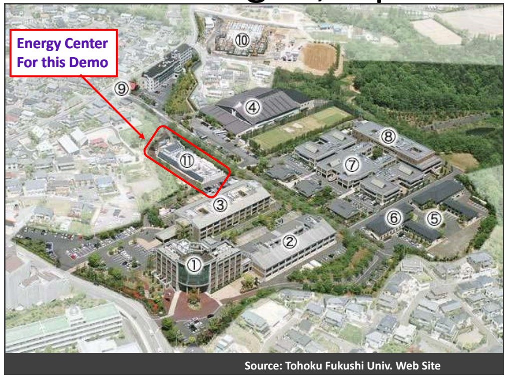
- Definitions
- Benefits
- Functionalities and technologies
- Business cases
- Roadmap
- Annex 1: Demonstration projects
- Annex 2: Microgrids use cases
- Annex 3: Microgrids definitions and nomenclature


Labein Microgrid Lab, Spain

Santa Rita Jail Microgrid, California



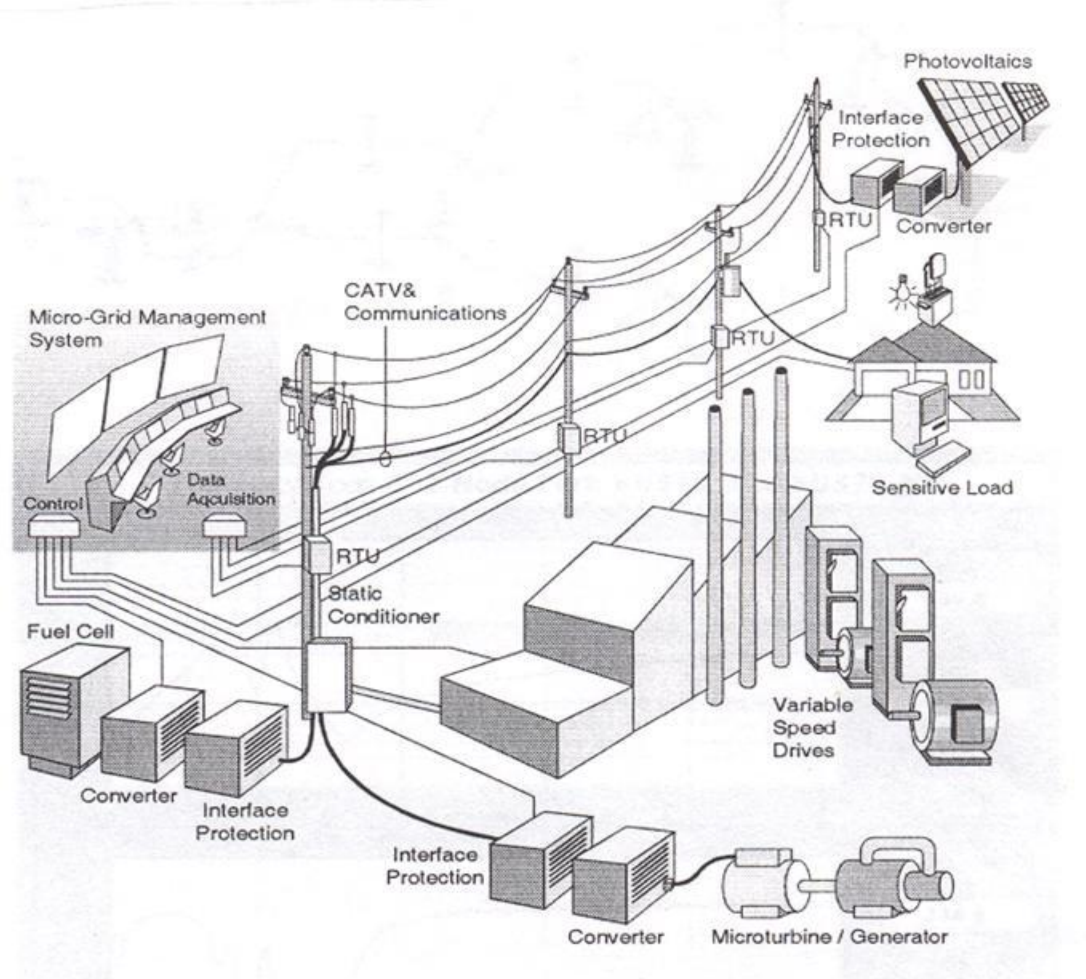
Sendai Microgrid, Japan



Mannheim-Wallstad Microgrid, Germany

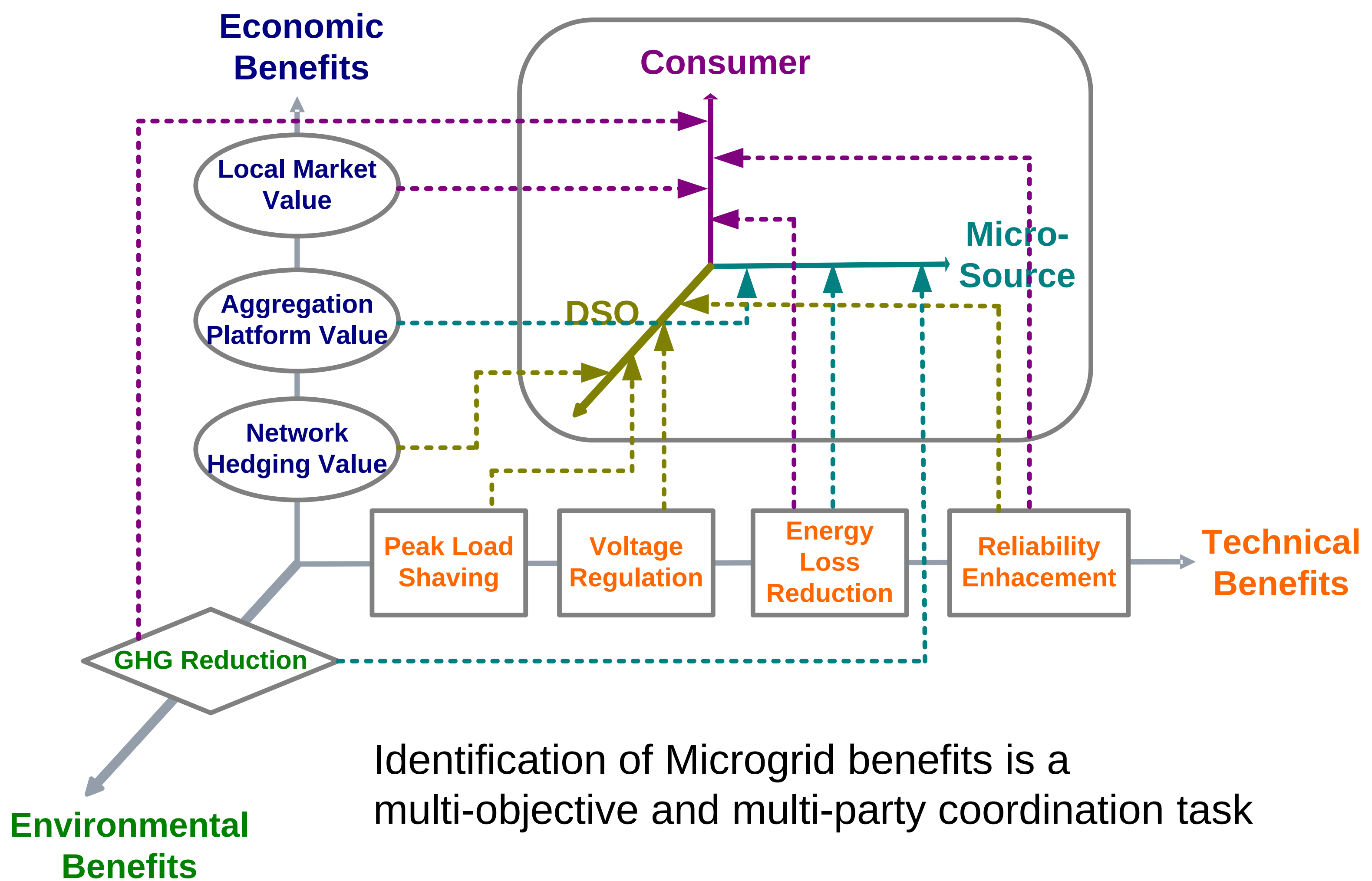
Definition of Microgrids

Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way, either while connected to the main power network and/or while islanded.



EU Microgrids (ENK5-CT-2002-00610) and MOREMICROGRIDS (PL019864)

Benefits by Criteria & Recipient



