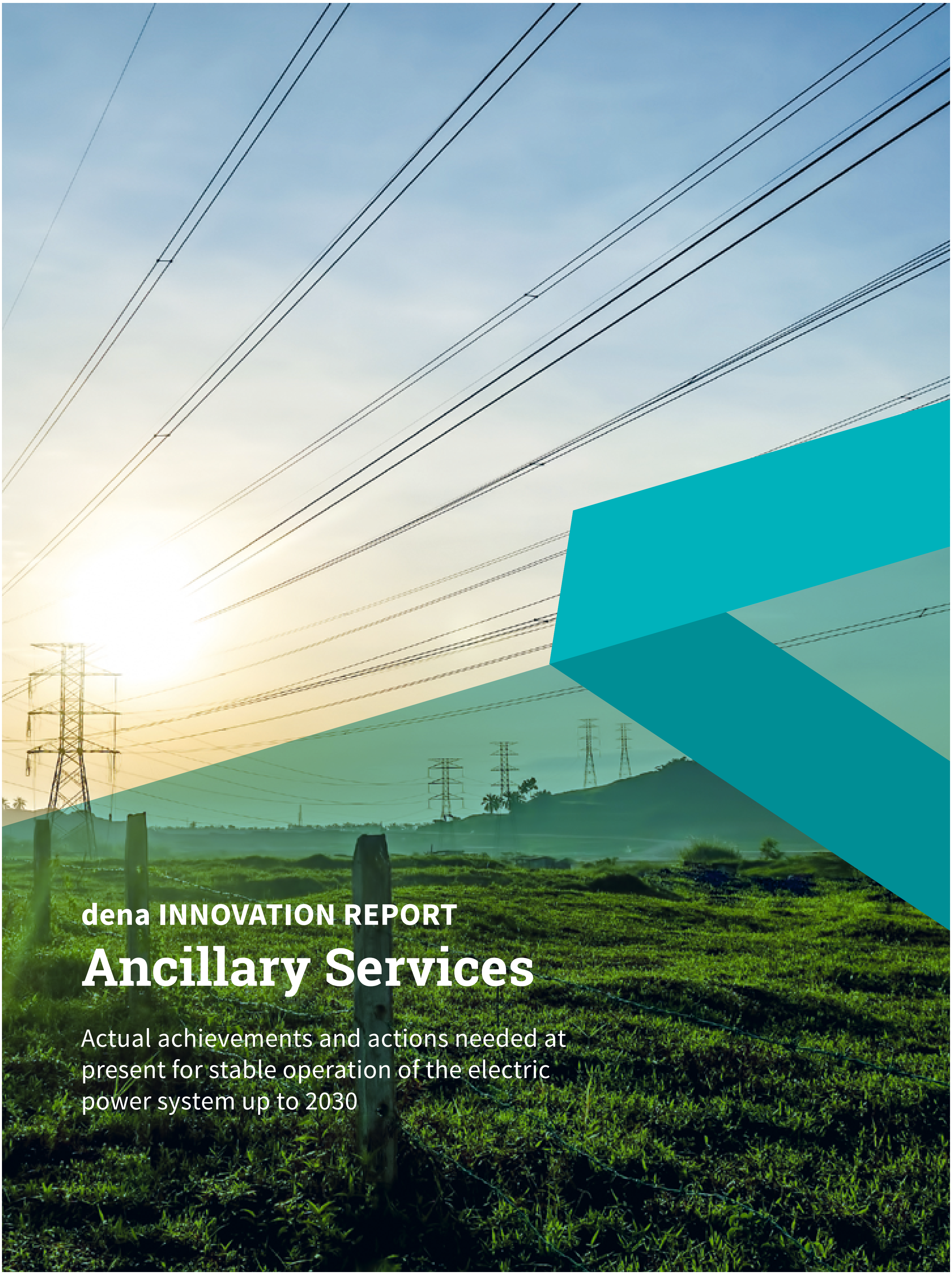
dena
German Energy Agency



dena INNOVATION REPORT

# Ancillary Services

Actual achievements and actions needed at present for stable operation of the electric power system up to 2030

# Table of contents

# Summary

## The pace of continuous development of ancillary services must be sustained.

The energy transition is characterised by a constantly increasing percentage of electricity being produced by decentralised renewable energy facilities. To a large extent, the security and stability of electricity supplies depend on whether it will also be possible to continue developing ancillary services in the future, and to adapt them to future demands.

In this Innovation Report, the dena ancillary services platform sets out the present state of development and need for action in the area of ancillary services, in order to provide players in the field with orientation during the transformation of the electric power system. The individual areas of activity are developing dynamically, and therefore require constant, vigilant evaluation.

For example, while development in the fields of balancing power and short-circuit current contributions is on target – according to our present knowledge – a need for action is already becoming apparent in the area of instantaneous reserve. Here risks have been identified, particularly in a system-split scenario, which as a consequence could lead to blackouts. The provision of reactive power also demands action, particularly from the point of view of macroeconomically cost-effective configuration.

Besides the provision of ancillary services, the demands on the grid connection and operation have important functions for the preservation of system security. Here it is particularly a question of compliance with the European regulatory frameworks and network codes.

