PACE

Pathway to a Competitive European Fuel Cell micro-CHP Market

REPORT

VPP session within European Grid Service Markets Symposium 2019

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Index

Executive summary

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From 3 to 4 July 2019, **80 experts** from various sectors of the **power market** shared their knowledge and experience in the field of **grid services**. The topics presented and discussed were wide-ranging and included **international collaboration, technologies, operations, market developments** and **business potential**. A rich program promoted the exchange between science and industry. 54 % of the participants came from academia, 24 % from industry, 11 % from Distribution System Operators (DSOs) and Transmission System Operators (TSOs) and a further 11 % from administration and associations. The audience was very **international**, with 75 % of the participants coming from outside the host country: 19 % from Germany, 9 % from the United Kingdom, 8 % from Italy, 6 % from Denmark and France each, 4 % from Netherlands and Belgium each. Austria, Croatia, Greece, Latvia, Norway, Slovenia and Sweden were also represented. 5 % of the participants came from outside Europe. The one and a half day symposium offered 13 scientific presentations and 6 poster presentations from the academic world, as well as 16 top-class invited speeches, mainly from industry, administration and associations. The many lively discussions and Question & Answer (Q&A) sessions eventually brought together technicians and business experts, helping to **bridge the gap between new, sustainable technologies and markets**. The change of perspective helped to clarify the different points of view. In her welcome speech, Mirela Atanasiu, Head of Unit at the EU Fuel Cells and Hydrogen Joint Undertaking, stressed the importance of both the technical solution and the market readiness to meet the challenges of the transforming energy system.

PACE was present with a specific Virtual Power Plant (VPP) panel session 'BUSINESS-POTENTIAL AND TECHNOLOGY-CHALLENGES', chaired by Andreas Svendstrup-Bjerre, Vestas Wind Systems A/S. The VPP session brought together the specialists from the Fuel Cells and Hydrogen (FCH) Micro Combined Heat and Power (mCHP) industry and the electrical grids and markets, initiating an exchange and new ideas for fostering the introduction of the FCH technology. Within the VPP session, Jacob Dijkstra on behalf of Municipality of Ameland (The Netherlands) reported on flexible infrastructure including

hydrogen technology for a closed energy system. Stefan Nellen from Qirion B.V. Energy Consulting (Alliander; The Netherlands) shared experiences with fuel cells participating in an flexibility market. Stephan Marty from Kiwi Power (UK) reported on experiences with Energy Performance Contracts (EPO) making use of flexibility offers. Aby Chacko from Tiko (Switzerland) shared experiences with VPPs in Germany and Switzerland. Marco Stabile from CESI (Italy) evaluated the impact of virtual qualified units on the Italian ancillary services market. In the subsequent panel discussion, the experts responded to questions and comments from the audience.

The third edition of the international Grid Service Markets symposium was supported by

- the Swiss State Secretariat for Education, Research and Innovation under contract No 17.00009,
- the Fuel Cells and Hydrogen 2 Joint Undertaking under agreements No 735485 and 700339, and
- the Lucerne University of Applied Sciences and Arts.

Presentations can be found at the Grid Service Markets (GSM) website (*https://gridservicemarket.com/downloads-gsm-2019/*). Papers will be published as proceedings in the Lucerne open repository (LORY; *https://zenodo.org/communities/lory/*).

The following pages give an overview of topics covered and impressions from the excellent work and exchange at GSM19.

1. VPP-PANEL: BUSINESS-POTENTIAL AND TECHNOLOGY-CHALLENGES (joint with PACE project)

Summary box of the chapter

The session consists of the following presentations:

- *Ameland: Frontrunner in the Energy Transition e.g. VPP Project with 45 Fuel Cells as part of an island wide Smart Grid, large H2 project*
  (Jacob Dijkstra; Municipality of Ameland, The Netherlands)

- *EnergieKoplopers (Energy Frontrunners): Lessons learned from a flexibility market for households with fuel cells*
  (Stefan Nellen; Qirion Energy Consulting (Alliander), The Netherlands)

- *NOVICE - Development and Demonstration of an Innovative Business Model for Energy Service Companies*
  (Stephan Marty; KiWi Power Ltd London, UK)

- *Demand side management and virtual power plants or Experience with virtual power plant operations in Switzerland and Germany*
  (Aby Chacko; Tiko, Switzerland)

- *Assessing the impact of virtual qualified units on the Italian ancillary services market*
  (Marco Stabile; CESI S.p.A., Italy)

In the subsequent panel discussion, the experts responded to questions and comments from the audience.

Session chair: Andreas Svendstrup-Bjerre, Vestas Wind Systems A/S, DK

1.1 Ameland: Frontrunner in the Energy Transition e.g. VPP Project with 45 Fuel Cells as part of an island wide Smart Grid, large H2 project

Focus on the importance of a closed energy system based on flexible infrastructure for better matching of supply and demand. Hydrogen can play a key role as connecting element such a future energy system.

Jacob Dijkstra, On behalf of the municipality of Ameland, NL

1.2 EnergieKoplopers (Energy Frontrunners): Lessons learned from a flexibility market for households with fuel cells

Flexibility creates possibilities for all parties involved. Fuel cells can be used for flexibility under certain conditions.

Stefan Nellen, Qirion Energy Consulting (Alliander), NL

1.3 Enhanced Energy Performance Contracting. The NOVICE Project

Energy Performance Contracts (EPCs) have many advantages: client does not require upfront capital; finance for the project is provided by the energy service company (ESCO) or a third party finance provider; energy savings are guaranteed by the ESCO, removing the operational risk from client; the loan is repaid from the savings on energy bills; single contract between client and ESCO covers all energy efficiency measures; deeper renovations can be achieved through taking a whole building approach.

