SYSTEM RESILIENCY AND FLEXIBILITY
SUMMARY REPORT

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An event organized under the auspices of the

Experts' Group on R&D Priority Setting and Evaluation (EGRD)

13 – 14 May 2019

Vienna, Austria

Hosted by the Austrian Ministry for Transport, Innovation and Technology

Venue Day 1: Technologiezentrum Seestadt, Seestadtstraße 27, 1220 Wien

Venue Day 2: Austrian Ministry for Transport, Innovation and Technology (BMVIT), Room EA08, Radetzkystraße 2, 1030 Wien

Executive Summary

Introduction

On 13 and 14 May 2019 delegates to the IEA Experts' Group on R&D Priority Setting (EGRD) organized a meeting to gain further knowledge of the research and innovation needs associated to system resiliency and flexibility. International technology experts from academia, research entities and leading agencies offered a wide range of perspectives and insights. The event was hosted by the Federal Ministry for Transport, Innovation and Technology, Vienna, Austria.

Rationale and Background

In the *World Energy Outlook 2018*, primary energy consumption is expected to increase by 27% by 2040. In 2017, energy-related CO_2 emissions rose by 1.6 % for the first time in three years. These forecasts point to a further increase by 2040 (+10 % compared to 2017).

Complementarily the Intergovernmental Panel on Climate Change (IPCC) special report *Global Warming of 1.5°C* states that CO_2 emissions have to decline by about 45 % by 2030 (from 2010 levels) in order to reach net zero emissions by 2050.

This leads to one of the questions that are currently of utmost importance: How do we design energy systems, to reach climate and energy objectives globally? An intelligent linking of generation, distribution and consumption is required. Connecting different parts and sectors of the energy system will play a crucial role. Sector coupling is considered as a guiding principle. Furthermore, also energy storage and 'power-to-x' technologies will play a key role.

At present the main options for balancing supply and demand in the electricity system beside (fossil) power plants are transmission grids between countries/regions, energy storage, demand side management, power to-x technologies and curtailment of RES.

The integration of variable RES requires flexibility in order to be able to compensate for possible imbalances between supply and demand in the future energy system. The high share of renewable energy sources in electrical power and district heating grids will force the transition from a purely demand-oriented energy production to a production-oriented demand.

The use of the storage capacity in electric vehicles will depend on attractive business models for car owners. The potential for energy flexibility in buildings is determined by a number of factors such as heat storage capacity of building components, quantities and sizes of thermal storage or the type of electrical devices like heat pumps.

Issues Addressed

- What will the future energy system look like? What are the key challenges and main risks for energy systems with a high share of variable energy sources?
- New technologies and new business models: where are we heading?
- Best practice examples: Which lessons have we learned so far?
- What are the resilient transformation paths for the future?
- Which are the main factors to be considered regarding R&D policies and decision making?

Flexibility: a key to reach the worldwide goals in CO_2-reduction
Nowadays a lot of small decentralized volatile power plants are producing renewable energy. In the future the share of renewable energy is growing constantly. A 100 % renewable energy system needs flexibility to deal with the huge amount of volatile power in the system. Flexibility can be defined as the ability of the power system to respond to variability and uncertainty with an adequate production.

Measures to reach flexibility
Innovative market models and measures like sector coupling, demand side management, energy storage, investments in grid infrastructure, digital solutions and cross-border harmonisation are essential to reach flexibility.

Risk assessment the way to a resilient energy system
In the last 10 years the risk assessment of natural gas supply has greatly evolved. The focus should particularly be on extreme events because they have an immediate impact on the energy system. Also cyber attacks will increase in the future and energy system cannot be protected by the traditional methods. Therefore an integrated, holistic resilience planning is the key to reduce the impact and recover the system quickly. Tools, analysis, technical assistance and research are available and should be implemented.

