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DRES2Market

Desarrollar un enfoque asequible y adecuado para facilitar la integración efectiva de grandes volúmenes de energía renovable en el sistema y la participación activa de los recursos distribuidos en los mercados de electricidad, así como fomentar y permitir su actuación en los servicios auxiliares

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Since 2017 she works for APPA Rennovables, as Project Manager, with the goal to offer the best service to associates and support in the representation of APPA Renovables always defending the interests of the Renewable Sector. Lucia has a huge experience in teaching and speaker on photovoltaics, as a speaker at national and international conferences and as a teacher of various Masters. APPA Renovables is the most important association of renewables in Spain, where she also manages the European project iDistributedPV, a joint effort of 12 different companies and associations from 6 different European Members.

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- EU Commission-DG Enterprise (Europe Innova): Member of experts' panel, R&D in energy sector. Main articles:
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Sergio Vicente Muñoz Delgado. Sergio, degree in Computer Science. Sergio is an IT Technician at OMIE. He is responsible for management, monitoring and integration of projects and software developments related to the Electricity and Gas Markets. He has worked for OMIE since 2012, initially as a market operator in the IT Department, undertaking control operations of the Day Ahead - Intraday Electricity Markets managed by OMIE. He was also involved in testing, execution and coordination for some integration projects, which required permanent interactions among working teams. Furthermore, he is constantly aware of new market and technology trends to introduce into the system.

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He is also director of the France-Japan ITER Physics Laboratory between AIX-MARSEILLE UNIVERSITY (AMU)/Aix Marseille University, Osaka University, Kyushu University and National Institute for Fusion Science (Japan). He is specialist of modelling and simulation of complex systems with a focus on nuclear fusion science. He is also leading an international project on Physics Innovation by Artificial Intelligence-based Optimal Experimental Design and reinforcement learning for plasma-material interaction processes. He has 180 publications in referred international journals, 7 books edited and more than 80 invited talks at major international conferences. He has been invited Professor at Princeton University (USA), Columbia University (USA), Osaka University (Japan), Kyoto University (Japan), and University of Sao Paulo (Brazil). He has been PI of several grants from : EURATOM, EUROFUSION, AIX-MARSEILLE UNIVERSITY (AMU), ANR and Japanese Society for Promotion of Science (JSPS). He is a JSPS fellow since 2006 and has received in 2015 an award with from Osaka University with a grant for Promotion of International Collaboration (Japan).

INTRODUCTION

The aim of DRES2Market project is to develop a complete and comprehensive framework to facilitate active participation of distributed generation based on renewable energy (solar PV and wind energy) in the electricity market and supply of ancillary services to the power system and developing a comprehensive and affordable approach to facilitate effective participation of distributed generation based on wind and solar PV energies on the electricity markets, enable to provide balancing and reserve services according to market criteria.

The RES, energy storage, and telecommunication and information technologies have significantly improved over the last years. The DRES2Market project proposes their large-scale application to enable participation of variable renewable energy in the electricity markets and provision of ancillary services. DRES2Market Project require partners to exchange information with the purpose of defining the research idea.

With reference to the market rules, the markets are analysed to identify best practices about how the variable renewable energy participates in the day ahead market and intraday markets, the operative of the continuous market and the gate closure periods, the different approaches that could be applied for the participation of variable renewable energy distributed generation in the wholesale market, and the information and economic flows that would be established among the market operator, the system operator, the aggregator and the non-incumbent market actors (I.e. individual and collective prosumers).Also, the role of establishing the functions of the aggregator to integrate a portfolio of prosumers to manage the relationship with the market and the system operator is analysed identifying the activities that would be developed. The most promising approaches or solutions for enabling the active participation of variable renewable energy in markets: grid codes, market rules, technologic solutions, operative procedures, and effective collaboration of the consumers' frameworks are identified and explained.

SIMULATIONS ENVIRONMENTS

The partners of the project have simulated and evaluated the impact of the proposed solutions and case studies in two main simulation environments: electricity markets and system operation.

The power exchange or market simulation environment, provided by OMIE, will be used evaluate the impact of the installation of different amounts of RES and VREs and the application of different market rules on the electricity market price, the revenues of the RES and distributed variable renewable energy producers, the prices of the interconnection and the exchange of electricity among the different systems. Also, the environment will allow the simulation of local markets of flexibility, oriented to the participation of prosumer through the intervention of aggregators.

The electricity systems and grid simulator, provided by IMDEA, will allow simulating in real-time a complete electricity system including the electricity flows in the transmission and distribution systems, the requirements of ancillary services, different grid codes and market rules. The environment will focus on the supply of system reserve by aggregation of prosumers and the simulation of the ancillary services markets considering the active participation of the demand. In order to perform this process, the IMDEA’s Smart Energy Integration Lab (SEIL) and a leading power system analysis software application will be at disposal of the partners.

The impact of the proposed solutions and case studies in two main simulation environments: electricity markets and system operation

Both environments will perform separate analysis, but also work in conjunction in some test cases. In this manner, a complete energy system and the potential markets are enabled to be simulated for a more thorough assessment of the solutions.

The additional support simulation tools that the consortium will use in the studies are:

- An **Active Demand Application** that will engage into the market simulation environment to perform the process of a retailer or aggregator of enabling demand response to their clients, in such way that both retailer/aggregator and clients benefit from the solution.
- A **Prosumer simulator** that allows the characterization of a PV installation for self-consuming, including the possibility of attached batteries and grid feed-in. The tool assesses the operative of the installation and generates the derived energy and economic flows.
- A **Dispatch calculation datasheet** that estimates the demand coverage according to different scenarios, generation dispatch, costs, and the introduction of different alternatives like demand response, consumption switching and energy storage.
- The **General Algebraic Modelling System** (GAMS) is an evolved and mature system that gives the consortium access to cutting-edge modelling and optimization technology.

The DRES2Market consortium agreed a set of test cases that has supported the definition of requirements for the subsequent collection and characterization of the simulation environments and tools. The test cases state the concepts, solutions, or scenarios to be performed in the simulations, what kind of data will be required, and the outputs purchased in the analysis.