Stephan Marty, KiWi Power Ltd, UK

1.4 Demand side management and virtual power plants or Experience with virtual power plant operations in Switzerland and Germany

The experience with the operations of virtual power plants in Germany and Switzerland for the provision of ancillary services to the transmission grid operators, congestion management for the distribution grid operator and energy optimization for the energy supplier will be shared in this presentation.

Aby Chacko, Tiko Energy Solutions AG, CH

1.5 Assessing the impact of virtual qualified units on the Italian ancillary services market

Marco Stabile, CESI S.p.A., IT

In the transition to a low carbon economy Italy is facing a dramatic increase in Renewable Energy Sources (RES) penetration, In the past years the rapid deployment of RES installation was fostered by a strong support in terms of subsidies and incentives, whereas the current policies are pushing the new RES generation to compete on equal basis with the conventional generation through appropriate schemes, mostly based on auctions.

This massive share of non-programmable RES generation makes very relevant the volume of energy exchanged in the Italian ancillary services market (ASM), as well as the related costs incurred by the market to guarantee an adequate level of security to the National Electricity Grid (NTG), costs that are transferred to the final consumer.

In this period of rapid changes, the electrical systems have also witnessed the advent of smart grids, domestic loads control, storage and the electrical mobility that could be key components in providing flexibility and reserves for supporting renewable energy integration in the grid.

Recent changes in the Italian regulation of the NTG demonstrate that the Italian ASM is opening up to new subjects different from traditional producers, defined by the Italian grid code as “significant units” within a total power not less than 10 MVA. These new players are called Virtual Qualified Units (VQU, in Italian UVA “Unità Virtuali Abilitate”) consisting in non-significant producers, storage systems and loads. To cope with these changes to the regulation framework the Italian TSO TERNA has launched few pilot projects to foster the participation in the Italian ASM of aggregators and demand response for providing balancing (up-ward and down-ward regulation) and reserves to the NTG.

In this context CESI has developed on behalf of TERNA an innovative simulation tool called MODIS that allows to quantitatively evaluate the impact on the ASM arising from a new transmission infrastructure, storage or a new VQU, in a planning perspective. Starting from the outcomes of the day-

ahead market (DAM), this tool, simulates the redispatching process of the ASM, minimizing market disbursement hour by hour over a whole year, necessary to ensure the fulfilment of the operational constraints.

This paper presents the methodology and a quantitative analysis to assess the economic benefit, that can be achieved by the VQU deployment in the NTG by 2025 and 2030. The economic benefit is quantified in terms of cost saving for providing regulating services and reserves in the Italian ASM. The methodology takes advantage from scenario simulations and what-if analysis through comparison of different simulations obtained using the MODIS model.

2. FLEXIBLE UNITS I / DEVELOPMENTS IN GRID SERVICE MARKETS I

Summary box of the chapter

The session consists of the following presentations:

- *Modelling and optimization of a flexible PEMFC power plant for grid balancing purposes (Elena Crespi (1), Giulio Guandalini (1), Jorg Coolegem (2), Marianela M. Betancourt (3), Sönke Gößling (4), Peter Beckhaus (4), Stefano Campanari (1); (1) Politecnico di Milano, Italy, (2) Nedstack Fuel Cell Technology B.V., The Netherlands, (3) Abengoa Innovación, Spain, (4) ZBT Gmbh, Germany)*

- *Using electric water heaters to provide multiple energy services (Hanmin Cai, Shi You; Technical University of Denmark, Denmark)*

- *Integrating decentral renewable assets with a network of smart home storage devices (Matthias Dilthey; sonnen, Germany)*

- *Energy system decarbonisation: Informing reform of energy market and regulatory framework (Goran Strbac; Imperial College London, UK)*

Session chair: Prof. K. Andreas Friedrich, Deutsches Zentrum für Luft- und Raumfahrt e.V., DE

2.1 Modelling and optimization of a flexible PEMFC power plant for grid balancing purposes

Elena Crespi, Politecnico di Milano, IT

Flexible power resources in the electric system, capable to rapidly ramp their electricity production or consumption, must compensate for the variability given by the increasing penetration of renewable energy sources. The EU project GRASSHOPPER[1] aims to setup and demonstrate a 100 kW_{el} PEM Fuel Cell Power Plant unit which is cost-effective, flexible in power output and scalable to MW-size, designed to provide grid support with a Demand Side Management program.

In this work, different layouts proposed for the pilot plant are simulated with Aspen Plus® for system performance evaluation, optimization of design and operating conditions. The system may operate at atmospheric or mild pressurised conditions (0.1-0.6 bar_g), using a compressor and optionally a turbine expander on the cathode exhaust side for energy recovery. The simulation includes a custom PEMFC model, reflecting the voltage dependence on pressure, relative humidity and gas composition. The main BoP components are also modelled in detail (see Fig. 1).

The increased voltage of the cell allows a slightly higher net system efficiency with pressurisation (taking into account increased BoP consumption) and nearly 2% additional efficiency in the option with turbine, reaching 54%$_{LHV}$.

2.2 Using electric water heaters to provide multiple energy services

Integrated demand response was designed and demonstrated in the urban area of Copenhagen Denmark. Electric heat boosters in a combined electricity and district heating system were controlled to provide frequency-controlled normal operation reserve to power system and peak shaving service to district heating system at the same time.

Hanmin Cai, Danish Technical University, DK

2.3 Integrating decentral renewable assets with a network of smart home storage devices

Matthias Dilthey, sonnen, DE

Due to the increasing decentralized infeed of energy from renewable sources, bottlenecks are becoming common in the power grid. To avoid unnecessary discard of valuable green energy, sonnenBatteries are able to charge or discharge energy upon signal and thus engage in measures (redispatch, grid reserve, wind power curtailment) to ensure that the transport is within the limits and capabilities of the grid. Examples are given on how the intelligent flexibility can shape the energy landscape on a local or national level.