## 1 Securing economically affordable provision for all players

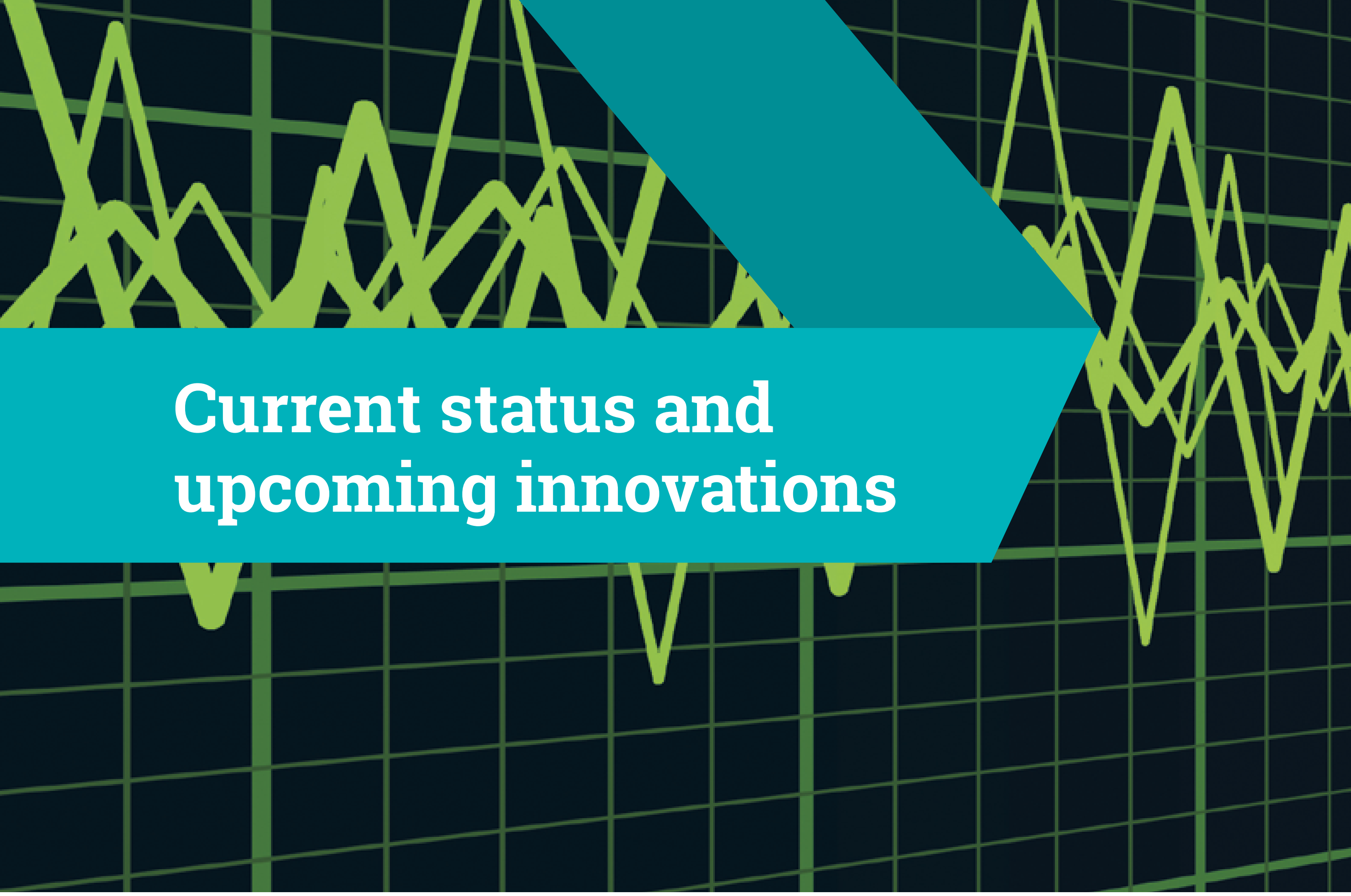
The use of ancillary service products entails costs for both grid and plant operators. In the course of its further technical development, the associated economic questions must also be answered. Analyses must be carried out to determine what costs arise for players through an enhanced provision of ancillary services. Regulatory frameworks must be designed in such a way that the type of provision chosen makes most sense, both technically and economically.

## 2 Continuing to develop interfaces between TSOs, DSOs and plant operators

Decentralised power generating plants are becoming increasingly responsible for stability in the electricity grid. These plants are almost all connected to the distribution grid. Especially when system stability is concerned, e.g. balancing power or redispatch, the interfaces between providers and all network levels affected must be improved. These improvements include new processes and data interfaces.

## 3 Developing technological alternatives for the provision of instantaneous reserve

Before the operating reserve can be activated, the rotating masses of conventional power stations cushion the effect of frequency fluctuations. This property is therefore essential for the stability of the electric power system. If the running times of conventional power stations continue to decrease in future, this function can be taken over by the frequency converters of renewable energy facilities. To this end, existing solutions must be further researched, and their capacity for use in the network system must be tested.



# Current status and upcoming innovations

## The energy transition presents new demands for ancillary services

The energy transition is bringing about a radical transformation of electricity supply in Germany. Renewable energy sources (RES) are being developed, while the market share of conventional, controllable power stations is increasingly diminishing.

This has direct effects on stable grid operation.