Recommendations
• Flexibility is the key to the integration of renewable energy and decarbonisation and must be considered along the energy value chain. • Building sector: Flexibility helps to stabilize the energy grid and depends on the building, the users and the conditions in the grids. • Flexibility allows the power system to manage changes. • Sector coupling: Fluctuations on the power supply side require a stronger link to other energy sectors, especially mobility and heat. • More research is needed: Living labs and large-scale demonstration projects are needed. • Lessons learned: The experiences that are currently made in other parts of the world such as Austria, Italy and the Nordic countries provide valuable insights how to gain more flexibility. • Need for common definition and understanding of resiliency. This particularly includes resiliency in the light of extreme events, being accidentally or intentionally, having an immediate impact on the energy system • An integrated, holistic resilience planning is the key. Tools, analysis, technical assistance and research are available but there is no model to implement it. • Modern energy systems are complex cyber-physical systems that are vulnerable to targeted attacks and dynamic failures and cannot be protected by the traditional methods. • We need to reaffirm that the resilience of the energy system affects not only the energy system but the whole society.

Welcoming Session

The workshop was opened by Sabine Mitter, Austrian Ministry for Transport, Innovation and Technology (BMVIT). She pointed out the Energy Research and Innovation Strategy of Austria which is based on a comprehensive open public consultation process. The main strategic aspects in Austria are that RDI should have a relevant and strong impact. In addition to that, the main focus should be on functionalities of (energy) services and an appropriate funding in instruments, in all phases of the innovation chain up to successful implementations**.**

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The chair of EGRD Birte Holst Jorgensen, Technical University of Denmark introduced EGRD in general and the workshop in particular. Attention was drawn to past workshops with a strong content connection f.e. `Future Energy Market Designs: Research and Innovation Needs´, ´The Role of Storage in Energy System Flexibility´, ´RD&D Needs for Energy System Climate Preparedness and Resilience´.

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Wolfgang Hribernik from the Austrian Institute of Technology explained in his presentation the Austrian perspective in energy flexibility - in the framework of a European energy transition. The electricity system in Austria and in Europe is in a transition (AT: 100 % RES for electricity in an annual balance by 2030, DE: nuclear phase-out by 2022 and coal phase-out by 2038, Europe: continuing strong expansion of renewable energies). In Austria the expansion of transmission capacities and the expansion of hydro storages (pump and reservoir) will play a decisive role in covering flexibility needs and security of supply. Demand side management (industrial plus residential) and storage technologies will play a significant role in local energy communities.

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Session 1 – Flexibility in Sustainable Energy Systems

Observations and key messages of Session 1
• Flexibility is the key to the integration of renewable energy and decarbonisation and must be considered along the energy value chain. • Building sector: Flexibility helps to stabilize the energy grid. • Energy flexibility of buildings is dependent on the building, the users and the conditions in the grids. • Building efficiency needs R&D on building automation control, self-consumption, low temperature district heating and cooling, bidirectional networks. • Flexibility allows the power system to manage changes. • A common vocabulary and classification of concepts shall be used. This helps understanding and comparing initiatives. There should be a focus on harmonisation, across Europe, right from the start. • Development of market model as an effective ecosystem is crucial.

Summary and Discussion

The share of renewable energy in the energy system is growing constantly. A 100 % renewable energy system needs flexibility because the energy production will be generated in a lot of small decentralized volatile power plants. In the presentation of the speakers a definition of flexibility was often mentioned. Flexibility is the ability of the power system to respond to variability and uncertainty with an adequate production. In order to reach flexibility innovative market models are essential along the whole value chain. This includes sector coupling, demand side management, energy storage, investments in grid infrastructure, digital solutions, harmonisation across Europe and a common vocabulary.

Flexibility in the building sector can play a major role to stabilize the energy grid. The great advantage of buildings is the ability to manage the demand of energy. In most cases buildings can be controlled to use more energy when available and reduce the loads during periods of shortage. Not all buildings have the same capability to fulfil flexibility functions. In the future when buildings are planned or retrofitted flexibility measures like building automation control, self-consumption, low temperature district heating and cooling, component activation or bidirectional networks should be considered.

All experts agreed that flexibility needs to be considered. The overall energy system needs to include a stable frequency and secure energy supply, but also a local perspective with the focus on secure transfer capacities.

Presentations

Flexibility for a sustainable energy system: the outcomes of the recent IEA EUWP workshop
(20 - 22 March 2019 in Rome)
Michele de Nigris, Ricerca sul Sistema Energetico (RSE)/IT

In the future energy system a very high share of variable renewables will be installed, to deal with the strong transformation of the energy system. Flexibility along the value chain and generation networks are needed. Therefore it is important to define flexibility. Several approaches are feasible: "Power system flexibility refers to a power system's ability to respond to both **expected and unexpected** changes in demand and supply" (Cochran et al. 2014). Another approach to define flexibility is: "Power system flexibility is defined as all relevant characteristics of a power system that facilitate the **reliable** and **cost-effective** management of **variability and uncertainty** in both supply and demand across all relevant timescales" (IEA, 2018).