SOME TEST CASES EVALUATED

As it has been commented previously, one of the main objectives of the project is to evaluate the impact of large penetration of renewable energies on the electricity markets and the system operation using case studies based on simulation processes, according to different time scopes: the electricity demand coverage using an hourly simulation dispatch taking into account the volatility of solar photovoltaic and wind energy, the participation of renewable energies and distributed generation based on solar photovoltaic in the European Continuous Intraday Electricity Markets and the Local Electricity Markets, and the impact of the System Operation and the Distribution Network.

1. CASE: EVALUATE TECHNICAL CHALLENGES OF DISTRIBUTED GENERATORS PROVIDING FAST FREQUENCY RESPONSE AND VOLTAGE SUPPORT.

The main objective of this test case was to identify the main challenges for providing ancillary services with distributed generators. This includes reactive power injection for improving the voltage profile and active power injection to provide fast frequency response services.

The evaluation of this test case will include different aspects, but will focus mostly on the technical challenges identified that affect DSO as the market for ancillary services on the distribution level has not been created so far. Recommendations for grid codes are suggested.

Test Case Description

The model and topology of Cygre European MV distribution network was used for all the analyses. Also, renewable energy sources were modelled as Voltage Source Converters (VSC) with their control system operate in a grid-following mode delivering active and reactive power to the network required by the system operator.

The new set of Grid Codes that are currently in development and will be imposed by TSOs and DSOs will require from RES to contribute in the network stability during the operations. Here the focus is on the requirements regarding the frequency and voltage support. Based on the basic working principles of synchronous generators connected to the network, RES are required to increase the active power injection in case of frequency drop, and vice versa. To do so, the DSO sets a characteristic defining the adjustment of the active power, based on the network frequency. The general shape of the characteristic is shown in the Figure 1 a. While the network frequency is within the allowed range (between w_low and w_high) the RES is not required to act. However, if the network frequency drops below w_low, the RES increases the active power following the defined slope. The similar requirement is defined for the adjustment of reactive power based on the voltage level at the RES point of connection (POC) (depicted in Figure 1 b).

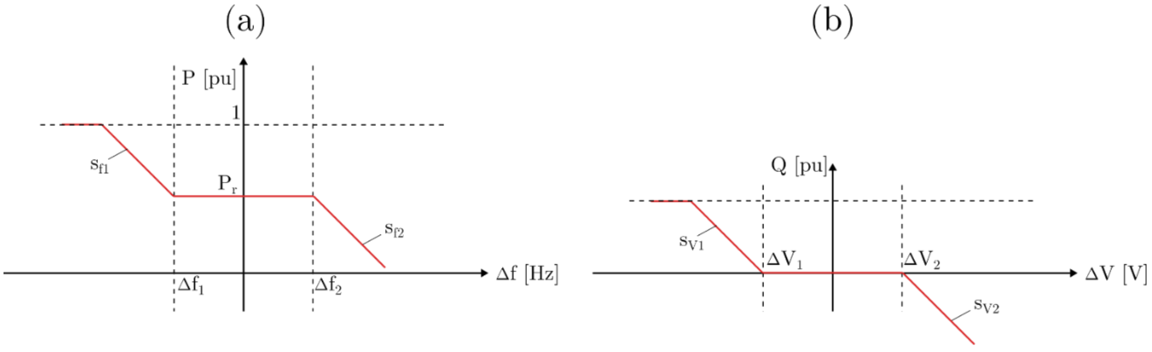


Figure 1. RES grid support characteristics

Apart from the renewable energy sources, the test network included two batteries. The batteries power stage was identical to the RES, however, the battery control systems allowed the power to flow both from and into the battery. This flexibility of the batteries, compared to the RES, allows provision of several additional services. The battery was also operated in the grid-forming mode, capable of controlling the voltage and frequency at the point of connection.

In this test case, the focus was on the network frequency and voltage stability analysis. For this purpose, several key performance indicators (KPIs) are used. The indicators defined here are observed in all test cases, allowing for comparative analysis among different test case scenarios. The key performance indicators used in this study are following:

- KPIs for network voltage stability:
    - dV/dP – This indicator is used to determine the change in the voltage amplitude caused by the change in the active power. The KPI value is determined for each bus for change in the active power of each load in the zone of interest. It is defined as:

$$\frac{dV}{dP} = \frac{V_2 - V_1}{P_2 - P_1}$$

    - where V presents the voltage amplitude, P presents the active power, while subscripts 1 and 2 represent the operating point prior to and after the change, respectively.
    - dV/dQ – This indicator determines the change in the voltage amplitude caused by the change in the reactive power. The KPI value is determined for each bus for change in the reactive power of each load in the zone of interest. It is defined as:

$$\frac{dV}{dQ} = \frac{V_2 - V_1}{Q_2 - Q_1}$$

    - where Q presents the reactive power, while subscripts 1 and 2 represent the operating point prior to and after the change, respectively.
- KPIs for network frequency stability:
    - RoCoF – This indicator defines the rate of change of frequency, hence the name RoCoF. Although it is mainly used in the transmission network studies, its importance raises in the network distribution level with the increase in converter-based generation, such are RES. In the distribution network the main concern regarding RoCoF is its impact on the protection equipment. The rapid change in the frequency caused by sudden demand or production change, can cause protection devices in the network to act (cite a paper on this). The RoCoF is defined as:

$$\frac{d\Delta f}{dt} = \frac{f^0 \cdot P_k}{2 \cdot \sum_{i=1, i \neq k}^{N} H_i \cdot S_i}$$

Where $\triangle f$ is the deviation of the frequency from the nominal value f^0, P_k is the change in the active power of network element k, and H_i and S_i are the inertial constant and apparent power rating of synchronous machine i, with i ranging from 1 to N, where N is the number of synchronous generators in the system.

- Nadir – The indicator specifying the maximum deviation of the frequency from the initial state during the transient.