2.4 Energy system decarbonisation: Informing reform of energy market and regulatory framework

This presentation will underline the barriers in the present market and regulatory framework that may weaken the business case for investment in smart grid technologies and systems. The importance of consumer participation and decentralisation will be discussed highlighting the need for aligning the market design with the decarbonisation objectives.

Goran Strbac, Imperial College London, UK

3. DEVELOPMENTS IN GRID SERVICE MARKETS II

Summary box of the chapter

The session consists of the following presentations:

- *Local market possibilities, experiences with and perspectives from the ENERA project (Philippe Vassilopoulos; EPEX SPOT, France)*
- *Impact of balancing and day-ahead market sequences on bidding behavior of market participants*
  (Ksenia Poplavskaya (1,2), Fabian Ocker (3), Karl-Martin Ehrhart (4); (1) Austrian Institute of Technology, Austria, (2) Delft University of Technology, Netherlands, (4) Karlsruhe Institute of Technology, Germany)
- *Architectures for Optimized Interactions between TSOs and DSOs: Experiences and learnings from SmartNet*
  (Ivana Kockar (1), Gianluigi Migliavacca (2), Andrei Morch (3), Siface Dario (2); (1) University of Strathclyde, UK, (2) RSE SpA, Italy, (3) SINTEF Energy Research, Norway)
- *Grid services as byproducts of a water electrolyzer*
  (Valerian Klemenz, Tanaka Mandy Mbavarira, Christoph Imboden; Lucerne University, Switzerland)
- *NODES – a new market design to trade decentralized flexibility*
  (Benedikt Deuchert; NODES AS, Norway)

Session chair: Thomas Kudela, Ørsted A/S, DK

3.1 Local market possibilities, experiences with and perspectives from the ENERA project

Philippe Vassilopoulos, EPEX SPOT, FR

"Decarbonization, decentralization of energy resources combined with digitalization is reshaping the power market. This trend is already visible on the Intraday power markets in Europe where automated trading applications are developing at a quick pace to help operate/market the significant amounts of intermittent renewable energy on the system closer to real-time. The question of increasing congestions and the need to integrate the distributed resources becomes a priority. This presentation describes the initiatives from EPEX SPOT to setup local flexibility markets for congestion management across the different voltage levels, and more specifically the most advanced one, the enera project in the North-West of Germany"

3.2 Impact of balancing and day-ahead market sequences on bidding behavior of market participants

Ksenia Poplavskaya, Austrian Institute of Technology, AT

There is an increasing pressure to reform European balancing markets and increase their efficiency, mandated by the European Guideline on Electricity Balancing. This study provides an insight into the consequences of the planned regulatory changes and focuses on bidding strategies of market actors and their impact on the market outcome.

Balancing market bidding represents a complex decision for prequalified market participants as they could profit not only from reserving capacity but also from increasing or decreasing their output. At the same time, they face opportunity costs due to trading options in the wholesale markets. The bidding decisions are affected by the planned splitting of balancing capacity and balancing energy markets. Other factors that influence actors' strategies is the introduction of voluntary balancing energy bids and the gate closure time of the balancing capacity auction with respect to the day-ahead market.

We investigate the impact of these changes by developing a theoretical bidding calculus for participants in multiple markets based on decision theory. We show that the sequence in which markets close and clear has an effect on market actors' cost structures and their incentive to bid their capacity in a given market. We analyze the changes in the cost structures and information available to the participants using four market design options. The business-as-usual option with a joint market is compared to split balancing capacity and energy markets with clearing for balancing capacity before, simultaneously with or after the closure of the day-ahead market. The possibility of submitting voluntary balancing energy bids is explicitly considered in the bid formulation.

Changes in balancing market design and sequence affect market actors' bidding strategies, i.e. additional markups due to opportunity costs, and the distribution of volumes between the day-ahead and balancing markets. Lowering opportunity costs for market actors can lower overall price levels and therefore balancing costs. Adjusting timing-related aspects of market design can help to achieve this. For instance, procurement of balancing capacity day-ahead after the closure of the day-ahead market can help ensuring that more expensive power plants with lowest opportunity costs bid for balancing leading to an efficient market equilibrium. The effect of the introduction of voluntary bids is twofold: It is expected to boost competition in the balancing energy market, but it will also affect expected profits of all balancing market actors and create additional opportunity costs reflected in the balancing capacity bids.

3.3 Architectures for Optimized Interactions between TSOs and DSOs: Experiences and learnings from SmartNet

Ivana Kockar, University of Strathclyde, UK

Increased levels of Distributed Energy Resources (DERs) and their participation in provision of Ancillary Services (AS) at both transmission and distribution levels, call for a more advanced dispatching management of distribution networks to transform distribution from a “passive” into an “active” system. Moreover, new market architectures must be developed to enable participation of DERs in energy and AS markets. New operational and trading arrangements will also affect the interface between transmission and distribution networks, which will have to be managed in a coordinated manner between TSOs and DSOs in order to ensure the highest efficiency, effectiveness and security.

Therefore, procurement and activation of resources from distribution network for ancillary services will require new grid organisation for ensuring and improving interaction between TSOs and DSOs. EU H2020 project SmartNet [1] proposes five different architectures or coordination schemes (CSs) that each present a different way of organizing the coordination between transmission and distribution system operators (TSOs and DSOs), when distributed resources (production, storage or demand) are used for ancillary services [2]. Each coordination scheme is characterized by a specific set of roles, taken up by system operators and a detailed market design.