Nowadays the greatest and cheapest source of flexibility in the generation is conventional power generation (thermal and hydro). In the future innovative market models for ancillary services (or capacity market) are needed to leverage flexibility from generation. To reach a high share of renewables we need a wide transformation to set up a cost-effective system.

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Energy Flexible Buildings – IEA EBC Annex 67
Søren Østergaard Jensen, Teknologisk Institut/DNK

The energy flexibility of a building is the ability to manage its energy demand and generation according to local climate conditions, user needs and grid requirements. In most cases buildings can be controlled to use more energy when available and reduce the loads during periods of shortage.

The available flexibility services from buildings depend, however, on the type of building, the types of energy service systems in the building, the control possibilities, the climate, the time of day and year, the acceptance of the users and owners of the building, the state of the storage, etc. The actual useful energy flexibility is further determined by the needs of the surrounding energy networks to which the building provides flexibility services.

The single building may provide a certain amount of energy flexibility, however, the energy flexibility of buildings should mainly be considered at an aggregated level, as the fluctuations of the load smoothens out and increases with increasing numbers of buildings participating in providing flexibility services.

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Flexibility needs in the future power system
Werner Friedl, ISGAN, Austrian Institute of Technology GmbH (AIT)/AUT

The power system is influenced by five trends: **Decarburization** means to decrease the carbon footprint from electric power production. **Decentralization** targets the transition from few and large, centralized, power plants to many smaller, decentralized, power production units. **Integration** stands for increasingly integrated electricity markets, greater interconnection of previously independent grids, and more integrated energy systems including sector coupling. **Digitalization** is the extensive implementation of and dependency on information and communication technologies and solutions. **Inclusion** aims to increase demand for sustainable, affordable and accessible energy for all including increased electrification of e.g. industrial processes and transport. These five trends are important to be considered by the needs of flexibility which is an **overall system perspective** (maintain stable frequency and secure energy supply) and a **local perspective** (maintain bus voltages and secure transfer capacities). The needs should also be considered for **operation** and **planning** of the power system.

Flexibility needs a holistic approach in the categorization of power, energy, voltage and transfer capacity. The provision of power stands for a short-term equilibrium between power supply and power demand, a system wide requirement for maintaining the frequency stability. Energy needs a medium to long-term equilibrium between energy supply and energy demand and a system wide requirement for demand scenarios over time. Voltage control is a short term ability to keep the bus voltages within predefined limits, a local and regional requirement. Transfer capacity needs a short to medium term ability to transfer power between supply and demand, where local or regional limitations may cause bottlenecks resulting in congestion costs.

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Energy flexibility, a framework and use-cases
Bram Sieben, Advisor to the Board at Alliander NV/NLD

In the Netherlands in comparison to Germany, Spain, France, UK and Ireland, the need for flexiblity increases relatively fast. Peak and mid-load flexibility demand increases 30 - 45% (based on 2015). Growing need for flexibility in the Netherlands is driven by the (accelerated) phasing out of coal and gas, the high cost of CO_2 emission. On a local level there are multiple ways to influence demand and supply: for instance technical assetmanagement solutions (e.g. cable pooling), tariffs and connection agreements (e.g. smart charging), flexiblity procurement (e.g. flexiblity market) and direct intervention (e.g. curtailment).

To reach flexibility it is essential to facilitate the aggregation of demand-side assets, focus on harmonisation, across Europe, right from the start, during and after implementation. A common vocabulary and classification of concepts should be used. This helps understanding and comparing initiatives. A necessary updated market model and an effective ecosystem should be developed.