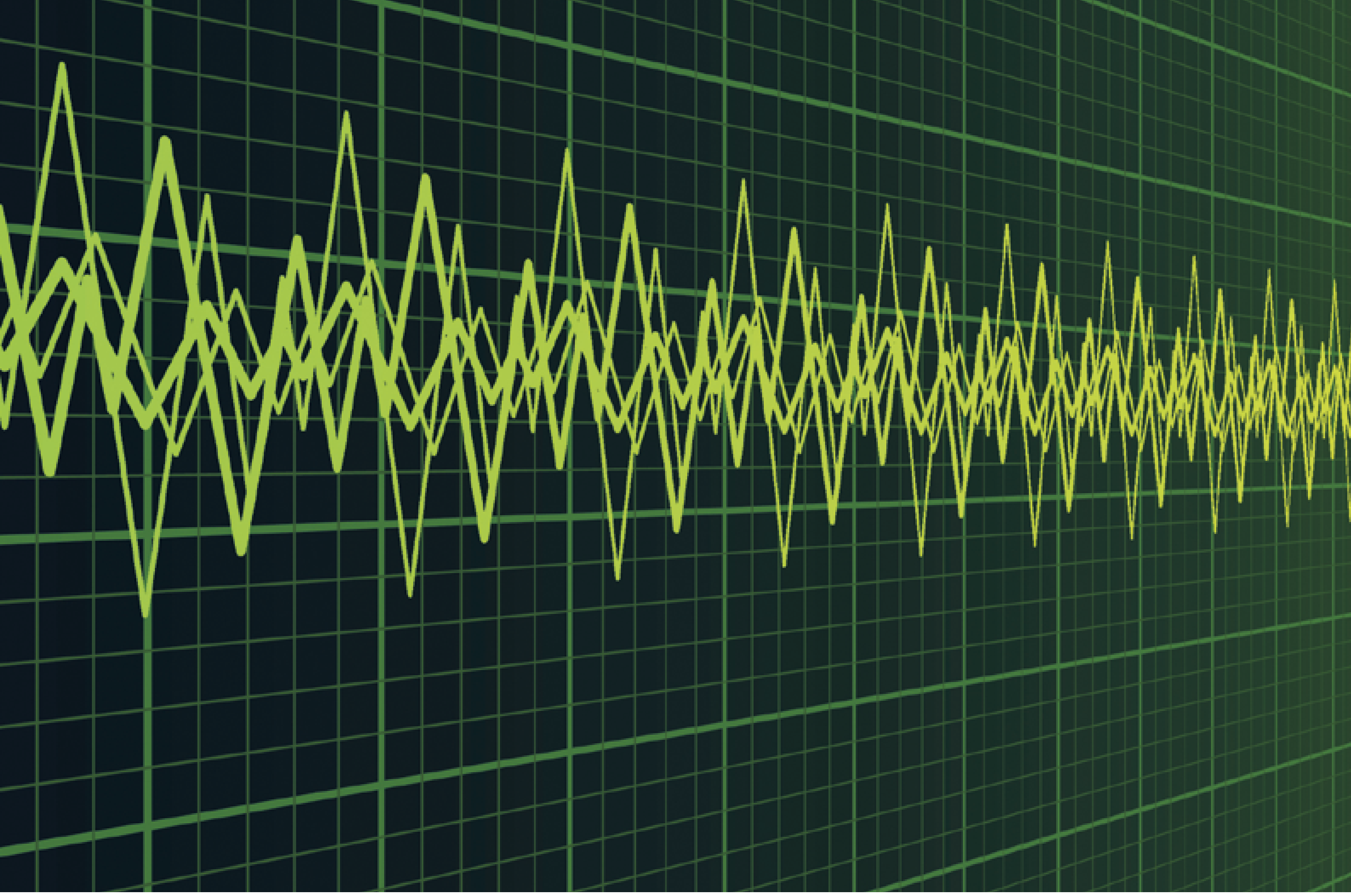
Volatile electricity provided by wind or sun results in widely variable load flow situations in grids. At the same time, there is a tendency for the distances electricity is transported to increase, for example because the wind turbines supplying the needs of the whole of Germany are predominantly located in North Germany.

With the energy transition, the quota of decentralised energy producers such as photovoltaic systems in the distribution grid has increased considerably, while by contrast the number of large power stations in the high and ultra-high voltage grid is on the decline.

Electricity generation is becoming increasingly based on millions of small systems rather than a few hundred large-scale power plants. At the same time, electricity consumers expect increasing flexibility. These developments present a major challenge for energy systems, but also harbour opportunities, and could become drivers for innovation in the electricity grid infrastructure.

Here ancillary services take on a particular significance. These are used by grid operators to keep the frequency, voltage and power loading in the grid within approved limits, or to return them to their normal range after malfunctions.

The ‘Ancillary Services’ Innovation Report presents the developments in this field over the past three years, and specifies the action required at present to make the grid sustainable. At the same time, it describes suitable measures for realising a secure and stable electricity supply. Additionally, the Innovation Report provides an overview of the broader landscape of research and development that is concerned with this important topic for the future.



**‘The high quality of supply in the electrical power system can only be sustained through innovations in the field of ancillary services.’**

**Hannes Seidl,** Head of Division Energy Systems and Energy Services, Deutsche Energie-Agentur (dena) – German Energy Agency

# What are ancillary services?

To guarantee the high quality, reliability and security of electricity transmission and distribution, grid operators are increasingly adopting measures to keep frequency, voltage and load of grid operating equipment within the approved limits, or return them to the normal range after malfunctions. These ancillary services are absolutely crucial to the operational reliability of electrical energy supply. Within ancillary services, a distinction is made between operational management, frequency control, voltage control und system restoration.

Providing ancillary services alone is not enough to guarantee the stability of the electric power system. An additional important aspect – and an equally complex one – is controlling malfunctions. This topic is not the focus of the present Innovation Report, but many aspects of it will be addressed here.