Evaluation and validation of the proposed schemes has been carried out both via simulation which has modelled market operation under different TSO-DSOs interactions, as well as in the laboratory and pilot project settings. This paper present experiences and learnings obtained during development and testing of the market clearing algorithm and simulator, including bidding by market participants and aggregation to provide flexibility used for ancillary services. We will also discuss how solutions proposed in the SmartNet align with the present national and European policy goals and positions of the key industrial stakeholders, and also elaborate on the final guidelines and regulatory recommendations that result from the SmartNet project.

3.4 Grid services as byproducts of a water electrolyzer

Valerian Klemenz, Lucerne University, CH

Sustainable production of hydrogen is a key element of the European energy transition agenda, especially for seasonal and mobile energy storage purposes. The technology is about to enter the market, as the economy of the solution has considerably improved over the years. The water electrolyzer (WE) as a key element of such hydrogen production can offer its high operational flexibility for grid services such as frequency control and congestion management. Servicing those markets as a byproduct, the WE achieves a value that is relevant to bridge the gap towards market parity.

The article reports on best opportunities for European grid service markets to be served by WEs. The results of the research, supplemented by a survey amongst transmission system operators (TSO) and distribution system operators (DSO) conducted in 2017/2018 are presented. Financial and business logic data is available for 25 European countries incl. Norway and Switzerland. 85 TSO grid services within 12 countries are commercially and technically feasible candidates.

With eight such cases (7 TSO grid services + 1 DSO grid service) a more detailed economic analysis is made for a WE with daily storage capacity. Offering the WE's flexibility to the grid service markets can reduce the levelised cost of hydrogen at the WE outlet (LCOH) by up to 10% under ideal conditions,

i.e. at a WE size of 500 kW and more operating at 6000 full load hours or more, without sharing the margin between balancing service provider (BSP) and the WE owner.

Existing market conditions such as subsidy rules hinder the practical operation of a WE for the provision of DSO grid services. Therefore, for the DSO grid service case, a hypothetical, but possible future congestion management case is analyzed. Not surprisingly, an economically feasible operation in that case can be achieved for high curtailment scenarios only.

3.5 NODES – a new market design to trade decentralized flexibility

Benedikt Deuchert, NODES AS, NO

NODES is building Europe's most customer-centric, integrated energy marketplace to unlock the value of local flexible power resources and support the drive to a sustainable, emission free future.

NODES launched its innovative, integrated market design at European Utility Week in Vienna in November 2018. The marked design, which is being described in a white paper on NODESmarket.com has been discussed amongst members of the Energy community across Europe.

NODES as a neutral market operator will present its market design and current status at the event.

4. FLEXIBLE UNITS II / GRID SERVICES OPERATION

Summary box of the chapter

The session consists of the following presentations:

- *Five actions to improve your short term forecasting of electricity demand and RES production (Johan Nihleen, Alexander Nordling; Vitec Energy AB, Sweden)*
- *Qualifying Tests of Electrolysers for Grid Services System Behaviour and Scalability (Regine Reissner (1), Shi You (2), Cyril Bourasseau (3), Pablo Marcuello (4), Vincent Lacroix (3), Gilles Lavaille (3), Daniel A. Greenhalgh (5), Laura Abadia (6), Christoph Imboden (7), Marius Bornstein (8) et. al.; (1) DLR, Germany, (2) DTU, Denmark, (3) CEA, France, (4) IHT, Switzerland, (5) ITM Power, UK, (6) Foundation for hte Development of New Hydrogen Technologies in Aragon, Spain, (7) HSLU, Switzerland, (8) NEL HYDROGEN AS, Norway)*
- *Overlook the Copernicus C3S-SIS-ENERGY service with a focus on seasonal forecast and additional climate indicators*
  (Raphaël Legrand; Météo France, France)
- *Dependence of operational processes*
  (Davor Bosniak; HEP, Croatia)

Session chair: Prof. Nikos Hatziargyriou, National Technical University of Athens, GR

4.1 Five actions to improve your short term forecasting of electricity demand and RES production

Johan Nihleen, Alexander Nordling, Vitec Energy AB, Sweden

What are the main drivers to improve your forecasting error for short term forecasting of electricity demand load and renewable production sources? During years of research, five actions with proven results have been found, which will be presented.

Vitec Energy has been a leading supplier of forecasting models and software for more than 30 years. Partners and users today are seven of our European Transmission System Operators together with sixty Access Responsible Parties, traders and renewables producers/operators.

4.2 Qualifying Tests of Electrolysers for Grid Services System Behaviour and Scalability

Regine Reissner, Deutsches Zentrum für Luft- und Raumfahrt e.V., DE

Some grid services available for loads are well established in several European countries with the services and prequalification tests quite similar however with differences. In the future process of decarbonisation of the electricity but also other sectors hydrogen produced from renewable electricity in water electrolysers is believed to play an important role. However to be part of the grid service market electrolysers have to pass the prequalification tests. In order to ease the market entry of electrolysers demonstration of the capability of electrolysers to cope with these requirements should be helpful.

For this purpose the project QualyGridS establishes standardized testing protocols for electrolysers to perform electricity grid services. Protocols are trying to unify the different tests needed for different European countries. Some general basic qualification tests are defined from which the suitability of the system for any grid service can be derived. More specificially adapted to some well-established services like e.g. FCR, a-FRR (positive and negative) tests are defined integrating the requirements for Germany, France, Switzerland and other countries.

The protocols are validated for both alkaline and PEM electrolyser systems, respectively, using electrolyser sizes from 50 kW to 300 kW within the project showing the capabilities of today's state of the art systems and extrapolation to larger systems. Testing protocols also include the review of existing and possibly set-up of new Key Performance Indicators (KPI) for electrolysers.

It is discussed if the standardised test curves might also be used for early qualification of other loads planned for participation in the grid services.