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Session 2 – Practical experiences with building flexibility into systems

Observations and key messages of Session 2
• The growing share of RES in future power systems requires new approaches towards system flexibility. Although specific approaches will depend on the details of the national power system (structure and distribution of energy sources, interconnectivity to other countries, distribution of the demand) many aspects are similar (a trend towards more decentralization, more digital infrastructure, changing role of consumers, …). • Sector coupling: Fluctuations on the power supply side require a stronger link to other energy sectors, especially mobility and heat. • More research is needed: Living labs and large scale demonstration projects are needed to test the implications of possible future energy systems in a sandbox setting. • Lessons learned: The experiences that are currently made in other parts of the world such as Austria, Italy and the Scandinavian countries provide valuable insights how to gain more flexibility by enabling a systems perspective.

Summary and Discussion

To build up experience in field tests is important to bring flexibility into the energy system. With the "Green Energy Lab" Austria is developing a big innovation lab for a sustainable energy future. The lab covers 5 million people in total and four federal states. The project includes several topics like open data platforms, second life batteries, blockchain grid, spatial energy planning and heat water storage pooling.

One project which is linked to the Green Energy Lab is the ThermaFLEX-project - an approach to analyse the potential of the heating sector. Flexibility can be achieved in three different ways: spatial flexibility through the use of district heating grids, temporal flexibility by using the grid as a thermal storage and also by acceptance of various energy vectors as a source, for example solutions like power, waste heat, solar thermal or P2X.

The goal of the project Nordic Flex4RES is to integrate a high share of variable renewable energy in the energy system and how a stronger coupling of energy markets across the Nordic region can be achieved. The Project found out that insufficient market signals do not provide incentives for the stakeholders to provide means of flexibility.

Renewable energy is changing the general conditions of the energy market. Consumers take more and more an active role and are becoming prosumers. That means for the distribution network to integrate all the actors in order to enable an efficient, economical and sustainable electricity system.

Presentations

Green Energy Lab: Demonstration projects and innovation paths for the flexible, customer-oriented energy system of tomorrow
Susanne Supper, Green Energy Lab/AUT

Susanne Supper presented the Green Energy Lab, Austria's biggest innovation lab for a sustainable energy future. The lab consists of a core region with 5 million people in total and covers the federal states of Vienna, Lower Austria, Burgenland and Styria. Within this innovation lab a multitude of interlinked sustainable projects are funded, covering many different topics such as open data platforms, second life batteries, blockchain grid, spatial energy planning and heat water storage pooling. The initiative sees itself as a testbed for building blocks for an integrated energy system of the future, funding is secured until at least 2025. An important aspect of the Green Energy Lab is the premise that increasing system flexibility is not a purely technical topic: stakeholder integration and end-user involvement is required in all projects. Further open innovation is an important factor in bringing together different actors and overcoming challenges when implementing cutting edge technological solutions to real life problems.

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The potential of flexible thermal grids to decarbonize the heating sector
Stefano Coss, Arbeitsgemeinschaft Erneuerbare Energie - Institut für Nachhaltige Technologien (AEE INTEC)/AUT

Stefano Coss gave a presentation on the ThermaFLEX-project, one of the flagship projects funded within the Green Energy Lab. The project analyses the potential contribution of the heating sector to system flexibility in an integrated heating and power system. This flexibility appears in three different ways: spatial flexibility through the use of district heating grids, temporal flexibility by using the grid as a thermal storage and also by acceptance of various energy vectors (power, waste heat, solar thermal, P2X) as a source. The flagship project brings together 27 partners from research, industry and technology and has an overall amount of roughly 4.6 million Euros (not counting approximately 10 different demonstrators with a budget of additionally 5 million Euro). The main focus of the project lies on large scale industrial demonstrators to decarbonize the heating sector. Besides technical measures and a focus on the implications of these on the whole energy system non-technical innovations such as new business models and user interaction also play a key role. The demonstrators within ThermaFLEX range from a 100%-renewable district heating system to large scale solar thermal generation and the implementation of a high-temperature heat recovery from flue gas.

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Choice of flexibility sources towards a 100% renewable based Nordic energy system
Klaus Skytte, Technical University of Denmark (DTU)/DNK

Klaus Skytte presented the Nordic Flex4RES-project which has the goal to demonstrate how the challenge of integrating high shares of variable renewable energy in the energy system can be handled efficiently through a stronger coupling of energy markets across the Nordic region, thereby facilitating a zero-carbon energy transition. The Nordic countries set themselves ambitious climate goals for the next years: Denmark wants to be totally independent of fossil fuels by 2050 and Sweden and Norway aim to be carbon neutral by that date. This shall be accomplished by accelerating the building up of RES on the supply side and by increasing energy efficiency on the demand side. The most important ingredient however will be system flexibility in coupled energy infrastructures. The analysis of the Flex4RES-project reveals that the main barriers to be overcome towards that goal lie within the regulatory framework: Insufficient market signals do not provide incentives for the stakeholders to provide means of flexibility in a coupled energy system and the frameworks for different energy sectors are very different at the moment.