## Operational management

**Definition:**
For grid operators, the tasks which fall under the heading of 'operational management' are: organising secure grid operation, continuously monitoring and controlling the electricity grid (including generation and the load) for threshold violations (e.g. current flow overloads). The objective is to guarantee secure operation of the entire power supply system.

**Essential products and processes:**

- Feed-in management,
- Redispatch/congestion management,
- Utilisation of reserve power plants,
- Operational planning/shutdown planning
- Data and information exchange (e.g. cascades)
- Planning utilisation of flexibility
- Control of flexibilities beyond grid levels

## Frequency control

**Definition:**
Frequency control is carried out by the transmission system operators. They have the responsibility for keeping electricity generation and consumption precisely balanced at all times, which is an indispensable requirement for stable grid operation. For this purpose, the transmission system operators use the inherent property of the system (up to now) known as 'instantaneous reserve', and procure balancing energy through tendering.

**Essential products and processes:**

- Instantaneous reserve[1]
- Primary balancing capacity,
- Secondary balancing capacity,
- Minute reserve capacity

[1] See list of footnotes, p. 46

# What are ancillary services products?

Grid operators use ancillary service products and a multitude of processes for providing the four ancillary services of operational management, frequency control, voltage control and system restoration. Ancillary service products are sourced from the grid operators' operating resources, but also from grid users, i.e. through power generating units or flexible loads.

The use of the term 'product' does not necessarily imply that remuneration is or should be provided for the ancillary service product. For example, remuneration is paid for the best-known ancillary service product, balancing power. By contrast, on the basis of stipulations in the technical connection conditions, reactive power is provided free of remuneration in Germany.

## Voltage control

**Definition:**
With regard to voltage control, the responsibility of the transmission and distribution system operators is to maintain the grid voltage in their respective grid areas within a range that is permissible for the voltage quality.

**Essential products and processes:**

- Transformer gradation and switchover
- Provision and control of reactive power
- Control of power generating plants
- Switching of grid operating equipment
- Short-circuit current contributions

## System restoration

**Definition:**
In the event of a large-scale power failure, the transmission system operators, in collaboration with the distribution system operators, must be able to restore the supply of electrical energy in the shortest time possible by means of system restoration.

**Essential products and processes:**

- Black start capacity
- Capacity for island operation
- Coordination beyond grid levels

# Six key topics

As part of the dena Study 'Ancillary Services 2030'[I] six key areas for development were identified:

- Operational management
- Balancing power (sub-topic of frequency control)
- Instantaneous reserve (sub-topic of frequency control)
- Reactive power (sub-topic of voltage control)
- Short-circuit current contribution (sub-topic of voltage control)
- System restoration

The key development areas of operational management, operating reserve, reactive power and system restoration may be subsumed as a whole under the topic of ancillary services, whereas instantaneous reserve and short-circuit current contribution transcend this topic, since they also play an important role in cases of malfunction.

[I] See list of publications, pp. 44-45


Key topics of the
Innovation Report
'Ancillary Services'
1
Operation management
2
Balancing power
3
Instantaneous reserve
Frequency control
4
Reactive power
5
Short-circuit
current contribution
6
System
restauration
Voltage control

# Specific challenges for innovation in ancillary services

## Operational management

For a diverse range of reasons, the increasing proportion of renewable energy sources in the electricity system is leading to increasing complexity in the electricity grid. Mastering this complexity is one of the decisive challenges in the ongoing development of operational management.

Moreover, the majority of renewable energy facilities in Germany deliver an input that depends on the weather, predicting which is beset with uncertainties. This leads to frequently changing, not always predictable power generation and load flow situations in the transmission and distribution grids, which at present the grid operators can only control by means of a significant increase in targeted system interventions. For example, local bottlenecks in the distribution grid are avoided by means of congestion management. If the input in areas remote from the load centre is particularly high, then redispatch in the transmission grid may additionally be required, since the transmission capacities are not sufficiently developed yet. Further reasons for the increase in complexity are the wider options in future for more actively integrating prosumers into the market, as well as the integration of additional industries and sectors into the electric power system as part of a cross-sectoral, integrated energy transition.

**The overall objective is system control that is also manageable and reliable in future, despite increasing complexity.**

## Balancing power

Because of the falling operating times at conventional power stations, in future the demand for balancing power will increasingly need to be met by alternative providers such as electricity storage systems, renewable energy facilities and flexible power loads. In order to be better integrated into the balancing energy market, weather-dependent providers, such as wind and photovoltaic systems, need shorter periods of time between tender and provision so that they can predict the operating reserve potential of the plants more precisely, as well as short product time slices[2], so that they can offer more than just the minimum over the entire time period when input capacity varies. However, when adapting the regulatory frameworks to the balancing energy market, the guiding principle must always be that the balancing energy can be provided securely and reliably.

Since the number of balancing power providers connected to the distribution grid will increase, this might result in interactions between local bottlenecks and grid security measures (e.g. choking of power generating plants because of local overloading) and the recall of balancing power. Avoiding this might make additional co-ordination between transmission grid, distribution grid and plant operators necessary.

**The objective is to provide balancing power at any time securely, reliably, efficiently and in sufficient quantity.**

## Instantaneous reserve

At the moment, rapid frequency fluctuations are being cushioned by the inertia of rotating masses of machine assemblies (turbine generator systems), which is an inherent property of the electricity system. This happens at the moment the frequency changes, in other words before balancing can take place via operating reserve, and is therefore essential for the stability of the electric power system. Turbine generator systems are found in all conventional power generating plants, including hydroelectric power stations and pumped-storage plants. The centrifugal masses of the large power station machine assemblies are used to input or output deficient or surplus energy in a matter of milliseconds, thereby maintaining the power balance until the operating reserve is deployed. In this way, the inertia of the rotating masses prevents rapid changes of frequency.