4.3 Overlook the Copernicus C3S-SIS-ENERGY service with a focus on seasonal forecast and additional climate indicators

Raphaël Legrand, Météo France, FR

For the actors of the energy sector, the information at each time scale from now casting up to seasonal forecast is crucial. Several kinds of numerical weather models address the different needs of the sector. Regarding the climate scale (past, seasonal scale and climate projection), the C3S-SIS-Energy project aims at making widely accessible energy dedicated indicators as electricity demand, solar and wind production.

4.4 Dependence of operational processes in a power system on weather conditions

Davor Bosniak, HEP, HR

Considering many changes in a contemporary power system, both at a generation side and a consumption side as well as moving customers into the focus of a power system, a structure of operational processes in a power system has significantly changed.

The aim of this paper is to highlight rising impact of weather conditions to operational processes in the energy sector in Croatia and the surrounding region. We describe the operational meteorological and hydrological influence to a power system and corresponding market conditions and analyze several events when large deviations in electricity demand and generation affected a power system management in Croatia. Case studies describe multiple perspectives: meteorological background that led to observed deviations, consequences on the operation of the power system and necessary activities on the energy markets. Based on these events, we discuss means how could the power system in Croatia be made more resilient to similar weather conditions.

The understanding of a sensitiveness of a power system to atmospheric processes is prerequisite for further interdisciplinary researches and growing learning process of getting enough “know how” in identifying in time key tipping points in this processes which could help in preparing enough flexibility and balancing energy in a power system to handle their impact. Therefore, continuous efforts in exploring those effects combined with actions through operative work, as well as investments in storages as an extra flexibility tool, is the key how to mitigate such weather risks and vulnerability of a power system and prepare it to meet forthcoming goals of the Clean Energy Package.

5. INTERNATIONAL COLLABORATION

Summary box of the chapter

The session consists of the following presentations:

- *Undersea cable between Italy and Montenegro: Project and forthcoming market and power flow consequences*
  (Elia Ettore; Terna SpA, Italy)
- *German-Austrian Market Split. Implementation and Impact from a TSO perspective*
  (Christoph Jachmann; APG, Austria)
- *Market coupling mechanisms. Transmission capacity allocation in zonal electricity markets*
  (Anthony Papavasiliou; Université catholique de Louvain, Belgium)
- *Network Codes, GLEB*
  (Mathieu Fransen; ACM, The Nederlands)

Session chair: Bruno Cova, CESI S.p.a., IT

5.1 Undersea cable between Italy and Montenegro: Project and forthcoming market and power flow consequences

Elia Ettore, Terna SpA, IT

The Montenegro-Italy (MONITA) project consists of a new 400 kV HVDC, 600 MW, 423 km length, undersea cable between Villanova (Italy) and Lastva (Montenegro) and the pertaining DC converter stations. The investment will link the Italian peninsula to the South East Europe (SEE) to allow for the following benefits:

1. Promoting the exchange of renewable energy

The HVDC link MONITA has been designed to help the most efficient use of generation capacity located in SEE countries, to facilitate opportunities for new generation investments in the Balkan region and the exploitation of RES potential both in SEE region and in Italy.

2. Creating a stronger interconnected European electricity grid

A power link between Italy and Montenegro will help to achieve the EU's goal of creating a stronger

and more interconnected European electricity grid, minimizing price differentials between Countries, ensuring that electricity demand, including through imports, can be met in all conditions, and enabling export potential of excess renewable production.

3. Enhancing the operation security in Italy and in the Balkan area

In particular, investment is needed to remove infrastructure bottlenecks between and within Member States, to improve security of supply, competition and to integrate the growing share of renewables.

At a first stage, cross-border transmission capacities between the two control areas will be assessed for both directions (Montenegro to Italy and Italy to Montenegro) on the different time frames (yearly, monthly, daily) applying a Coordinated Net Transfer Capacity (CNTC) methodology.

Afterwards, once when FCA and CACM market codes will have been adopted by CGES (Montenegrin TSO), the capacity calculation methodology shall be coordinated pursuant to these regulations within the Capacity Region ME-IT border will belong to.

The European Commission has awarded HVDC link MONITA as a Project of Common Interest (PCI).

Commercial operation is expected to start by December 2019.

5.2 German-Austrian Market Split. Implementation and Impact from a TSO perspective

Christoph Jachmann, APG, AT

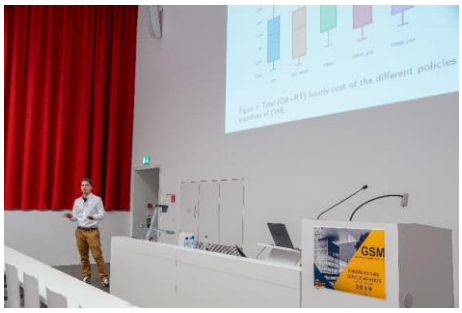
Since the liberalisation of the electricity markets Austria had been part of a joint bidding zone together with Germany and Luxembourg. A potential split of the bidding zone had been intensively debated over the last years on European level. Following a decision by ACER (European Agency for the Cooperation of Regulatory Authorities) and an agreement between the Austrian and German regulatory authorities, the bidding zone had to be split as of 1st October 2018.

Hence, APG, together with German TSOs and power exchanges active in both countries, had to introduce capacity allocation procedures within an ambitious timeframe. The procedures to be implemented were mainly regional or European processes and partly subject to regulatory approval. Consequently, the implementation project relied on multiple international partners and needed to involve stakeholders on national, regional and European level. On the technical side numerous processes and IT systems had to be adapted and thoroughly tested before all procedures could be set into operation for 1st October 2018.