In Figure 2 the configuration of the test network used in this study is shown. Two main switches are closed, thus both feeders are fed from the main network directly. The connection between the two feeders (contactor S1) is open separating the two zones of the network. The contactors S2 and S3 are closed during the network operation. This creates a mesh network topology in the zone fed from Feeder 1 (zone 1), while the network fed from Feeder 2 (zone 2) has a radial topology. The analysis conducted here focuses on the frequency and network stability analysis in the zone 1.

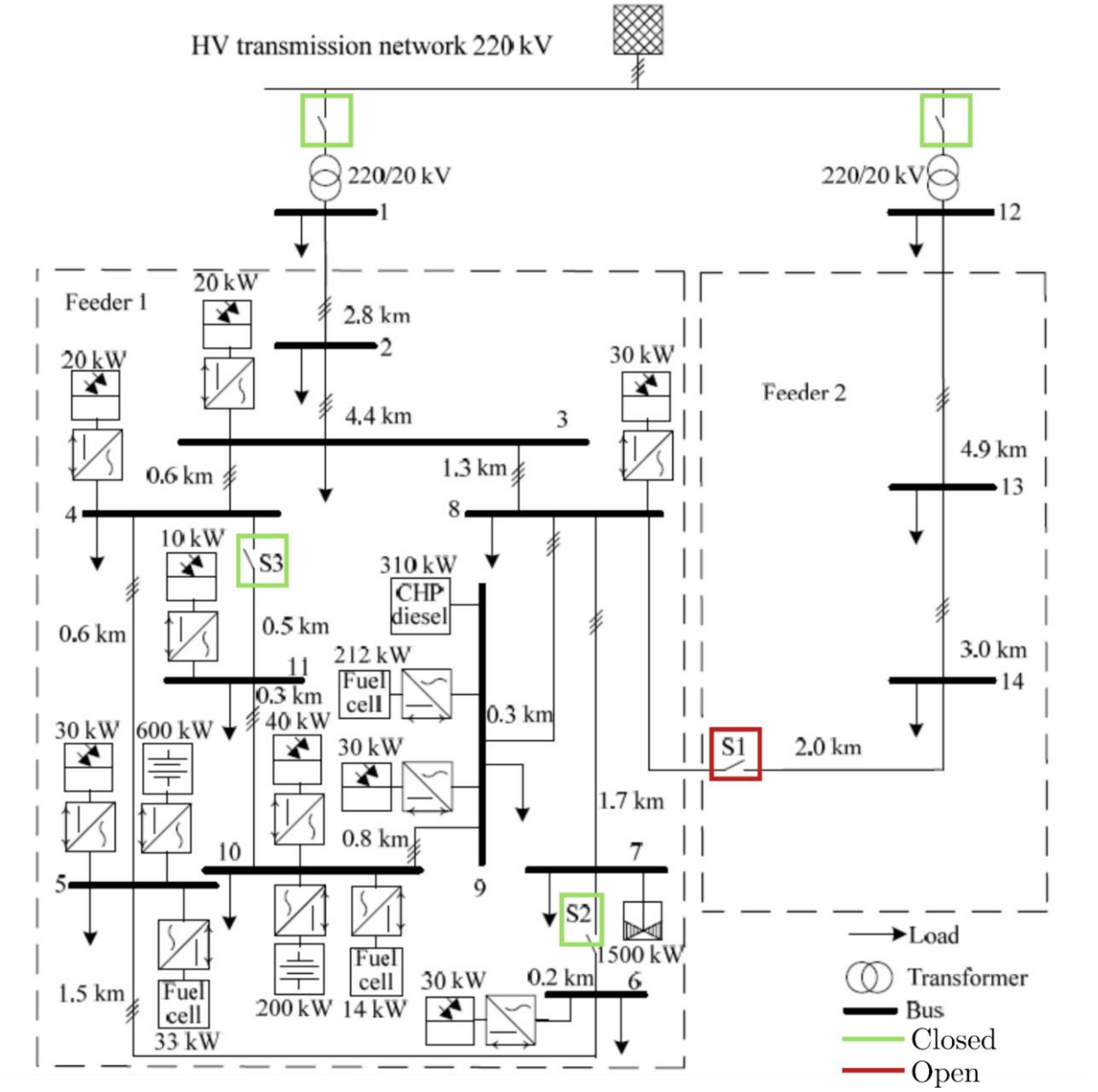


Figure 2. Network configuration used in the analysis

Six scenarios were used to evaluate different impacts on voltage and frequency stability from renewable and storage grid integration. The first scenario represents the base case without any frequency or voltage support that is used for the comparison with other cases.

The scenarios developed in this study are following:

- Scenario 1: The network operates with the RES penetration specified in the benchmark network. The RES operate as grid-following devices without any grid support in voltage or frequency. The batteries are not connected to the network. This case is used to study the initial network operation.
- Scenario 2: The RES voltage and frequency support is included. Thus, RES are adjusting the active and reactive power delivered to the network based on the network operating conditions.

- Scenario 3: The penetration of RES is increased by 50%, while the rest of the network is not changed. This scenario presents a study on the increased RES production (repowering) during ideal operating conditions for all the RES in the network.
- Scenario 4: The total capacity of RES is increased three times compared to the original network specification. This scenario presents the case where the amount of the RES connected to the medium voltage network significantly exceeds the initial network specifications.
- Scenario 5: The batteries are connected to the network. The penetration of RES in the network is set to the initial level, specified in the original Cigre benchmark network. This scenario shows the battery providing ancillary services and improvements in the network performance.
- Scenario 6: The batteries are connected to the network. The penetration of RES is three times higher than the initial RES capacity. This scenario shows the battery impact in the case of high levels of RES penetration.

The operating mode of all RES in the network is summarised in the Table 1.