Owing to market conditions, however, in future the running times of conventional power stations will be reduced. This means that future renewable energy facilities must be able to meet the demand for instantaneous reserve. Besides this, studies show that significant stability problems can already occur today in the event of a system split[3], because it is not possible to guarantee sufficient inertia for system stability in every grid region at all times.[VI]

**The objective in this case is to keep sufficient instantaneous reserve available at all times, so as to be able to guarantee system stability in normal operation and also in the event of a wide-ranging system split.**

## Reactive power

Electricity grids are basically configured in such a way that reactive power is available to maintain the prescribed voltage ranges. As a whole, the demand for reactive power in the grids is increasing. The reasons for this are to be found in the lengthening transport paths that result from the decoupling of power generation and consumption centres, the local voltage increases that result from connecting several decentralised power generating plants in the distribution grid, and in the increasing proportion of cabling in the distribution grid.

The increasing demand for reactive power can be met through the grid operators' operating resources, but also by decentralised power generation plants. In addition to this, the reduction in conventional power stations' operating times also leads to a reduced supply of reactive power from these facilities, for which alternative providers must compensate.

The challenge this presents is to develop control concepts that permit the coordinated use of reactive power potential from a multitude of provision options, and if necessary to make the potential from subordinate grid levels available to superordinate grid levels by adjusting specific values at the transfer points between them.[4] Additionally, the provision of reactive power entails costs for all stakeholders (grid and plant operators), which can therefore impact on the cost-effectiveness of facilities. The challenge in this case is to solve the question of how reactive power can be configured so as to be macroeconomically optimised and economically affordable for all stakeholders.

**The objective is to efficiently maintain voltage ranges and the reactive power balance at all voltage levels.**

## Short-circuit current contribution

A sufficient supply of short-circuit current contribution needs to be available to ensure that short-circuit events are safely registered by the corresponding protective devices, to guarantee the transient (i.e. temporary) stability of electrical assemblies, and to restrict the voltage drop to an area as small as possible if a failure occurs. However, the short circuit power must not be unacceptably high, as otherwise operating resources could be damaged in the event of a malfunction, and power switches may not be able to disconnect securely. As a result of the energy transition, future facilities will increasingly be feeding into the grid via frequency converters. However, because of their magnetic flow, during short-circuit events synchronous generators deliver an increased short-circuit current, which triggers a shutdown by the protective devices.

In the case of a facility which feeds the grid via a frequency converter, the increased short-circuit current does not arise, since the frequency converter inputs the prescribed power at all times. In the distribution grid, therefore, it is necessary to adapt the protection concepts to these new demands. The digital protective technology available for this purpose is highly advanced, and can be used flexibly. Radically new protective principles for high and ultra-high voltage are in the development phase (e.g. travelling wave analysis) or are being researched.

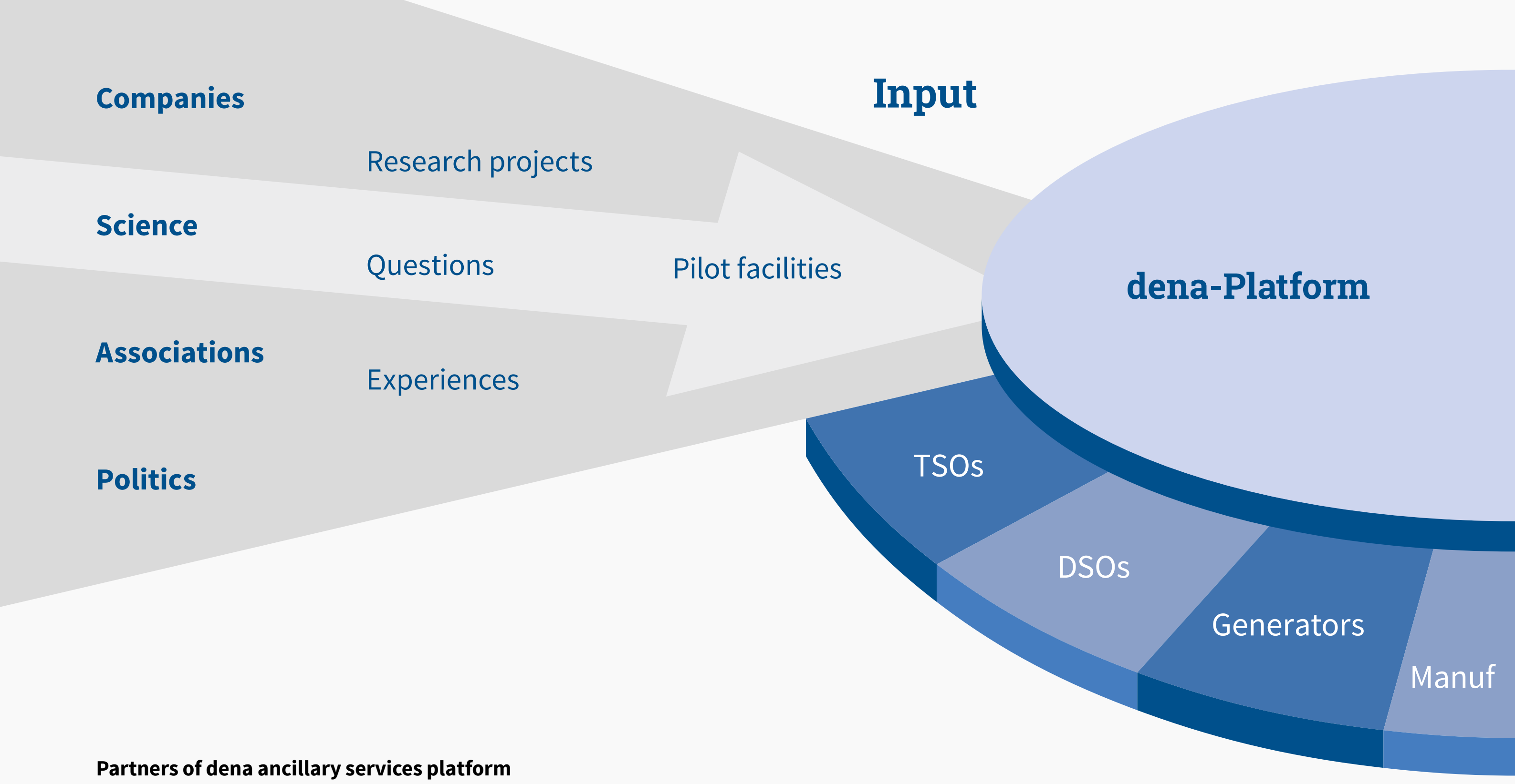
**The objective is being able to securely identify and rectify malfunctions in every grid situation in the future as well.**