Next to changes in capacity allocation procedures, the split of the bidding zone between Germany and Austria has had impacts on available cross border capacities and market results. In order to address

some of these effects, TSOs and power exchanges performed several simulations and analysis during the implementation of the project. While these simulations could show an increase of overall cross border capacities in the CWE region[1], conclusions for the potential market outcome could not be drawn due to limitations in anticipating the market behavior after the split. With the successful go-live of capacity allocation on 1st October 2018, the split has become reality and the actual impact can be observed.

5.3 Market coupling mechanisms. Transmission capacity allocation in zonal electricity markets



Anthony Papavasiliou, Université catholique de Louvain, BE

We propose a framework for modelling zonal electricity markets that avoids circular definitions and discretionary parameters. Using this framework, we compare flow-based market coupling (FBMC) and available-transfer-capacity market coupling (ATCMC) to nodal pricing. Our findings raise the question of whether the switch from ATCMC to FBMC has increased value for the European market.

[1] This does not consider the border DE-AT, on which capacity for commercial use had been previously unlimited.

5.4 Network Codes, GLEB

In December 2017 the Electricity Balancing Guideline legislation was adopted by the European Commission. This guidelines includes an ambitious timeline to integrate European balancing markets by the 2023. In this presentation objectives of the EBGL, progress to date and what TSOs propose to implement will be reviewed.

Mathieu Fransen, ACM, NL

6. POSTER SESSION - ALL TOPICS

Summary box of the chapter

The following papers were presented as posters:

- *REMOTE project: techno-economical sizing of H2-based energy storage systems in remote areas*
  (Paolo Marocco (1), D. Ferrero (1), M. Gandiglio (1), A. Lanzini (1), M. Santarelli (1), K. Fløche Juelsgaard (2), K. Panopoulos (3), D. Consoli (4), M. Ciani Bassetti (4), I. Rosso (5), D. Thomas (6), S. Chatzigavriil (7), M. Lai (8), A. Veiga (9), K. Sundseth (10), B. Kvaal (11); (1) DENERG, Politecnico di Torino, Italy, (2) BPSE, (3) CERTH, (4) EGP, (5) EPS, (6) HYG, (7) HOR, (8) IRIS, (9) POW, (10) SINTEF, (11) TREN)

- *Operating results of PEMEL, AEL and SOEC systems*
  (Michael Alkämper, Sebastian Stypka, Bernd Oberschachtsiek, Angelika Heinzel; Zentrum für Brennstoffzellentechnik GmbH (ZBT), Germany)

- *Feasibility analysis of off-grid hydrogen energy storage system for energy independent island in south Korea*
  (Xia Zhang, Byeong Soo Oh; School of Mechanical Engineering, Chonnam National University)

- *PowerAlliance – Extending Grid Capacity on the Medium Voltage Level through Intelligent Sector Coupling*
  (Joachim Bagemihl (4), Gwendolin Wilke (1), Ramón Christen (1), Vincent Layec (2), Holger Wache (2), Mirjam West (3), Silvia Ulli-Beer (3), Juliana Zapata (3), Yves Wymann (4), Thomas Stadler (5), Franz Stabauer (6), Daniel Laager (7), Jürgen Breit (8); (1) Lucerne University of Applied Sciences and Arts, Switzerland, (2) University of Applied Sciences and Arts Northwestern Switzerland, (3) Zurich University of Applied Sciences, Switzerland, (4) Alpiq AG, Switzerland, (5) Xamax AG, Switzerland, (6) ASKI Industrie-Elektronik GmbH, Austria, (7) EBM, Switzerland, (8) Stadtwerke Crailsheim, Germany

- *A Market Data Clustering Aimed to the Economic Analysis of an ESS-based Power Plant providing Ancillary Services*
  (Francesco Maria De Venezia, Simona Parrella, Vito Calderaro, Vincenzo Galdi, Antonio Piccolo; University of Salerno, Italy)

- *Efficient preparation of TSOs for the integration of Capacity Calculation Regions (CCRs) in terms of security and welfare*
  (Jadranko Kučica; Coratian Transmission System Operator Ltd., Croatia)

Session chair: Christoph Imboden, Lucerne University

6.1 REMOTE project: techno-economical sizing of H2-based energy storage systems in remote areas

Winner of the poster award 'Most Innovative Contribution'

P. Marocco (1), D. Ferrero (1), M. Gandiglio (1), A. Lanzini (1), M. Santarelli (1), K. Fløche Juelsgaard (2), K. Panopoulos (3), D. Consoli (4), M. Ciani Bassetti (4), I. Rosso (5), D. Thomas (6), S. Chatzigavriil (7), M. Lai (8), A. Veiga (9), K. Sundseth (10), B. Kvaal (11)

(1) DENERG, Politecnico di Torino, Corso Duca degli Abruzzi 25, 10129 Torino, Italy
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The development of efficient and sustainable energy solutions and the attempt to reduce carbon dioxide emissions are leading to an increasing penetration of Renewable Energy Sources (RES). Effective Electrical Energy Storage (EES) solutions need therefore to be developed to deal with the issue of fitting locally available RES and loads. Hydrogen can become an interesting option because of its high energy density, long-term storage capability and modularity. In particular, in isolated micro-grid and off-grid remote areas, intermittent RES integrated with H_2-based storage systems can provide a reliable, cost-effective and decarbonized alternative to on-site electricity generation through diesel engines.

In this context, the EU REMOTE project aims at demonstrating the technical and economic feasibility of H_2-based energy storage solutions in remote locations: four demonstration sites have been selected in four different locations across Europe. According to the site, different RES sources are exploited: solar, wind, biomass or water fall. Their usage is optimized thanks to the operation of an H_2-based power-to-power (P2P) technology. In fact, surplus RES energy can be supplied to the electrolyzer for H_2 production. The fuel cell is then employed to generate electricity back during renewable power shortages. A battery bank can be also adopted as complementary shorter term electricity energy buffer. A centralized controller on site integrates the advanced algorithms performing

the high level management and remote secured access of the whole ESS.