Table 1. Operating mode of all RES in different scenarios

Node	RES type	Rated power [kW]	Scaling factor					
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
3	Photovoltaic	20	1	1	1.5	3	1.5	3
4	Photovoltaic	20	1	1	1.5	3	1.5	3
5	Photovoltaic	30	1	1	1.5	3	1.5	3
5	Battery	600	1	1	1	1	1	1
6	Fuel cell	33	1	1	1.5	3	1.5	3
7	Photovoltaic	30	1	1	1.5	3	1.5	3
8	Wind turbine	1500	1	1	1.5	3	1.5	3
9	Photovoltaic	30	1	1	1.5	3	1.5	3
9	Photovoltaic	30	1	1	1.5	3	1.5	3
9	Diesel Gen-Set	310	1	1	1.5	3	1.5	3
9	Fuel cell	212	1	1	1.5	3	1.5	3
10	Photovoltaic	40	1	1	1.5	3	1.5	3

10	Battery	200	1	1	1	1	1	1
10	Fuel cell	14	1	1	1.5	3	1.5	3
11	Photovoltaic	10	1	1	1.5	3	1.5	3

Technical challenges

Increased integration of RES present several technical challenges to DSOs:

- Voltage and line congestions, being the main network capacity related issue. This is not the objective of this Test Case.
- Voltage instability, because of increased levels of grid-following converters.
- Frequency instability, because of reduced system inertia, more interactions with other networks areas.

Here are the main technical challenges identified for frequency and voltage stability in distribution networks:

- Base scenario (Scenario 1) indicates that without the Grid Codes implemented RES real power injection produces significant voltage variations. In addition, voltages are sensitive to changes of local loads, especially, local reactive power injection. This is an important results indicating that by using reactive power voltage levels can be controlled and, therefore, corrected. No frequency support is provided and the inertial response depends purely on the external network.
- When RES are deployed in network using the Grid Codes for frequency and voltage support (Scenario 2), the network performance improves. Voltage sensitivity is decreased and frequency response marginally improved. Further increase of RES by 50% (repowering, Scenario 3) brings more benefits in the same way by improving frequency response and voltage levels.
- In Scenario 4 RES levels are 3 times those in Scenario 2. This represent unrealistically high levels of RES deployment. Apart from possible line congestions and reverse power flows, voltage levels are more sensitive to reactive power changes, while active power causes less problems. Network planning tools must be deployed for the optimisation of the network resources and its operation. However, as a result of increased RES, frequency response is improved.
- Scenarios 5 and 6 show the impact of 2 batteries connected to the network with two levels of RES penetration. While under nominal RES integration (Scenario 5) significant improvements in voltage and frequency stability are recorded, the network planning tools must be used for any repowering of the network as it was unstable in Scenario 6 increased levels of RES. This is a logical result because the voltage sensitivity is much higher and battery control systems must be tuned.

Market Challenges

The market evaluation of the test cases is somewhat more difficult as the current regulation only obliges DSOs to provide customers with good quality of voltage, however, the provision of good frequency currently lies with TSO (as analysed in WP2). It is expected that in future both TSO and DSOs will be responsible for both qualities. Creating and managing these new ancillary service markets represents the main challenge.

With respect to voltage stability, the results of Test Case 1 showed that increased levels of RES integration may introduce certain network issues, however, they may also form a part of the solution. The following are the principal findings:

- Voltage levels are closely linked with the network design, but show increased sensitivity to RES integration levels.
- Battery deployment (as well as STATCOM) greatly improve voltage profiles. Battery and STATCOM voltage services may be both used to control voltage.
- So far it was the operator obligation to control the voltage levels, however, for some voltage and line congestion a market solution in form of a local market could be found (instead of DSO being solely responsible)

With respect to frequency stability, it is expected the distribution networks will participate in inertial markets and provision of frequency ancillary services similar to those already present at transmission level (Fast Frequency Response, Enhanced Frequency response etc). The main findings from the frequency analyses are provided here:

- In all the scenarios RES integration was proportional to the network robustness, so the more RES the more robust the frequency response (that is logical).
- Battery storage can significantly improve frequency response and a local ancillary service market could be used to deal with local frequency issues (not at transmission level, but at distribution level).

Proposed approach and recommendations

It is clear that increased levels of RES integration will require several changes in how distribution networks are planned and operated. Novel technical and ancillary market solutions will be necessary.

- From the DSO point of view, the operation of the ancillary service markets should be included in the network planning tool to avoid possible voltage and line congestions while increasing RES levels or repowering networks.
- Existing Grid codes seem adequate to deal with both voltage stability and network frequency response. There is a potential for more use of reactive power capacities of RES in a coordinated way.

- Operation of battery storage for both voltage and frequency stability should be defined in a better way. Both regulatory framework and service market integration of battery systems should be defined.

2. CASE: LARGE RENEWABLE ENERGY PENETRATION IMPACT IN THE ENERGY SYSTEM

The objective of this Test Case was to analyse the technical and economic impacts of massive penetration of PV self-consumption. In particular, this Test Case evaluated PV installations in Poland that has seen a huge increase of micro PV installations in Poland – from 50 000 at the end of 2018 to 450 000 at the end of 2020 with further growth expected.

Test Case Description

The most promising distributed solar PV solutions identified in Poland (like homeowner, company and municipal organisation) with assumed range of PV sizes and energy storages were evaluated by analysing proposed criteria:

- Economic:
    - ✓ The estimation of the cost of the solutions (investments, operation and maintenance costs, etc.),
    - ✓ Impact of net – metering,
    - ✓ The identification of the economic flows,
    - ✓ The revenue and profitability model, (IRR, NPV, payback)
    - ✓ The calculation of the LCOE&LCOS of the solution
- Technical:
    - ✓ Solar generation,
    - ✓ Energy flows (energy bought from the grid, consumed from net metering, consumed from storage systems, consumed from panels, fed-in energy lost),
    - ✓ Reduction of carbon emissions,
    - ✓ Cycles of the storage system consumed,
    - ✓ Degree of self-sufficiency

Test conditions used were the following:

- Radiation profiles, PV generation and consumption data, specific characteristics of the demand profile.
- Real historical and current data from Polish markets (electricity tariffs and prices, economic and technical data, storage system).
- Real net-metering scheme,
- Real prices of PV panels, PV installations, energy storage,
- Inclusion of replacement costs, corporate taxes, inflation rate, charge and discharge rate