## System restoration

According to current regulations, in the event of a complete or widespread power failure in the European integrated grid, system restoration is implemented on the basis of a central concept. This involves starting up small- to medium-sized (50–150 MW) gas turbines and hydroelectric power stations in the transmission grid that are capable of black start, each of which forms an individual microgrid at the start of the grid restoration process. In the subsequent course of the system restoration, large power stations (> 500 MW) are additionally connected. These are not capable of black start, but are started up via smaller power stations that have this capacity. Simultaneously with the connection of additional power generation capacity, loads are added. On the basis of this, the microgrids that were created in the course of restoration are successively synchronised and connected.

In many distribution grids up to the low voltage level, not just consumers but also producers are already connected today. For example, a house can function as a producer and a consumer. Therefore, in order to know the extent to which electricity consumption or generation must be supplemented during grid restoration before connecting additional grid areas, the weather situation and other forecasts relevant to generation must be incorporated in the system restoration concept. In addition to this, to achieve a controlled grid restoration, the communications technology option of intentionally choking the electricity generation from decentralised generation systems is required, in order to avoid load changes that are difficult to predict before or after reconnecting grid lines.

**The objective is to further develop the centralised system restoration concept, so that when additional grid areas are connected, changing load flows caused by the input of decentralised energy units can be taken into account.**




**Partners of dena ancillary services platform**

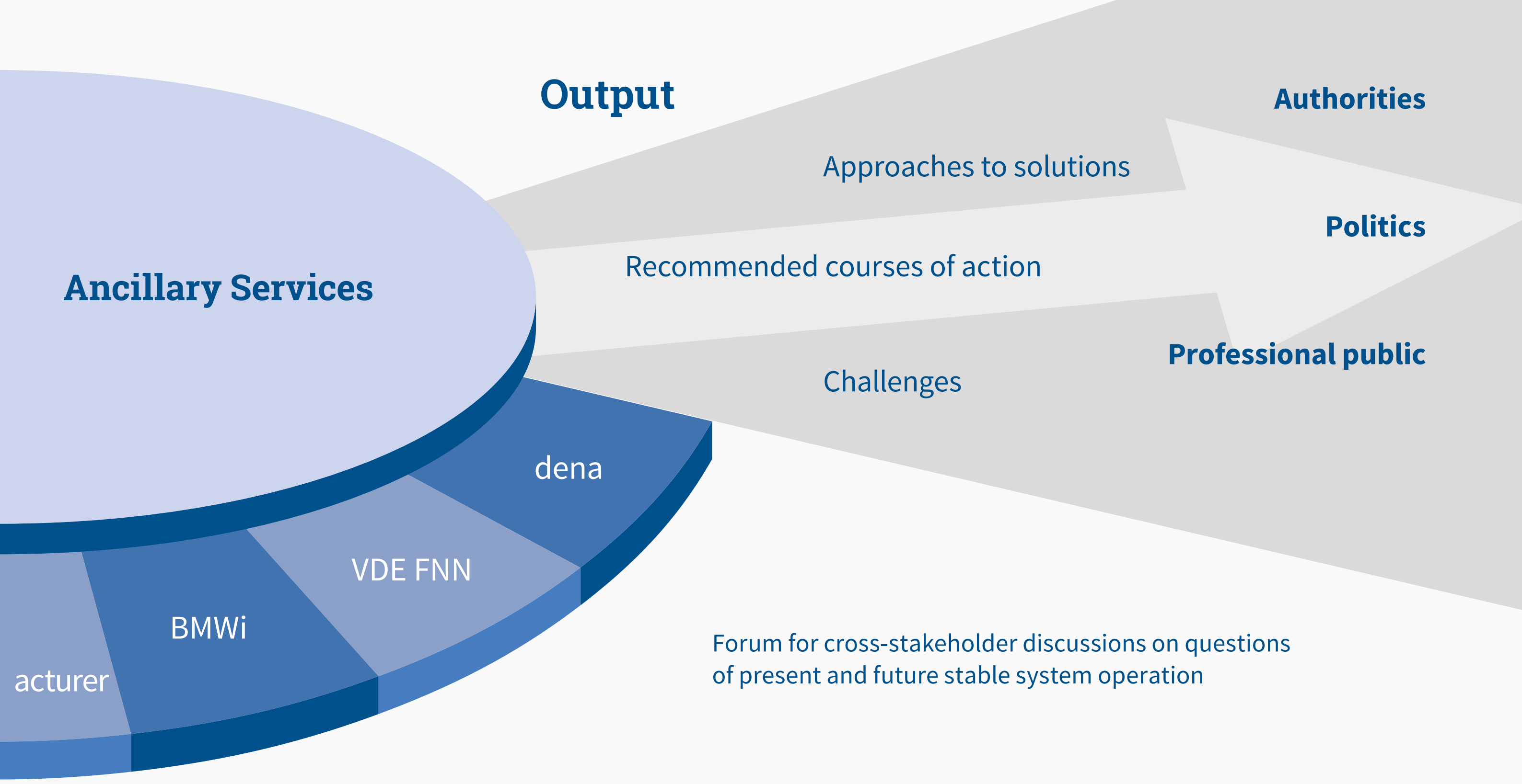
# Objectives of the dena ancillary services platform