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Flexibility from the network: Puglia Active Network project
Michele Giovannini, E-Distribuzione/IT

Michele Giovannini gave a presentation on the measures that e-distribuzione, the largest Italian DSO, is currently undertaking to manage the increasing number of RES in their distribution grid with a total of 23 GW at the end of 2018. This often leads to reverse power flow from medium voltage into high voltage grids. When transforming a traditional centralized power system into a distributed one with high share of RES the role of the DSO is fundamentally changing: Consumers take an active role and the distribution network needs to integrate all the actors in order to enable an efficient, economical and sustainable electricity system. Since 2010 e-distribuzione has developed a real-time architecture in their grid, which was tested in several R&D-projects. Currently the *Puglia Active project* with a total budget of 170 M€, cofounded by the EU, aims at developing a Smart Grid all over the Southern Italian region of Apulia and will be operative starting July 2019. Within this Smart Grid there will be more than 1 GW of RES that can be observed and controlled, 74 charging points for electric vehicles, 200 switching stations and almost 30 000 kilometres of medium voltage power lines. The project serves as a testbed to develop more efficient and reliable grid performances, creating new services enabled to the final customer and empowering electric mobility. A key role is played by real time monitoring of MV distributed generation.

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Session 3 – Challenges, obstacles and risks on the way to a resilient energy system

Observations and key messages of Session 3
• Risk assessment of natural gas supply has greatly evolved in the last 10 years • Need to better understand concepts of resiliency and risk assessment and derive analytic frameworks • Need for common definition and understanding of resiliency. This particularly includes resiliency in light of extreme events, being accidental or intentional having an immediate impact on the energy system • An integrated, holistic resilience planning is the key to lessen impact and recover quickly. Tools, analysis, technical assistance and research are available but there is no "size fits all" model how to best implement it. • Modern energy systems are complex cyber-physical systems that are vulnerable to targeted attacks and dynamic failures and cannot be protected by the traditional methods. • Recent research has demonstrated promising results of AI-based adversarial resilience learning leading to operational flexibility of modern energy systems. • Natural gas networks contain linepack, which can be flexed to provide significant amounts of within-day storage. • Research should consider how much within-day flexibility is needed and how it can be reduced by different methods.

Summary and Discussion

The session focused on a resilient transformation path for the future energy system in times of climate change. It included the framework to analyse the resilience of the energy security of supply in Europe, the technical assistance to countries in need for resilience planning and technical solutions following disasters, cyber resilience of the future grid and finally the flexibility provided by the gas sector in the UK.

The European Union set targets not only to reduce the CO_2 emissions but also to secure the energy supply of gas and electricity. In three different projects the gas supply, gas emergency plans and reliability of gas networks in case of disruption where tested and evaluated. Resilience, flexibility and renewable energy are strongly linked to each other.

To strengthen the energy system against hazards, a holistic resilience planning and technical solutions are necessary to respond and recover quickly from disruption. The speakers presented different risks like a storm on a carbic islands or cyber attacks in the Ukraine.

Presentations

Risk and resilience assessment: key challenges from the European experience
Marcelo Masera, European Commission

Dr. Marcelo Masera, JRC, presented the key challenges of risk and resilience assessment of the European energy system. Following the disruption of gas supply from Russia to Europe in 2008, the EU embarked on the long journey to create the European Energy Union to secure energy supply – both gas as well as electricity supply. This included the 2020 targets of 20% renewables, 20% energy efficiency and 20% GHG reduction, all of which were later updated for 2030. This was complemented by the SET-plan to accelerate the clean energy revolution of the EU. On risk assessment of gas supply, three projects were presented: a simulation or stress test of gas supply, gas emergency plans and reliability of gas networks in case of disruption. On risk assessment of electricity supply, the term of adequacy key. It is the measure of the ability of a power system to supply aggregate electric power and energy requirements of customers, covering long term resources, seasonal outlooks and month, week and day ahead assessment at national, regional and Pan-European levels. The challenge is to secure system adequacy for a European energy sector that is highly interconnected, with increasing variable energy sources, an aging generation fleet, inappropriate frameworks and new elements of demand response, storage, sector coupling etc. A concrete resilience case of gas supply was presented, covering the disruption of gas supply from Russia via Ukraine to the EU. Due to various substitution mechanisms, well functioning markets and diverse supply resources, the overall European system was resilient, though there was lack of infrastructure. The JRC analytic framework of resilience includes impact of the crisis, recovery and medium-run performance.