Identification of Microgrid benefits is a multi-objective and multi-party coordination task

Who will develop a Microgrid? Who will own or operate it?

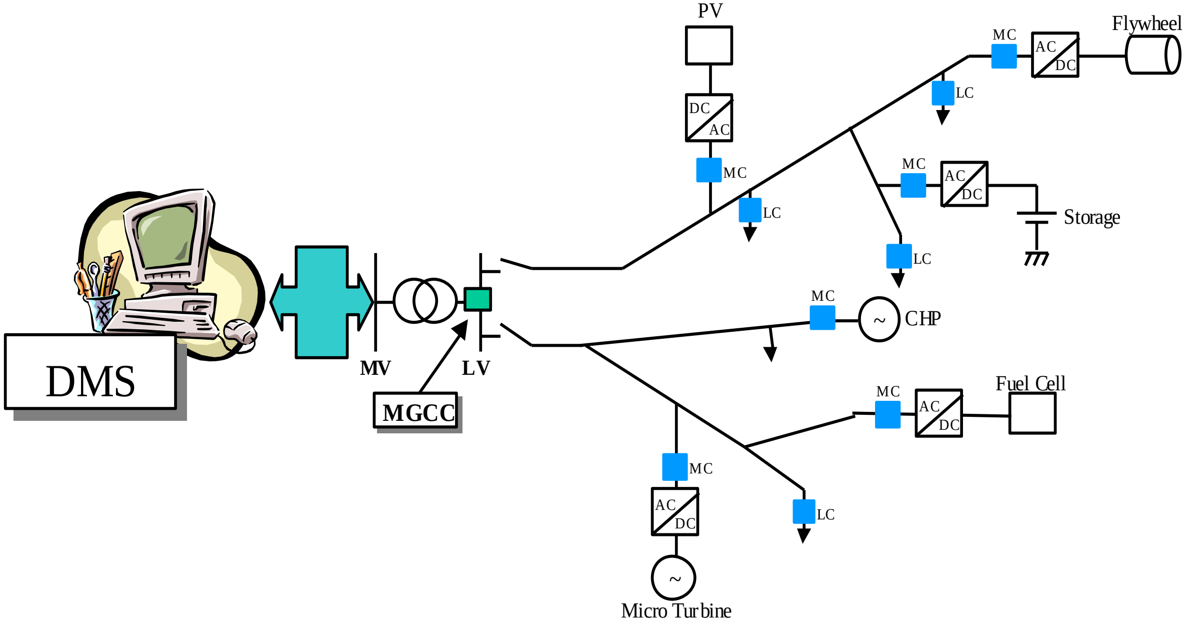
- Investments in a Microgrid can be done in multiple phases by different interest groups: DSO, energy supplier, end consumer, IPP (individual power producer), etc.
- The operation of the Microgrid will be mainly determined by the ownership and roles of the various stakeholders. Three general models:
  - DSO owns and operates the distribution grid and also fulfils the retailer function of selling electricity to end consumers. (DSO Monopoly)
  - ESCO are the actors that maximize the value of the aggregated DG participation in local liberalized energy markets (Liberalized Market)