The aim of this study is to develop a techno-economic analysis of different system configurations. The more traditional ones, i.e. diesel generator and, where available, electrical grid connection, were compared with innovative solutions consisting of renewable sources coupled with means of energy storage. Hydrogen associated with batteries are taken into account to store the surplus RES energy. Main input data for the analysis were provided by the REMOTE project partners: techno-economic data from the technology suppliers and electricity consumption values from end users of the four isolated locations. The economic viability of the considered scenarios was outlined by computing the Levelized Cost Of Electricity (LCOE). The final objective is to prove the competitiveness and sustainability of the P2P systems based on hydrogen.

6.2 Operating results of PEMEL, AEL and SOEC systems

Michael Alkämper, Sebastian Stypka, Bernd Oberschachtsiek, Angelika Heinzel

Zentrum für Brennstoffzellentechnik GmbH (ZBT), Germany

6.3 Feasibility analysis of off-grid hydrogen energy storage system for energy independent island in south Korea

Xia Zhang, Byeong Soo Oh

School of Mechanical Engineering, Chonnam National University

6.4 PowerAlliance – Extending Grid Capacity on the Medium Voltage Level through Intelligent Sector Coupling

Joachim Bagemihl (4), Gwendolin Wilke (1), Ramón Christen (1), Vincent Layec (2), Holger Wache (2), Mirjam West (3), Silvia Ulli-Beer (3), Juliana Zapata (3), Yves Wymann (4), Thomas Stadler (5), Franz Stabauer (6), Daniel Laager (7), Jürgen Breit (8)

(1) Lucerne University of Applied Sciences and Arts, Switzerland, (2) University of Applied Sciences and Arts Northwestern Switzerland, (3) Zurich University of Applied Sciences, Switzerland, (4) Alpiq AG, Switzerland, (5) Xamax AG, Switzerland, (6) ASKI Industrie-Elektronik GmbH,

In order to mitigate the risks of climate change an extensive energy system decarbonization has to be put into reality until mid of this century. In case installation for renewable generation assets progresses at the necessary high rates, the system will increasingly experience excess power production as long as competitive storage systems are lacking. As a consequence, renewable generation needs to be switched off. Reasons for this are a temporarily insufficient electricity demand and grid congestion on all voltage levels. Flexible demand is needed, but a shift of demand towards times of abundant wind and solar generation is rarely happening today: demand is largely inelastic due to technical, regulatory and economical hurdles. With the progression of sector coupling in the energy system - i.e. the electrification of transport and heating - this situation will change fundamentally, so that a

Austria, (7) EBM, Switzerland, (8) Stadtwerke Crailsheim, Germany	further increase in grid congestion is to be expected. It is of utmost importance that electricity in comparison with fossil energy carriers will not be burdened with associated costs as much as it is the case today. More specifically, grid costs, taxes and levies etc. need to be lowered in order to make the transition to renewable electricity economically attractive and to make renewable energy the new normal. The basic idea of the PowerAlliance project is to utilize the redundant grid capacity installed to provide today's high level of security of supply - the so-called n-1 security. The project demonstrates that this capacity can be put into service without compromising n-1 security for crucial consumers and processes by applying a smart mechanism based on dynamic load management. As a market based incentive, a so-called "PowerAlliance tariff" is introduced. The underlying pure energy prices (price level and price volatility) of the project simulation reflect a dynamic built up of renewable generation as it is needed to reach the decarbonization goals. All other price components (grid taxes and levies) for the n-1 security of supply level are following a „business as usual" logic (so called "Standard Tariff"). In comparison to this standard tariff the PowerAlliance tariff is significantly lower. In addition, the project is applying assumptions regarding cost degression of the main technical drivers such as PV, batteries and power-to-x. Specifically, it is demonstrated how capacities connected to the medium voltage grid are affected by the application of the proposed innovative grid tariff system, including new grid schedule processes

on the Distribution System Operator (DSO) level as well as a version of the traffic light system approach. The PowerAlliance tariff is intended to be applied particularly for new grid connection capacities within the scope of sector coupling and storage, as well as for renewable generation. With the PowerAlliance model, a regime to promote the absorption of excess power can be efficiently introduced. Here, "efficiently" in the sense of PowerAlliance means that a macro economical balance can be achieved between the high simultaneity of production and consumption and load shifting in times of grid congestion while avoiding unnecessary high costs of grid upgrades and negative power prices in the long run.

6.5 A Market Data Clustering Aimed to the Economic Analysis of an ESS-based Power Plant providing Ancillary Services

Francesco Maria De Venezia, Simona Parrella, Vito Calderaro, Vincenzo Galdi, Antonio Piccolo

University of Salerno, Italy

The new paradigm of the power system is based on an increasingly widespread use of Non-Programmable Renewable Energy Sources (NP-RES). This situation determines very strong effects on the grid requiring a more efficient management and a wider use of Ancillary Services, especially in the areas with high penetration of wind and solar power plant.

One of the most promising solution to face the issues related to the spread of NP-RES is the use of Energy Storage System (ESS). In fact, ESSs can provide multiple services and features to improve safety and reliability of power systems.

However, in order to select the proper storage technology able to support network services, it is advisable to analyse the characteristics of the ancillary services market. In fact, the large amount of available data and the dependence on non-recurring weather conditions that are very difficult to forecast, requires a careful pre-analysis.

In this paper, a clustering algorithm for the ancillary services market ex-ante, based on the Ward methodology, is proposed.

The proposed approach is applied on a historic series of ancillary service ex-ante market data, by using the Pearson coefficient to highlight the similarities between the historical sub-series of months. Then, by applying the Ward method, similar months are grouped together in order to extract the market characteristics of interest such as, average price and share of hours of supply of resource in the market.