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Resilient Energy Systems: Risks and Challenges
Jessica Lau, National Renewable Energy Laboratory (NREL)/US

The risks and challenges of resilient energy systems were presented by Jessica Lau, NREL. The key message was that preparing for and strengthening assets and processes are keys to lessen impacts and recover quickly from hazards and other threats. As the economic and human impact of disasters is growing, a holistic resilience planning and technical solutions are key to anticipate, prepare for and adapt to changing conditions and withstand, respond to and recover rapid from disruption. There is a need to provide access to tools, analysis, technical assistance and research to enhance energy security, resilience and in the end economic stability. Two cases were presented – one on a Caribbean island nation susceptible to tropical storms and a training request from Asian countries for resilience planning within the energy sector. The lessons learned included lack of data and information and comprehensive metrics for resilience. This also includes validation of technical solutions and policies. It is challenging to stay ahead of threats and hazards and coordinate buy-in and investments at all levels of government. The disaster of Puerto Rico was expected to be a resilience planning role model but turned out to be much more complicated and complex.

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Smart Grid Cyber-Resilience
Sebastian Lehnhoff, OFFIS e.V./GER

Dr. Sebastian Lehnhoff, OFFUS, presented recent research on smart grid cyber resilience. The energy system of today is under transformation, characterized by many smaller, interconnected systems and subject to competition and new business models. It is digital and connected to the power grid infrastructure via several billion devices on the internet. New smart services can be provided and further developed via cloud, outsourcing, AI, big data etc. This means that it is susceptible to both the occurrence of the classical IT challenges as well as new sophisticated cyberattacks. Energy systems are complex, cyber-physical systems with a wide range of entry-points into a security-critical infrastructure. There are two prevailing concepts, either you acknowledge that systems are faulty and we have to do with it. Or alternatively, we have to fix the system and make it 100% safe. An example was given on the cyberattacks on the power system in Ukraine 2015 and 2016, where three utilities were affected leading to black out. The existing monitoring systems of critical attack vectors are not sufficient for detecting critical situations in the energy system. The challenge is that all conceivable attack vectors manifest themselves in a combination of trust facets, which have to be assessed. A new concept of adversarial resilience learning has been developed, where agents via machine learning interact on a shared environment. In conclusion, traditional means and methods have proven to miss targeted attacks and to cope with the vulnerabilities to dynamic failures. Multivariate impact analysis is necessary as basis for automated decision-making during operation. Adversarial resilience learning is an AI-based game theoretic approach to vulnerability testing where equilibria is more relevant than absolute safety. This means that the most promising response to highly targeted attacks is operational flexibility.

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Britain's gas system, a case for reducing flexibility to increase wider system resilience?
Grant Wilson, University of Birmingham/GBR

System resiliency and flexibility was presented by Dr. Grant Wilson, University of Birmingham. He presented the findings of the FlexiNET project on flexibility of the British energy systems, with a particular focus on natural gas supplies and demands. Natural gas is the biggest source of interseasonal daily demand swing, in particular local demand for space heating, itself dependent on the weather. Excluded are gas demands directly connected to the high pressure gas transmission grid e.g. interconnectors, power stations, storage and industry. The gas system copes with the within-day demand swing by utilizing the inherent storage capacity within the pipes themselves – also called line pack flexibility. As the pipeline pressure can be changed, the line pack can be flexed over a range within safe operating pressures. It thereby provides a large capacity for within-day flexibility. Analysis shows that local gas line pack was flexed more than 183 GWh for 75% of the days from October to March over 63 months of data between 2013-01-01 to 2018-03-07. The question is how much this flexibility provided by the gaseous energy vector can be replaced, by what and at what cost? Further research is needed on the level of within-day flexibility and how it can be reduced by different methods such as behavioural change, thermal storage, demand reduction and time shifting of demand.