Technical Challenges

- Use of different generation technologies （prime movers）
- Presence of power electronic interfaces
- Small size （challenging management）
- Relatively large imbalances between load and generation to be managed （significant load participation required, need for new technologies, review of the boundaries of microgrids）
- Specific network characteristics （strong interaction between active and reactive power, control and market implications）
- Protection and Safety / static switch
- Communication requirements

Microgrids – Hierarchical Control

MicroGrid Central Controller (MGCC) promotes technical and economical operation, interface with loads and micro sources and DMS; provides set points or supervises LC and MC; MC and LC Controllers: interfaces to control interruptible loads and micro sources



Centralized vs. Decentralized Control

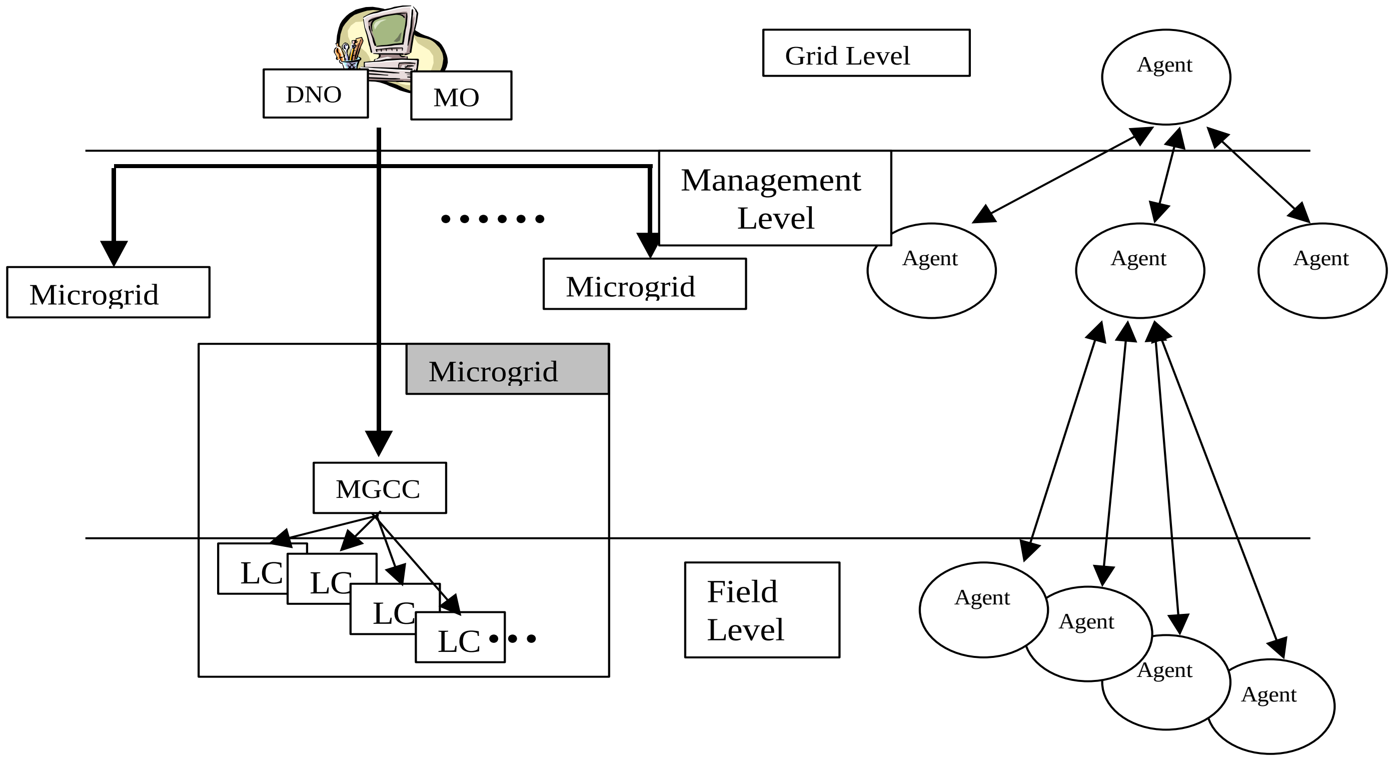
Centralized & Decentralized Control

- The main distinction is where decisions are taken
- Centralized Control implies that a Central Processing Unit collects all the measurement and decides next actions.
- Decentralized Control implies that advanced controllers are installed at each node forming a distributed control system.
- Choice of approach depends on DG ownership, scale, ‘plug and play’, etc.

Decentralized Control – MultiAgent Systems

- Autonomous Local Controllers
- Distributed Intelligence
- Reduced communication needs
- Open Architecture, Plug n' Play operation