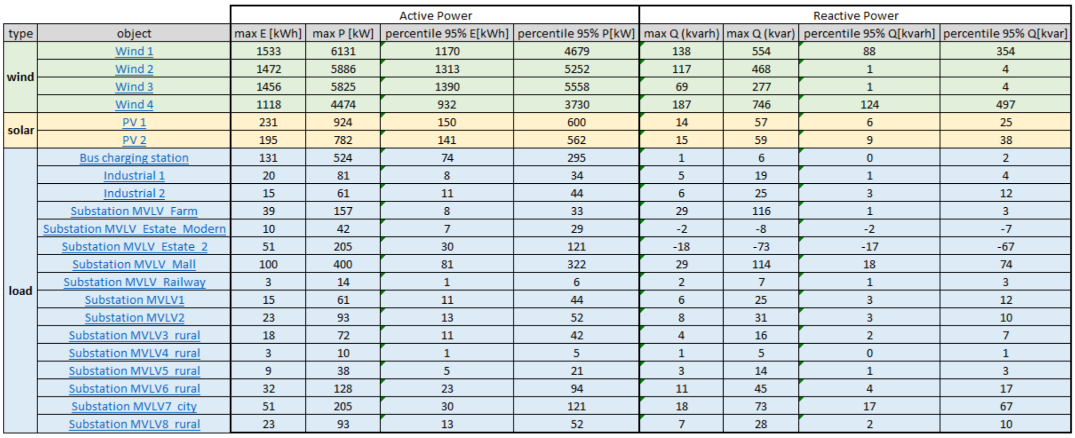
- Assumed ranges of PV installations in selected scenarios
- Number of analysed solutions, kind of prosumers.
- Range of PV sizes.
- Price of the electricity.
- Net – metering scheme
- Investment and maintenance costs (“what – if” scenarios possible)

The same test network (shown in Figure 1) of European configuration of CIGRE MV Benchmark Network was used in all the simulations.

A software tool OrigAMI developed by Enea Operator was used for aggregation, analyses and reporting of data collected by AMI smart meters. The data was obtain using advanced metering infrastructures data. OrigAMI system allows to export 15 minutes profiles reports of active and reactive power for each smart meter. For the purpose of the analysis, following profiles were generated:

- Generation profiles (2 x photovoltaics farms, 4 x wind farms)
- Loads - different types, described below

Table 2. Selected profile parameters



		Active Power				Reactive Power			
type	object	max E [kWh]	max P [kW]	percentile 95% E[kWh]	percentile 95% P[kW]	max Q (kvarh)	max Q (kvar)	percentile 95% Q[kvarh]	percentile 95% Q[kvar]
wind	Wind 1	1533	6131	1170	4679	138	554	88	354
	Wind 2	1472	5886	1313	5252	117	468	1	4
	Wind 3	1456	5825	1390	5558	69	277	1	4
	Wind 4	1118	4474	932	3730	187	746	124	497
solar	PV 1	231	924	150	600	14	57	6	25
	PV 2	195	782	141	562	15	59	9	38
load	Bus charging station	131	524	74	295	1	6	0	2
	Industrial 1	20	81	8	34	5	19	1	4
	Industrial 2	15	61	11	44	6	25	3	12
	Substation MVLV_Farm	39	157	8	33	29	116	1	3
	Substation MVLV_Estate_Modern	10	42	7	29	-2	-8	-2	-7
	Substation MVLV_Estate_2	51	205	30	121	-18	-73	-17	-67
	Substation MVLV_Mall	100	400	81	322	29	114	18	74
	Substation MVLV_Railway	3	14	1	6	2	7	1	3
	Substation MVLV1	15	61	11	44	6	25	3	12
	Substation MVLV2	23	93	13	52	8	31	3	10
	Substation MVLV3_rural	18	72	11	42	4	16	2	7
	Substation MVLV4_rural	3	10	1	5	1	5	0	1
	Substation MVLV5_rural	9	38	5	21	3	14	1	3
	Substation MVLV6_rural	32	128	23	94	11	45	4	17
	Substation MVLV7_city	51	205	30	121	18	73	17	67
	Substation MVLV8_rural	23	93	13	52	7	28	2	10

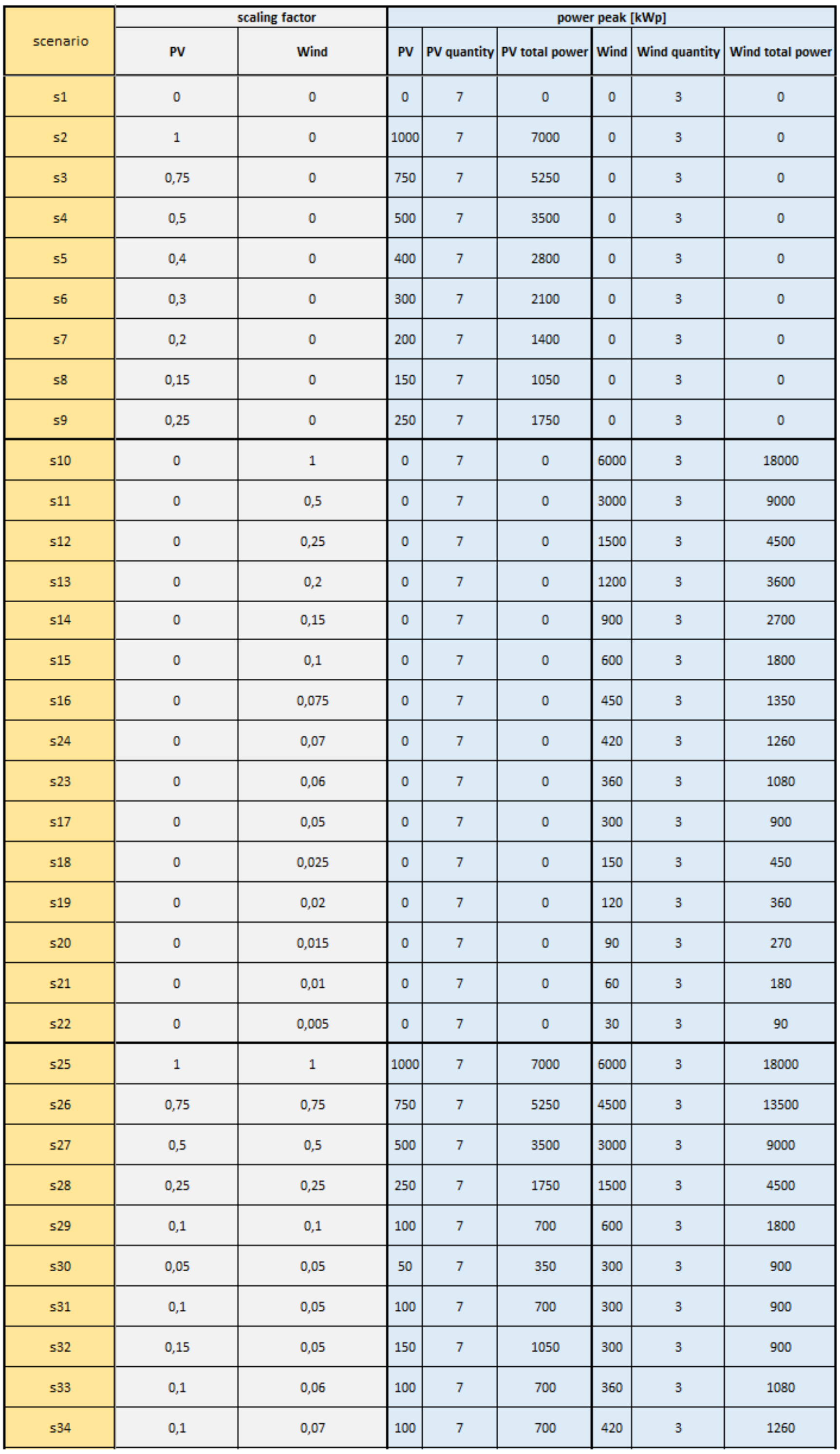
Example profiles in 15 minutes intervals were provided for one year for:

- Wind Farms
- Photovoltaics farms
- Industrial loads
- Building loads
- Railway loads
- Shopping mall loads
- Rural demand loads

Impact evaluation of RES large penetration for grid congestions was analysed using PowerFactory and a multiple scenario concept has been proposed for the study. Each scenario consisted of different configuration of power generation which was reflecting different ratios of scaling factor parameter which acts directly on energy profiles by scaling the values (expressed in individual values of kWp of generation and load). Scaling factor equals 1 reflects base input values and another specific scaling factors have been chosen to effectively determine the impact of RES on the grid.

The scenarios carried out reflected in different cumulative peak powers are listed in the table below:

Table 3: Evaluated scenarios



scenario	scaling factor		power peak [kWp]					
	PV	Wind	PV	PV quantity	PV total power	Wind	Wind quantity	Wind total power
s1	0	0	0	7	0	0	3	0
s2	1	0	1000	7	7000	0	3	0
s3	0,75	0	750	7	5250	0	3	0
s4	0,5	0	500	7	3500	0	3	0
s5	0,4	0	400	7	2800	0	3	0
s6	0,3	0	300	7	2100	0	3	0
s7	0,2	0	200	7	1400	0	3	0
s8	0,15	0	150	7	1050	0	3	0
s9	0,25	0	250	7	1750	0	3	0
s10	0	1	0	7	0	6000	3	18000
s11	0	0,5	0	7	0	3000	3	9000
s12	0	0,25	0	7	0	1500	3	4500
s13	0	0,2	0	7	0	1200	3	3600
s14	0	0,15	0	7	0	900	3	2700
s15	0	0,1	0	7	0	600	3	1800
s16	0	0,075	0	7	0	450	3	1350
s24	0	0,07	0	7	0	420	3	1260
s23	0	0,06	0	7	0	360	3	1080
s17	0	0,05	0	7	0	300	3	900
s18	0	0,025	0	7	0	150	3	450
s19	0	0,02	0	7	0	120	3	360
s20	0	0,015	0	7	0	90	3	270
s21	0	0,01	0	7	0	60	3	180
s22	0	0,005	0	7	0	30	3	90
s25	1	1	1000	7	7000	6000	3	18000
s26	0,75	0,75	750	7	5250	4500	3	13500
s27	0,5	0,5	500	7	3500	3000	3	9000
s28	0,25	0,25	250	7	1750	1500	3	4500
s29	0,1	0,1	100	7	700	600	3	1800
s30	0,05	0,05	50	7	350	300	3	900
s31	0,1	0,05	100	7	700	300	3	900
s32	0,15	0,05	150	7	1050	300	3	900
s33	0,1	0,06	100	7	700	360	3	1080
s34	0,1	0,07	100	7	700	420	3	1260

The main result from conducting analyses in Power Factory for each scenario was line loading in %. Level of 100% should be considered as moment in time when the network protections are triggered causing the power supply to be cut off and thus saving the equipment and infrastructure elements from irreversible damage.

Topology of CIGRE network with proposed specific and permanent location of loads and generation sources caused maximum load of Line 1-2 in each scenario, which is considered as “critical line”.

Example view of Line 1-2 year’s loading and histogram chart exported from Power Factory is shown below:

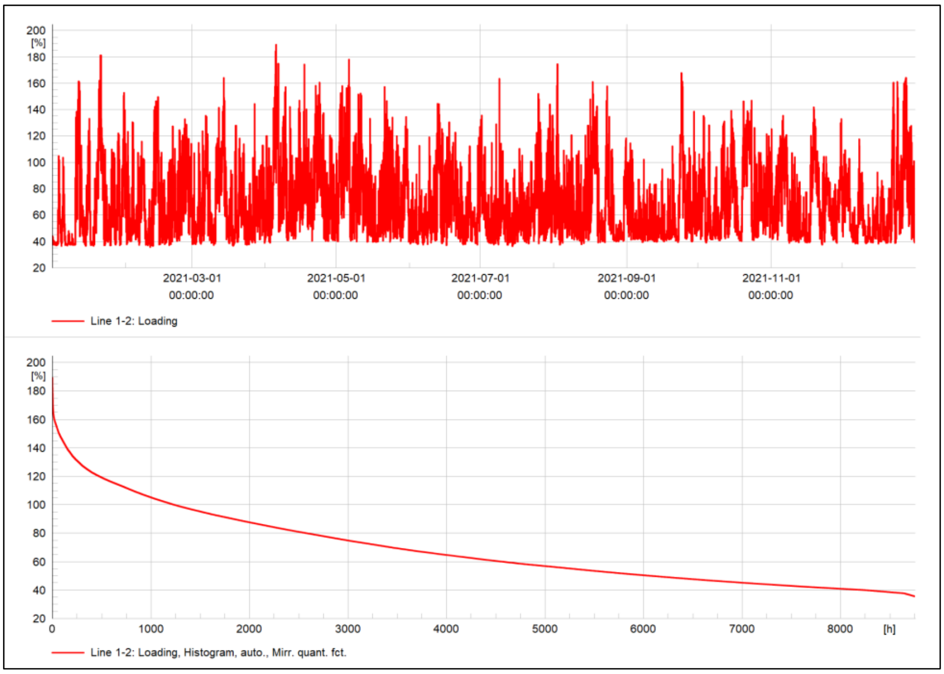


Figure 3. Line loading over a year period and the related histogram

Technical challenges

This TEST case presented the following challenges for RES integration:

- Nominal PV integration as assumed in Scenario 2 already caused line congestions at some periods. Even worse line congestions were recorded in Scenario 10 and wind integration. Similar results were recorded in Scenario 25 when both PV and Wind were connected.
- Battery storage use is shown in Scenarios 35 and 36. A significant improvement of line loading can be achieved. Of course, that depends on the correct sizing and location of storage units.
- Advanced network management tools are necessary for increased RES integration.

Market Challenges

There are several market challenges related with increased levels of RES. Their integration to continuous day ahead market has already been studied and is addressed in a separate Test Case. However, there are opportunities for creating local flexibility markets directed to both DSOs and aggregators.

Also, there is a great potential of participating in continuous markets for the RES with battery storage for "capacity firming". Otherwise network battery storage can be used by DSOs (directly or via market incentives) to manage power flows and possible line and voltage congestions.

Costs of the RES based solutions (investments, operation and maintenance costs, etc.) should be evaluated carefully using novel tools before any market application.

Proposed approach and recommendations

Massive penetration of RES should be supported by the following actions:

- RES Trimming, VPP, self-consumption, dynamic line rating and demand flexibility management technics will be necessary to avoid congestions in the network with increased levels of RSS.
- Network management must be planned carefully, with accurate prediction of RES generation. New planning and operational tools are necessary
- In general, increased levels of RES coupled with energy storage for "capacity firming" have positive effects on the local decarbonisation of distribution networks and local markets.

3. CASE: DISTRIBUTED RENEWABLE ENERGY AND ACTIVE CONSUMERS PARTICIPATION IN THE INTRADAY CONTINUOUS AND LOCAL FLEXIBILITY MARKETS

Objective of the assessment

- To evaluate the positive impact of enabling the large penetration of renewable energy in the wholesale electricity markets due to the flexibility of the solution RES + batteries + integration with energy consumption industrial processes (active collaboration with consumers). In the last years, relevant technological improvements have been achieved in the field of the renewable energy generation, in the energy storage solutions, in the intensive application of information and telecommunication technology applications for controlling and monitoring procedures and in the application of demand response management solutions.

- This evaluation process is based on the simulation of the active participation of the distributed generation, the self-consumption and the consumers participation (individually or aggregated) in the intraday continuous and local flexibility markets. During this process, the users will communicate with the aggregator when a requirement is thrown by the system or just establish a contract for remote management of their consumption.
- The simulations include consumers of different categories (SME, industry, residential…), consumption levels and availability. The test has been developed in the OMIE´s Intraday Continuous Market Platform and the consortium members have used tools to automate the integration of the aggregators with the wholesale markets and their clients (the distributed generation, the self-consumption and the consumers).

The flexibility in the electricity markets

The intraday continuous market, also called single intraday coupling (SIDC), gives market agents the chance to manage their energy imbalances with two fundamental advantages:

- It is an integrated European electricity market[1], agents can benefit from the liquidity available in markets in other areas of Europe, given that cross-border transportation capacity is available between the zones.
- Continuous trading until one hour before the energy dispatch: market players can adjust their positions in the market to one hour before the moment of delivery.

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[1] EPEX spot, GME, Nord Pool Spot and OMIE manage the initiative called XBID Market Project to create an integrated cross-border European Intraday market, which has started its operations in June 2018. In November 2019, several other countries joined the project and expanded the continuous trading of electricity across the following zones: Bulgaria (IBEX), Croatia (CROPEX), Czech Republic (OTE), Hungary (HUPX), Poland, Romania (OPCOM) and Slovenia (BSP).

The purpose of this market is to facilitate the trade of energy between different areas of Europe continuously and to increase the global efficiency of transactions on the intraday markets across Europe.

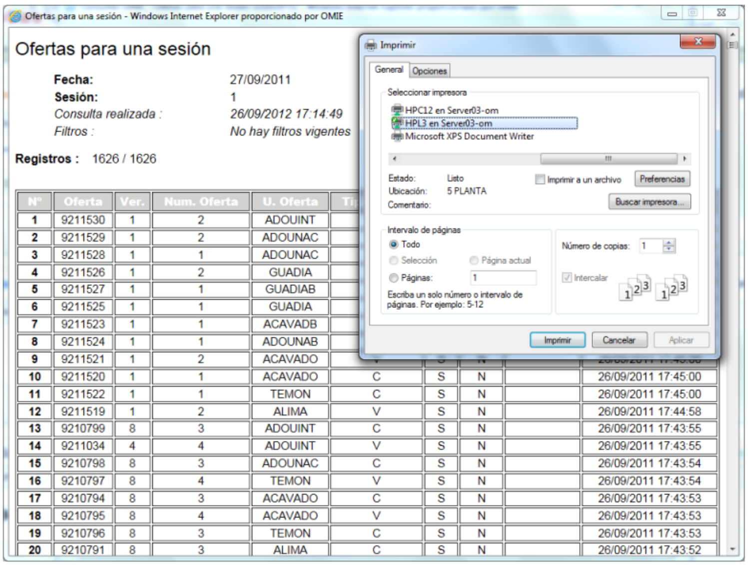

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Figure 4. Intraday Continuous Market (Example)

The opening of the negotiation of all contracts of the intraday continuous market for the next day (D + 1) in the price areas of Spain and Portugal will be made after the end of the first auction of the current day (D), provided the system operator has published the Definitive Viable Daily-ahead Schedule for the following day (D + 1) previously.