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Session 4 – Flexible and resilient energy systems: towards R&D policies and decision making

Observations and key messages of Session 4
• We need to reaffirm that the resilience of the energy system affects not only the energy system but the whole society. • Especially in the case of rapid change, vulnerable sectors and areas need careful policy actions. • The progress in scientific knowledge, which is the result of research and development, makes it possible to quantitatively identify the risks of energy systems more detail and take measures to suppress the degradation of systems in advance, in addition to the advancement of countermeasures in individual fields.

Summary and Discussion

System resiliency is a broad concept to evaluate degradation of system quality. It is essential to secure stable energy supply, stable society elements such as employment and non-energy infrastructure, protection of human life and business activities. Extraordinary external events affect entire society, not limited energy system. Flexibility is the one element of a resilient energy system.

Phase out of coal and natural gas was discussed. Both phase outs aim at CO_2 mitigation in the long-run, however, natural gas phase out case was triggered by local earthquakes. Sudden change in energy supply would have impact on energy price, employment and infrastructure adjustment. Policy measures such as economic incentives in the form of financial support, subsidies for services and equipment, and legislations are considered to assist transitions.

Research and development both in hardware and software is essential to design resilient energy system. If we limit the discussion in hardware countermeasures for power system, activities are needed to prepare the extreme events such as storm, wind, icing, lightning, earthquake, landslide, sabotage, flood, fire and aging. Software related activities are also important fields to assess system resiliency qualitatively. Risk assessment based on scientific knowledge on hazard, exposure and vulnerability will provide useful information to identify possible risks and related countermeasures in policies.

Presentations

Opportunities and challenges in the context of the coal phase-out in Germany
Arjuna Nebel, Wuppertal Institute/GER

Main driver coal phase out in Germany has been the climate policy. In addition, Commission on Growth, Structural Change and Employment announced coal power generation phase out by 2038 in the statement of January 2019, including financial compensation for particularly affected regions and possibly occurring price increase and detailed monitoring of the security of supply. Expected capacities of coal and lignite power capacity will not be zero in 2038, if it is assumed that 40 or 50 years of coal power plant lifetime. However, extension of current decreasing trend will provide almost zero capacity around 2038. Major instruments to ensure the security of supply are close monitoring, prohibition on decommissioning if security of supply is threatened, capacity reserve, network reserve, new gas-fired power plant tender, load flexibility for industrial customers and expansion of the transmission grid and stronger integration into the European internal market.

Coal industry employment has been decreasing already by purely economic reasons. However certain regions are heavily dependent on coal mining. The coal phase out will probably not be enough to reach the climate targets, but it will not cause security of supply issues either because the decommissioning rate is manageable.

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Learnings from the Hokkaido Blackout
Manabu Nabeshima, Electric Infrastructure Division, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (ANRE/METI)/JPN

Japanese power system has two frequency zones and interconnection capacities between traditional utility zones are narrow. The earthquake hit Hokkaido, northern island of Japan, on September 6, 2017. The epicenter of the earthquake was close to Tomato-Atsuma thermal power plant, where around half of the power was generated for the area of Hokkaido at that time. Sequence of events that led to the blackout are: 3 units shut down, 4 power transmission lines were damaged, and under frequency relay and interconnection between main island were insufficient to sustain the frequency. It took approximately 45 hours to supply power for nearly the entire Hokkaido area. Ministry of Economy, Trade and Industry (METI) asked the citizens to cut back electricity demand from 08:30 to 20:30 and 10 to 20% of demand saving was achieved. Required measures are expansion of the interconnection capacity, addition of load shedding capacity and ensuring resource adequacy. Implications for renewable energy resources (RES) include independent mode operation instruction of on-site photovoltaics for homeowners, clear grid code to make renewable energy resource more resilient to frequency changes, and sufficient balancing capacity for RES to re-connect to the grid after blackout.