- FIPA organization
- Java Based Platforms
- Agent Communication Language



Demonstration sites

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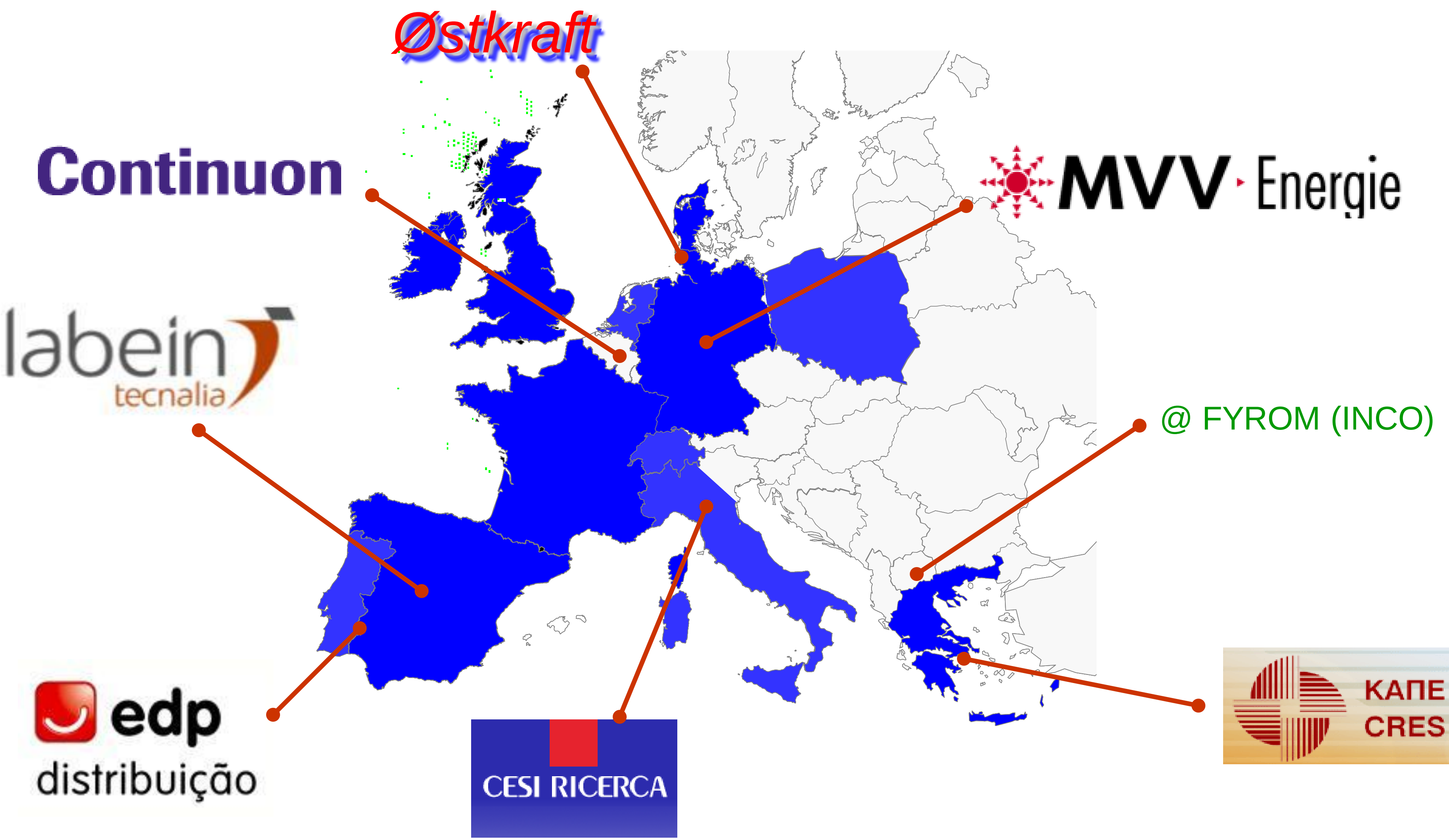
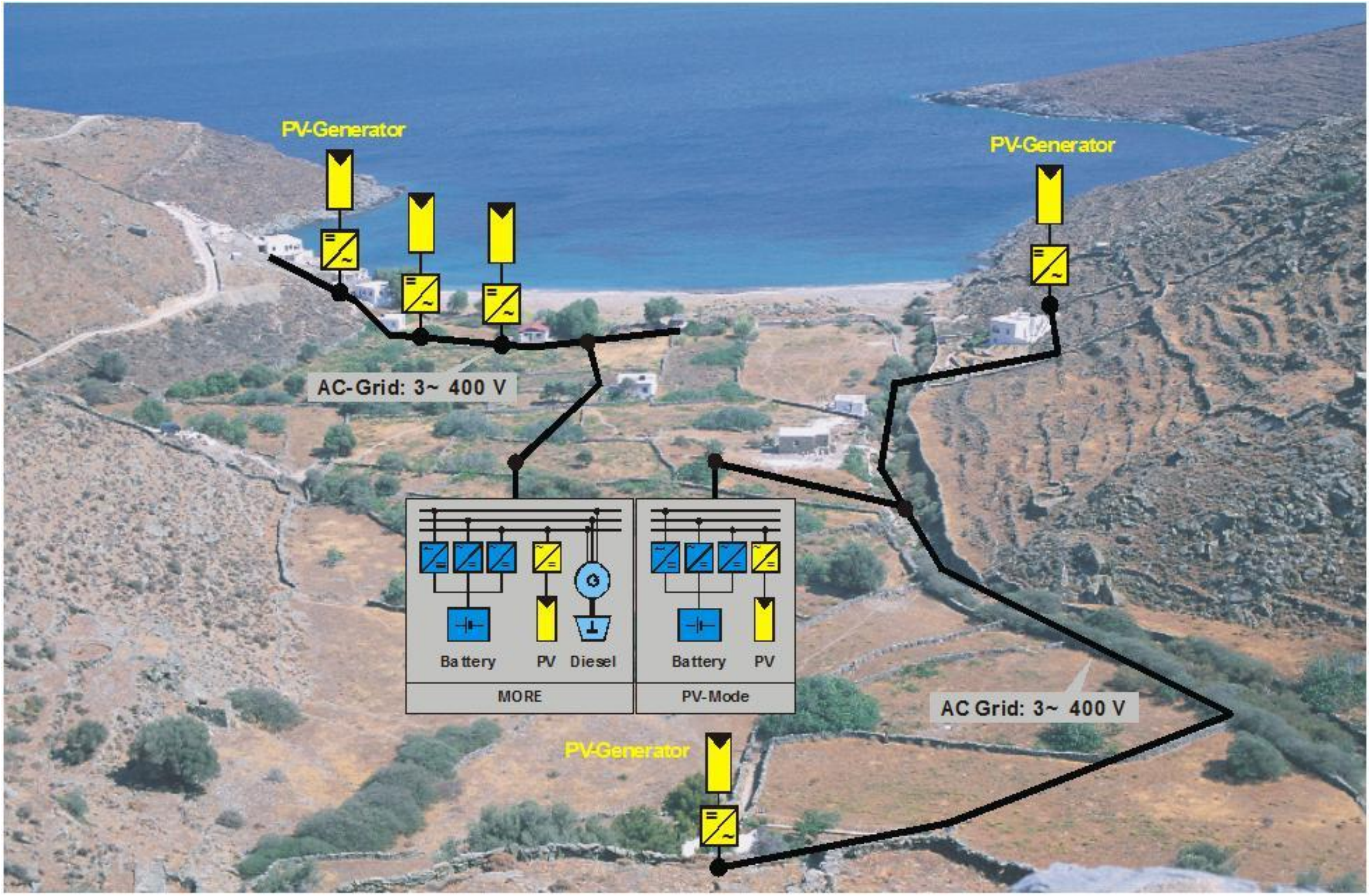