The proposed methodology has been applied to evaluate the economic feasibility of ESS power plant by using real data of the Italian Ancillary Services Market ex-ante of Central South and South Italian areas.

6.6 Efficient preparation of TSOs for the integration of Capacity Calculation Regions (CCRs) in terms of security and welfare

Jadranko Kučica,

For each Capacity Calculation Region (CCR), a coordinated capacity calculator needs to be established to define cross-zonal capacities for day-

Coratian Transmission System Operator Ltd., HR	ahead, intraday timeframes and long-term timeframes. The CCRs have to be adopted to comply with the legal requirements of the CACM Regulation in order to reflect a better coordination of capacity calculators and the progressive introduction of flow-based approaches. Forced by Article 29(9) of the CACM Regulation, the goal of coordinated congestion management methods between the neighboring regions requires cooperation between coordinated capacity calculators for exchanges and confirming information on interdependency. This dynamic approach is in line with Regulation (EC) No 714/2009, which requires Member States to promote cooperation and monitor the effectiveness of the network at the regional level. That cooperation at regional level is compatible with the progress towards a competitive and efficient internal market in electricity. It is anticipated that the CCRs of CWE and CEE (under Core project) will be the first adjacent regions to implement the flow based capacity calculation methodology, and thus as the first CCRs are obliged to submit a proposal for a common flow based capacity calculation methodology. When this common flow based capacity calculation methodology is implemented, it should in practice bring merging of the CCRs for capacity calculation purposes. This integration needs to ensure smooth and sufficiently fast enough integration of CCRs as well as consequently adequate preparation of TSOs according to future demands. Also, the cooperation of CCRs leads to less reliance on assumptions, higher transparency and efficiency in flow determination, market efficiency and possible

higher capacity for exchanges. It is also anticipated that as the current level of interconnection increases. In the near future, the level of interaction between CCRs needs to be re-evaluated in terms of security, and welfare should also be increased. As it is known, these interconnections must be properly modelled and considered to work successfully in the internal European market coupling.

7. Impressions from the social program

Summary box of the chapter

Two social events enabled the participants to get to know each other and offered a lot of space for an in-depth exchange:

- *the dinner at Chateau Gütsch, and*
- *the boat trip across Lake Lucerne.*

On the evening of 3 July, the attendants of the GSM19 met for a common dinner at Chateau Gütsch. An awesome view and a good meal create a cheerful atmosphere.

The evening program on 4 July offered a boat trip across Lake Lucerne with dinner, music and the opportunity to dance.

8. Glossary

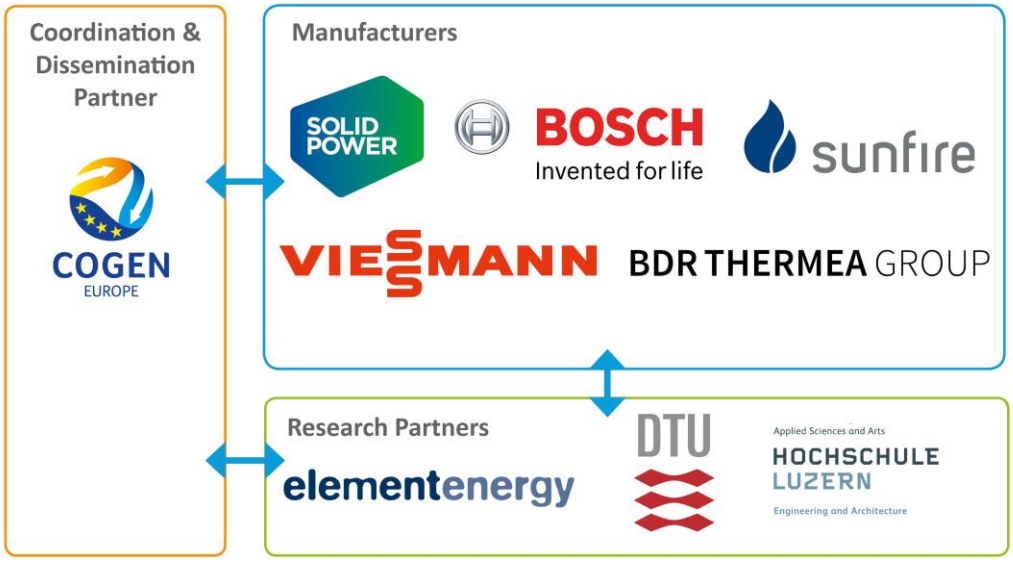
CHP	Combined Heat and Power
DSO	Distribution System Operator
EC	European Commission
FC	Fuel Cell
FCH	Fuel Cells and Hydrogen
GSM	Grid Service Markets
mCHP	Micro Combined Heat and Power
PACE	Pathway to a Competitive European Fuel Cell micro-Cogeneration Market
Q&A	Questions and Answers
TSO	Transmission System Operator
VPP	Virtual Power Plant

About PACE

PACE is a major EU project unlocking the large-scale European deployment of the state of the art smart energy solution for private homes, Fuel Cell micro-Cogeneration. PACE will see over 2,500 householders across Europe reaping the benefits of this home energy system. The project will enable manufacturers to move towards product industrialisation and will foster market development at the national level by working together with building professionals and the wider energy community. The project uses modern fuel cell technology to produce efficient heat and electricity at home, empowering consumers in their energy choices.
PACE project, which stands for "Pathway to a Competitive European Fuel Cell micro-Cogeneration market", is co-funded by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) and brings together European manufacturers, research institutes and other key energy stakeholders making the products available across 11 European countries.

For more information, visit *www.pace-energy.eu*
or contact Mr Janos Vajda via *info@pace-energy.eu*

The PACE partners are



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