The ‘Ancillary Services’ Innovation Report is informed by the expertise of the cross-sectoral dena ancillary services platform, in which market players, associations and the Federal Ministry for Economic Affairs and Energy are represented. dena has set up the Platform with the aim of actively influencing the way in which ancillary services develop up to 2030 and pressing ahead with the ancillary services roadmap, to which the present Innovation Report makes reference.[II] The tasks of the platform include:

- continuously recording and evaluating ongoing activities in the field of ancillary services,
- pooling key projects and institutions in this field,
- developing process standards for the coordination of transmission grid, distribution grid and plant operators, and
- consolidating and communicating results and recommendations for action to politicians and experts.

The dena ancillary services platform brings together key players in the sector and sets processes of discussion and change in motion. As part of this, it identifies relevant areas of activity and contributes to a reassessment of processes and risks – for example, with the ‘Instantaneous Reserve 2030’ report initiated by the Platform.[VI] Moreover, it also sheds light on economic questions related to the provision of ancillary services and quantifies them, for example through the Platform activities ‘Economically affordable provision of reactive power: a stakeholder process’[IV] and ‘Report on the development of a procedure for the quantitative assessment of different options for the provision of reactive power’.[X]

Its multi-stakeholder approach makes the Platform a solution-oriented sectoral forum for an efficient exchange of ideas between different market perspectives. This is important, because ancillary services not only possess fundamental importance for the areas of responsibility of regulated grid operators, but also for market players such as producers, suppliers or consumers, and only in this way can sustainable solutions for the energy system of the future be developed.




# Achievements of the dena ancillary services platform

## 1 Promoting political/ regulatory decision-making

Including:

- Recommended courses of action for balancing power are implemented
- Contribution of alternative providers for ancillary services is recognised in discussion paper 'Electricity 2030' of the Federal Ministry for Economic Affairs and Energy (BMWi)

## 2 Initiating research and pilot projects

Including:

- Piloting the reactive power management investigated in the dena study 'SDL 2030'
- On the basis of the findings of the report on instantaneous reserve, the research project 'Grid regulation 2.0' was initiated and applied for

## 3 Recommending courses of action in key topic areas

Including:

- Identifying problems and developing approaches to solutions for the TSO/DSO interface
- Defining stakeholder positions and design options for economically affordable provision of reactive power

# Practical examples

**Examples of best practice for innovative applications of ancillary services:**


'Green Access' research project


Reactive power management


Balancing power from wind turbines


Decentralised energy supply

Battery bulk storage systems for ancillary services

## Best-practice projects

# ‘Green Access’ research project

The energy transition – including the integration of decentralised power generating plants into the grid, the opportunities of electromobility and many current developments based on intelligent grids – presents the energy supply system with new challenges in the areas of expansion of the power grid and secure, reliable distribution grid operation.

The aim of the ‘Green Access’ project is to show how intelligent automation of the distribution grid can best exploit existing grid capacities and prevent restrictive congestion.

In this it builds on existing technologies of modern grid control but, at the same time, also considers the medium and low voltage grid in combination.

We are excited about the interaction between the different control systems and components. I find it particularly exciting that, in addition, we are developing an adaptive, self-learning system that adjusts itself autonomously to changes in the grid structure.

We are working together in an overarching consortium of new partners in order to bring on board a wide range of expertise and develop efficient, sustainable operational control concepts for modern distribution grids.

**Dr.-Ing. Thomas Kumm**
Grid management Electricity and telecommunications Strategic grid development EWE NETZ GmbH

**Contact:**
EWE NETZ GmbH
Cloppenburger Str. 302
26133 Oldenburg, Germany
Tel.: +49 (0)441 4808-0
Email: info@ewe-netz.de

**www.ewenetz.de**

## Best-practice projects

# Balancing power from ENERCON wind turbines

Handing over responsibility for the system, in the form of balancing power, to onshore wind energy forms one of the key building blocks of the energy transition. As a system-relevant power station, wind energy can help guarantee a stable grid and reduce conventional minimum generation – as long as the necessary framework conditions are created.

It has already been possible to demonstrate the technical suitability of wind energy for providing operating reserve and the macroeconomic benefits of this procedure in the pilot projects.