The participation of distributed generation and prosumers in the European Intraday Continuous Market

This test is focused on developing and validating an operative procedure that enables the active participation of the DER and prosumers in the Continuous Intraday Market.

The proposed operative consists in establishing a portfolio of consumers (industrial, services and residential) with solar photovoltaic equipment that will be managed by a retailer according to previous trade conditions and the Intraday Continuous Market price signals. Based on this operative the active participation of the consumers in the market will contribute to:

- The system balancing, reducing the cost of the adjustments.
- The export of surpluses of generated energy by self-consumption.
- The adoption of effective active demand management measures, reducing unnecessary energy consumption.
- Optimise the use of batteries and the charging processes of electric vehicles.

The implementation of this procedure requires the adoption of information and telecommunication solutions that enable the automatic operative of the aggregators in the market integrating the price signals, the electricity balancing of the portfolio (and the prosumers´ position), and the management of the electric equipment (consumption and demand) of the clients.

The test: the active participation of the distributed generation, the prosumers, and the consumers in the local flexibility markets

In order to evaluate the potential contribution of the prosumers and distributed generation in the electricity balancing system, a case study has been developed to simulate their active participation in the market with the following topics:

- A test data in the Continuous Intraday Market Data of OMIE simulating the participation of the generation and the demand in the market and producing price signals has been created.
- A portfolio of eighty-seven consumers (industrial, services and residential) with generation power capacity and, in some cases, energy storage devices has been established to be managed by a retailer (aggregator).
- An IT tool has been developed to automatise the operative between the retailer and consumers in the market. It would not be effective in operative terms to manage this operative manually, every signal price would require that people to manually run the instruction according to the market price signals producing delays, misunderstandings, and other inefficiencies. This tool has been integrated with the Continuous Intraday Market system and with the electric equipment of some consumers.

In this environment, the active participation of the prosumers in the market using and aggregator has been simulated. The operative procedure is introduced in the following figure.

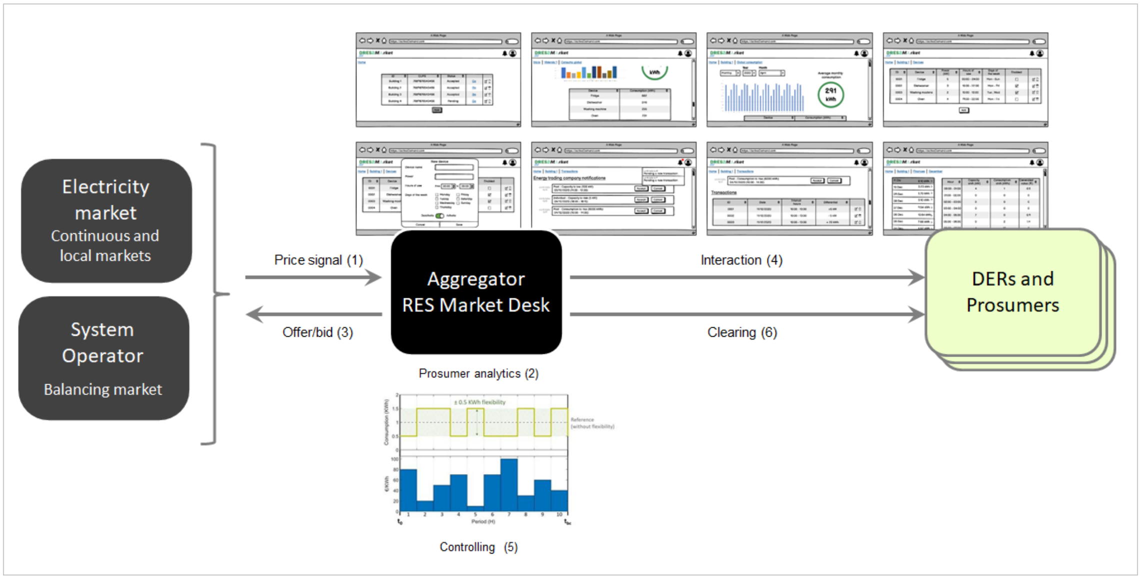

Figure 5. Active prosumers and DERs participation in the Intraday Continuous Market Simulation Process

The evaluation

- The proposed procedure that integrates automatically the Continuous Intraday Market, the retailer and the consumers enables the active participation of the distributed generators, prosumers, and consumers in the wholesale market.
- Without the automatization of this procedure, the active participation of the consumers in the market would not be possible.
- The proposed procedure avoids the existence of electricity generation surpluses produced by distributed generators that would not be used.
- The proposed procedure promotes the active participation of the demand (active demand management), reducing unnecessary consumption.
- The prosumers and the consumers can obtain an additional revenue (or a reduction in their electricity supply costs) based on the sale of electricity surplus and/or their active participation in the active demand processes.
- This procedure benefits the efficient and smart use of the electricity.
- The proposed approach reduces the balancing costs of the systems: additional players could participate in this market process (increasing its competence).
- Depending on the prosumer cluster there are systematic situations (specific hours) with surplus of production and/or opportunities for active demand management.
- The result of this test with eighty-seven prosumers during one month of test are as follows:
-

Concept	Monthly impact
Surpluses of avoided energy because it is sold to the grid	• 28.3 MWh
Revenue due to the surpluses of avoided energy	• 5,652 €
Reduction of consumption due to active demand management	• 34.3 MWh
Revenue due to reduction of consumption due to active demand management	• 7,637 €
Energy storage from the grid	• 2.3 MWh

BIBLIOGRAPHY

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