Pilot Microgrid in Kythnos



Supply of 12 buildings （EC projects MORE, PV-Mode, More Microgrids）

WG C6.24: Capacity of Distribution Feeders for Hosting DER

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Objectives

Study DER penetration potential and technical evaluation practices adopted by DSOs all over the world

Convener: Stavros Papathanassiou (Greece), completed in 2013

Membership: 32 experts from 19 countries/5 continents

Technical Brochure highlights

- **Overview of technical issues limiting DER hosting capacity**
- **Outline of DSO evaluation**
- **practices (21 countries)**
- **Discussion on means**

employed by DSOs to increase hosting capacity

- **Case studies**

cigré

Background

- Demand for the connection of Distributed Energy Resources (DER), mainly renewables, at MV and LV distribution constantly growing
- DER capacity exceeding load demand of feeders now a common situation
- Planning and operating issues/concerns due to high DER penetration levels:
  - Voltage regulation (voltage profile, interaction with regulation means of the network)
  - Harmonics
  - Short circuit capacity
  - Protection issues
  - Overall line/substation power factor
- Outcome: DNOs often reluctant to connect new DER → Investment delays, interconnection cost escalation

Scope

- Study **limits** of distribution feeders for hosting DER
- Derivation of **practical guidelines** for connection of DER (if possible, without resorting to detailed studies)
- **Topics** to be elaborated within the WG:
  - **Problems** caused by connection of DER at distribution level
  - Review national **experiences**, case studies
  - Derivation of **simple guidelines** based on existing practices
  - Effect of **DER, DSM, EVs and network control** in increasing hosting capability
  - Limitations and gaps to adopt **DER control** at the MV, LV levels, technical and commercial

Technical Issues

- Thermal ratings (transformers, feeders etc) especially on:
  - ✓ Low load – max generation situations - unavailability of network elements (N-1 criterion)
- Voltage regulation
  - ✓ Overvoltage (e.g. minL – maxG situation or/combined with high penetration in LV network) - Undervoltage (e.g. large DER after OLTC/VR) - increased switching operation of OLTC/VR
- Short circuit
  - ✓ DER contribution on fault level - compliance with design fault level etc
- Reverse power flow – impact on:
  - ✓ Capability of transformers, automatic voltage control systems (e.g. OLTC), voltage regulation, voltage rise etc
- Power quality
  - ✓ Rapid voltage change, flicker, DC current injection etc
- Islanding – Protection
  - ✓ Issues relevant to personnel/consumers/facilities safety, mis-coordination among protection equipment and reduced sensitivity operation zone

Simplified rules/practices for Host Capacity Definition

According to several DSOs practices, simplified and applicable rules of thumbs have been gathered and sorted as follows:

- Criteria based on ratings/thermal limits
- Criteria based on short circuit capacity
- Criteria based on the load-to-generation ratio
- Other criteria

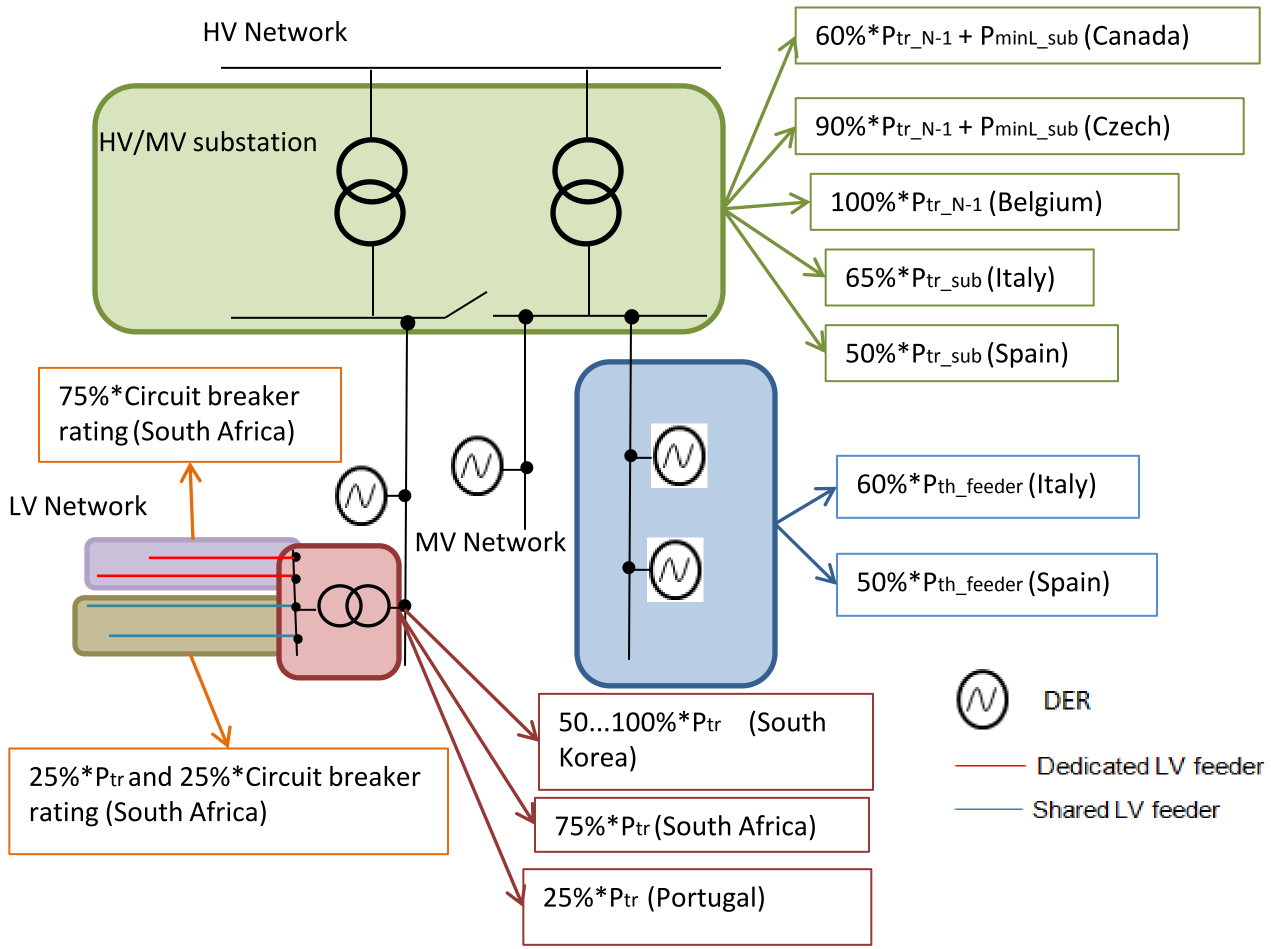
The above mentioned can be used as:

- **Strict** method of determining the hosting capacity (potential violation leads to rejection of DER application for connection to the network) or
- **First, preliminary and fast interconnection study** the violation of which leads to the conduction of analytical interconnection studies.

Simplified rules/practices for Host Capacity Definition
Criteria based on ratings/thermal limits

Take into account:

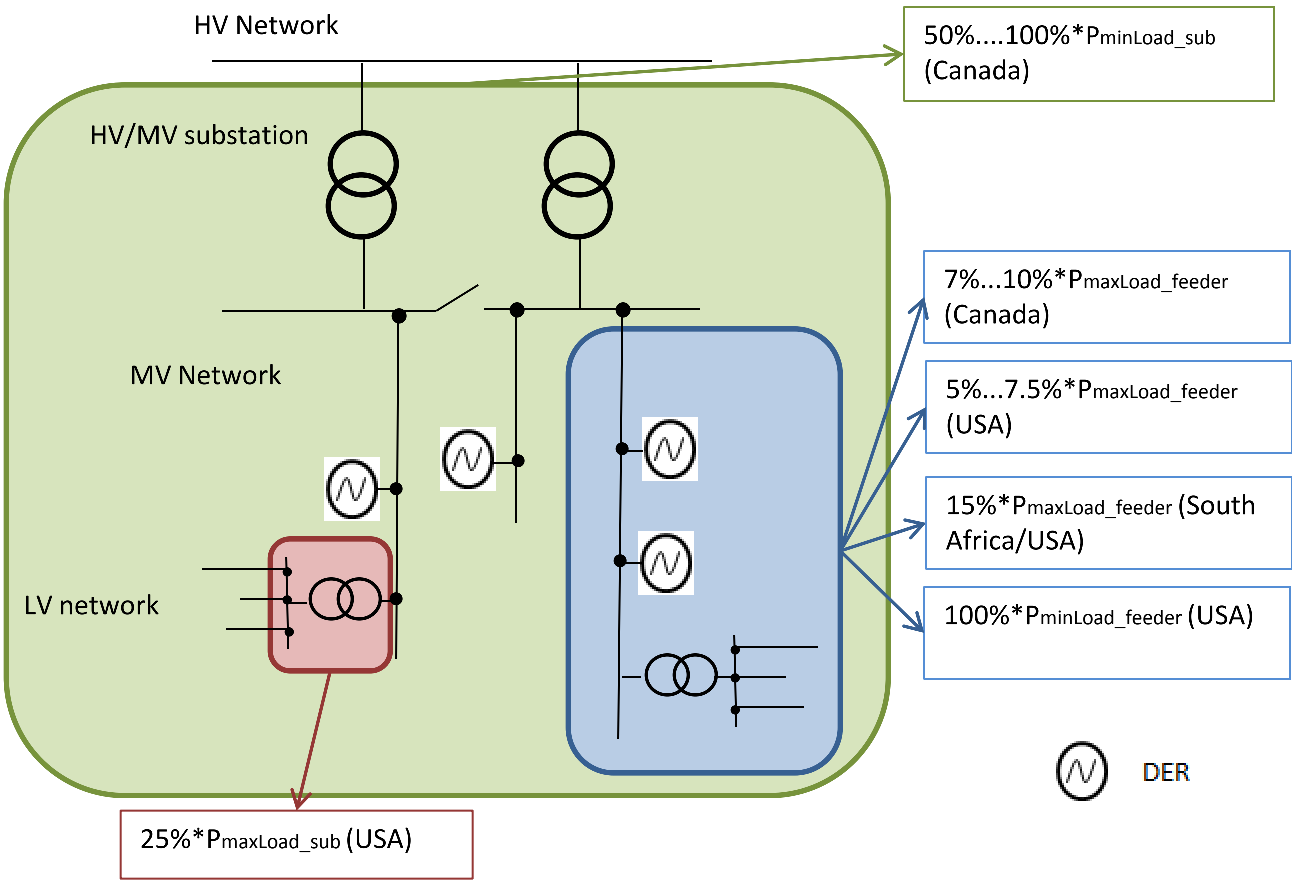
1. N-1 situation
2. Connected load
3. Possible voltage rise
4. Possible reverse power flow



Simplified rules/practices for Host Capacity Definition
Criteria based on load/generation ratio

Take into account:

1. Connected load
2. Avoidance of islanding situation
3. Voltage regulation
4. Possible voltage rise



Simplified rules/practices for Host Capacity Definition Other Criteria

1. Criteria based on short circuit capacity
   - Compliance with design fault level (especially at the busbars of the HV/MV substations)
   - DER short circuit contribution to network short circuit ratio
   - DER nominal power to network short circuit ratio

2. Criteria based on limitations defined by TSOs
   - There is a well defined hosting capacity for each TS/110kV substaition (contract between TSO-DSO) **(Czech)**
   - There is a calculated hosting capacity for the local HV network **(Canada)**
   - For DER with nominal power greater than 1 MW, the TSO is informed by the DSO for evaluation of possible impacts on its network **(France)**

Simplified rules/practices for Host Capacity Definition - USA Practices

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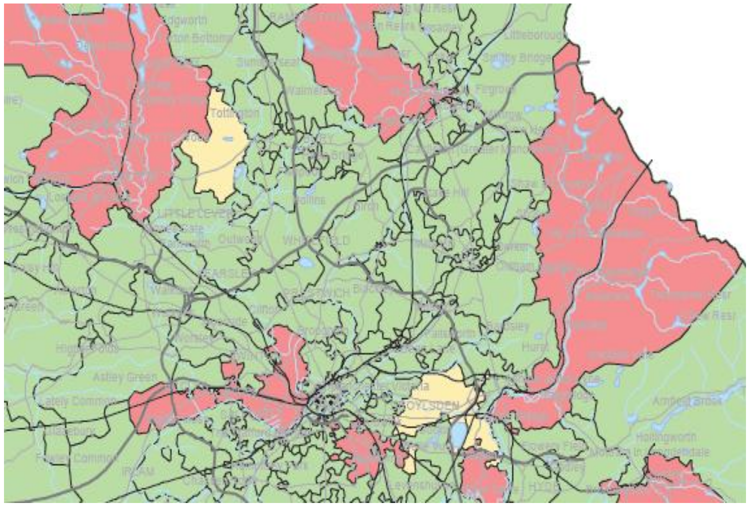
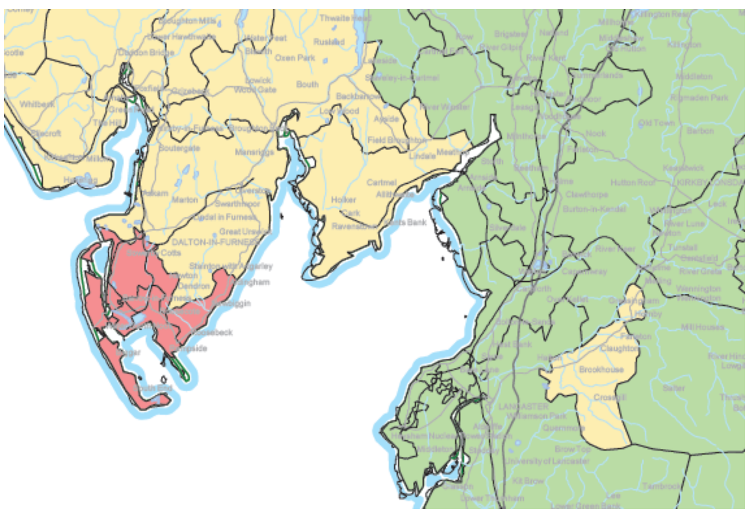
- The most DSOs have adopted the FERC (Federal Energy Regulatory Commission) interconnection procedures or similar to them.
- The DSOs separate the whole interconnection evaluation procedure in the simplified **(Fast Track Process)** and the analytical one **(Study-detailed Process)**
- Flow charts (too complicated some times) are used to set criteria that are considered as a safe-side evaluation **(screening criteria)**
- The violation of the simplified procedure leads to the conduction of analytical interconnection studies.

Transparency and Publicity Practices





Electric Northwest – U.K.

Map showing the available substation short-circuit DER capacity

Distribution areas of 132/33 kV

- Short circuit > 100% fault rating of substation
- Short circuit = 95-100% fault rating of substation
- Short circuit < 95% fault rating of substation

Map showing the available substation thermal DER capacity

Distribution areas of 132/33 kV

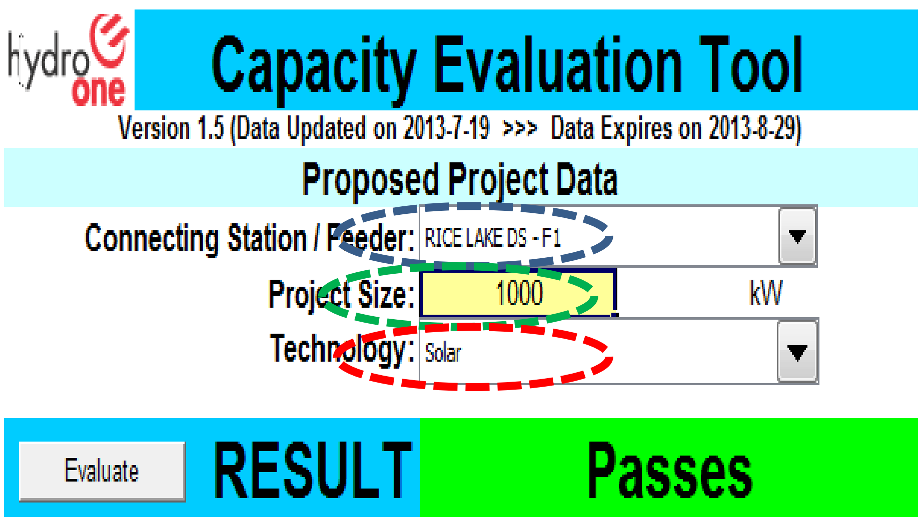
- Unlikely to have sufficient hosting capacity
- Limited hosting capacity
- Available spare hosting capacity