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Risks of Natural Gas exploration as one of the drivers for the energy transition in the Netherlands
Frank Witte, The Netherlands Enterprise Agency (RVO)/NLD

The Dutch government decided to phase out production from Groningen gas field by 2030. Groningen gas field has long history of natural gas production, however earthquakes induced by gas production have played a key-role in the decision making process. The letter to the parliament in March 2018 includes several measures such as importing high-caloric gas with nitrogen dilution, transforming industry towards high-caloric gas, decreasing export and transitioning in built environment to natural gas free in 2050. Newly built houses will be forbidden to install natural gas heating system, while use of natural gas for heating is to be phased out gradually for existing houses. Climate agreement for buildings have CO2 free built environment target in 2050, and target of 1.5 million houses and 15% office free from natural gas in 2030. There are several policy instruments used such as laws for newly built houses, financing, subsidies an support for area approach, scaling up and innovation. 27 residential areas were selected for natural gas free experiments in municipalities. Also, an innovation subsidy scheme will provide incentives for district heating, all-electric, green gas and their combinations. Natural gas phase out will be a strong driver for energy transition supported by strong legislation.

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Italian strategy towards Power System resilience and regulatory scenario
Emanuele Ciapessoni, RSE/IT

Power system is a continent-wide very complex interconnected synchronous network, and increasingly vulnerable to different threats with significant cascading impact. Uncertainties in loads, renewables and larger interconnection have changed grid operation. Initiating events influences stabilities of voltage, current and frequency. And uncertainties could amplify the effects through cascading to blackout. Reliability has been defined considering security and adequacy in the traditional way to prepare single facility failure (i.e. N-1 contingencies). Power system degradation limitation in case of extraordinary events has led to resilience concept instead of N-k security criteria (i.e. multiple contingencies). The definition of resilience in International Council on Large Electric Systems (CIGRE) WG C4.47 is 'ability to limit the extent, severity and duration of system degradation following an event'. Typical approaches are separation between property and key measures, reference to degraded performance and extreme event, characterization of degradation by means of extent, severity and duration. Causes of power system vulnerability are categorized into two dimensions (i.e. natural and man-related, external and internal). Bow tie model is the framework to deal with causes-contingency-consequences including blackout chains with multiple contingencies and cascading, and it can be used to evaluate multi hazard-vulnerability scenarios with risk of loss of load and countermeasures. Ricerca sul Sistema Energetico (RSE) is very active in resilience related subjects and collaborates with working group (WG) of CEI (Italian electrotechnical committee). ARERA (Italian Regulatory Authority for Energy, Networks and the Environment) established a resilience table from the results of CEI WG. According to final deliberation of ARENA operators with more than 50,000 customers presented resilience enhancement plan with cost benefit analysis. It is concluded that resilience and risk are fundamental concepts for operating modern power systems, and in Italy a probabilistic risk based method is used in planning for resilience according to ARERA deliberations, risk methods for operation are still quite far from being deployed in control centers, currently weather forecast is used by TSO and will be used by DSOs, and future methods and tools will support operators by suggesting the most suitable countermeasures (passive and active) for different threats over different time scales (from planning to operation).

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Final session: Workshop summary and R&D Recommendations

During the final session the participants summarised the key takeaways from the workshop's four sessions and discussed what the key R&D recommendations to governments should be in the area of System Flexibility and Resiliency. Besides that the participants shared their overall impressions from the workshop and the topic. Related to that the EGRD workshop discussed and questioned whether or not the broader topic of System Resiliency and Flexibility should be dealt with in a more integrated way by governments. Today, in general, the government authorities dealing with promoting enhanced flexibility (balancing the system, developing regulations and market design to enable the uptake of larger shares of renewables, demand-side management, storage, further digitalisation etc.) are not necessarily the same authorities that are dealing with matters related to system-wide resiliency (cyber security, contingency plans, crisis management etc). At what stage might this be a matter that becomes a concern from politicians and where further efforts are needed for risk assessment related to future scenarios with extreme weather events and different shares of variable renewables in the system? The participants agreed that it could be a topic that could benefit from further discussion and knowledge-building and encourage governments to continue their work on defining what flexibility and sector coupling mean.

Observations and key messages of the final session
• The energy system will get complex in the future with more interconnections and technologies. That means more options and a higher resilience but also more failures. • On the other hand a complex system with many actors has a higher resilience because more options are available if something goes wrong. • It is important to differentiate between resilience in case of emergencies and hazards and the requirements of decarburization.