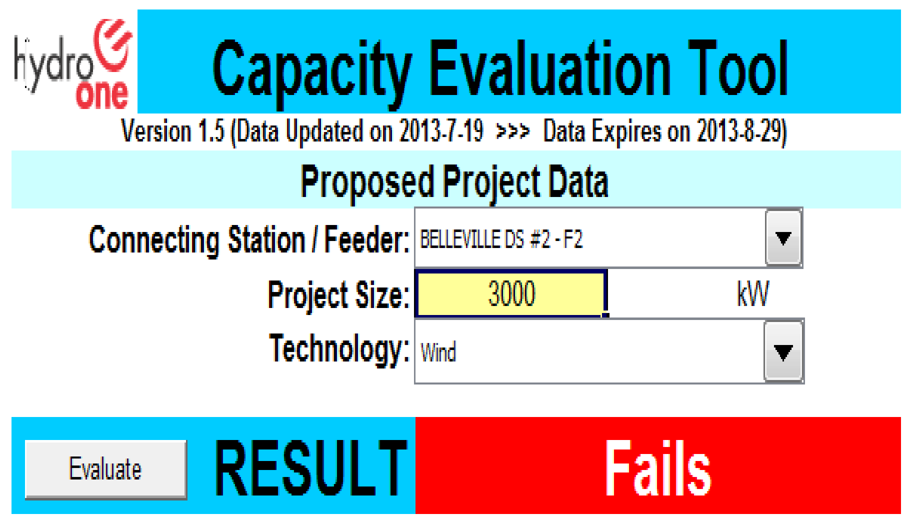
Transparency and Publicity Practices

Application that calculates the station and feeder capacity (Hydro One – Canada)

Criteria:

- Available thermal capacity of transformers and feeders
- Available short circuit capacity
- DER to load ratio





Means employed by DSOs to increase the Hosting Capacity

- Swallow and deep connection works:
  - Reinforcement, rearrangement
  - New (dedicated) networks

- Short-circuit issues:
  - Network elements upgrading
  - Generators characterized by low short-circuit contribution, transformers with high impedance value and installation of series inductors

- Voltage regulation:
  - Upgrading OLTC/VR (higher bandwidth, readjustment of control settings, cancellation CTs to modify OLTC settings)
  - Readjustment of MV/LV transformers fixed taps or/and installation of MV/LV transformers equipped with OLTC
  - Conversion of fixed shunt capacitors to switched

Means employed by DSOs to increase the Hosting Capacity

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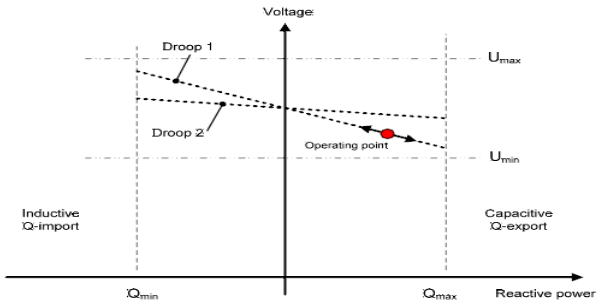
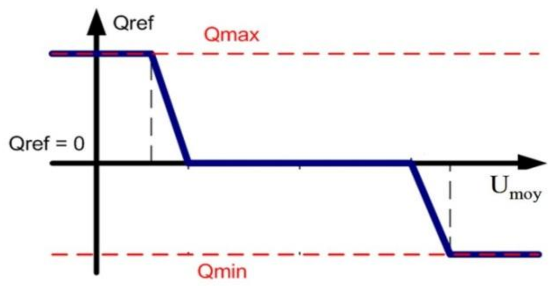
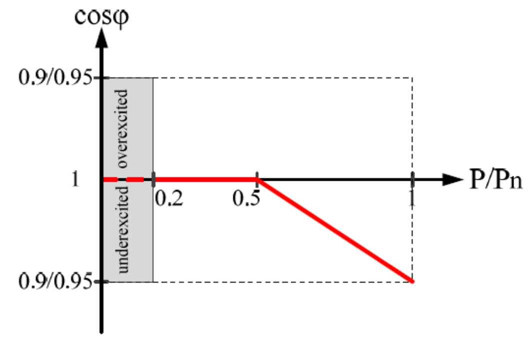
- Control of DER
  - ➢ Reactive power control (P-Q, V-Q κ.α.), active power curtailment







- Future concepts
  - ➢ Centralised or decentralised storare for peak saving
  - ➢ Coordinated (centralised or decentralised) voltage control
  - ➢ Usage of SCADA software or other (smart grids, web-interfaces e.g.)

Conclusions

Limiting factors for DER interconnection:

- Thermal ratings
- Voltage regulation
- Short circuit current
- Reverse power flow
- Power quality

Simplified rules/practices for defining Hosting Capacity:

- Criteria based on ratings/thermal limits
- Criteria based on short circuit capacity
- Criteria based on the load-to-generation ratio
- Other criteria

Transparency and publicity practices adopted by DSOs:

- Tables, geographical maps, applications (calculators)

Means available to increase DER hosting capacity:

- Reinforcement, rearrangement or even construction of new network
- Reactive and active DER power control
- Storage machines (centralised, decentralised)
- Coordinated voltage control, smart grids etc

New CIGRE C6 Working Groups

WG C6.27 "Asset management for distribution network with high penetration of DER", convenor Britta Buchholz, 2012-2014

JWG C6.25/B5/CIRED "Control and Automation Systems for Electricity Distribution Networks of the Future" , convenor Giuseppe Mauri, 2012-2014

JWG B5/C6.26/CIRED "Protection of Distribution System with Distributed Energy Resources" , liaison *member Birgitte Bak-Jensen, 2012-2014*

JWG C4.C6.29 "Power quality and PVs" , liaison *member Stavros Papathanassiou, 2013-2015*

JWG C4/C6.35/CIRED "Modelling and dynamic performance of inverter based generation in power system transmission and distribution studies", 2013-2016

WG C6.36 "The Impact of Battery Energy Storage Systems on Distribution Networks", Convener Richard Rivas, under approval…

The Challenge

Cigre Strengths

Cigre Next Steps