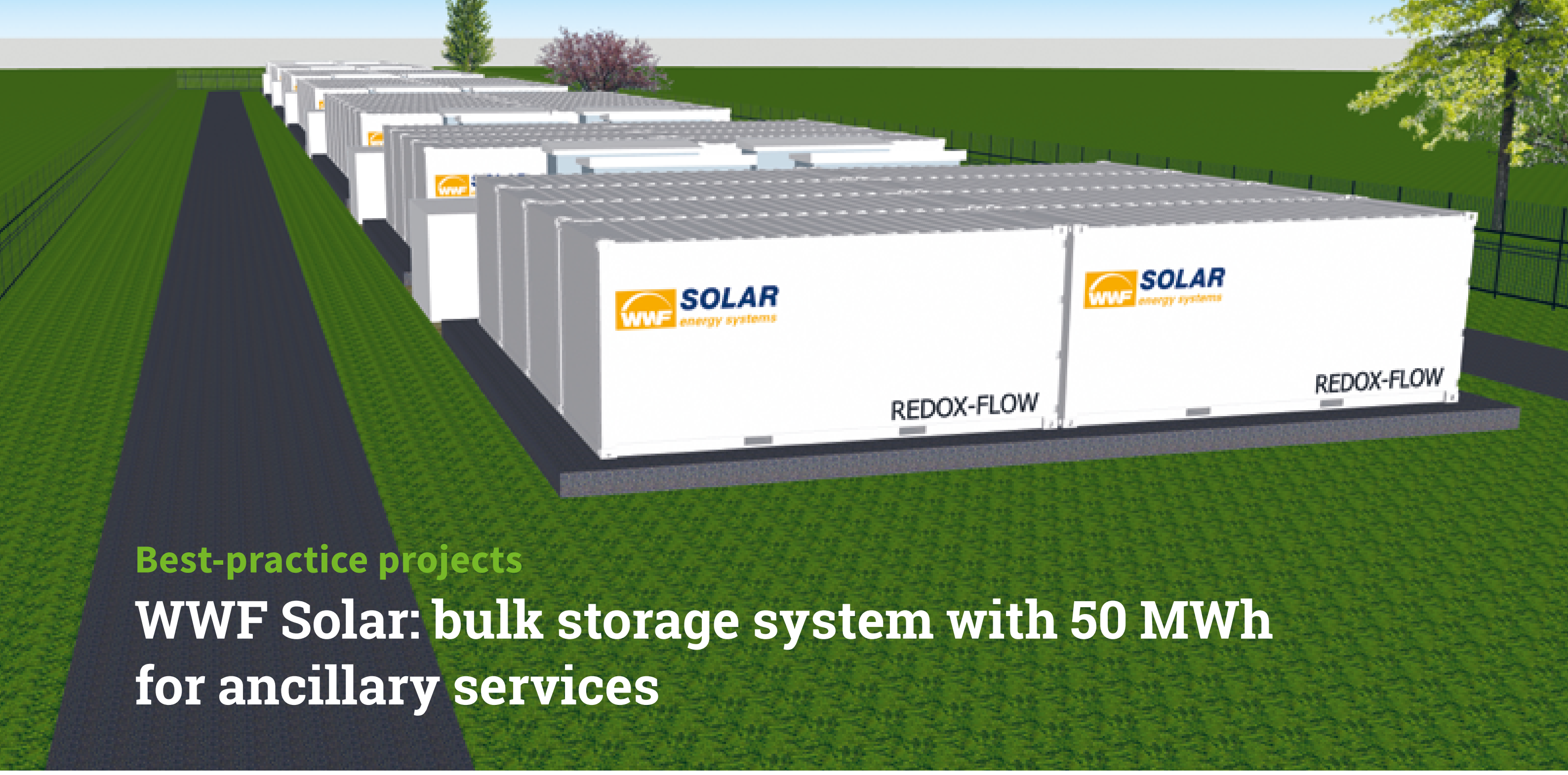
It is now the task of legislators and the transmission system operators to make complete integration into the operating reserve market possible, and to support the system change on the basis that providing operating reserve from the distribution grid is also possible, and that renewable energy sources und onshore wind power plants can enjoy access to the operating reserve market without discrimination.

Moreover the integration should not just be limited to minute reserve, but include all types of operating reserve and other ancillary services.

**Contact:**
ENERCON Limited Liability Company
Dreekamp 5
26605 Aurich,Germany
Tel.: +49 (0)49 41 927-0
Email: info@enercon.de

**www.enercon.de**

**Andreas Linder**
Sales – Grid Integration
Enercon GmbH




## Best-practice projects

# WWF Solar: bulk storage system with 50 MWh for ancillary services

Located in Eberswalde, Germany, and specialising in integrating renewable energy sources into the grid, WWF Solar GmbH and its American partner UniEnergy Technologies – the manufacturer of Vanadium Redox Flow storage systems – have begun building a bulk storage system for providing secondary balancing capacity.

Near AK Berlin Berlin-Schönefeld, Königs Wusterhausen OT Niederlehme, a multi-purpose power station is being constructed to provide ancillary services for the transmission system operators of the German control area in the high voltage grid. For this purpose, 25 Vanadium Redox Flow Storage Systems with a power of 12,500 kW and a capacity of 50,000 kWh are being used. An additional component of the project is a photovoltaic system of around 3,800 kWp, which is being built on an area of around 8 ha, disjunctively to the storage system.

The connection to the grid will be effected via the power station's own transformer station (20kV/110kV, 50kVA) to the 110-kV lines of the distribution system operator E.DIS AG, about 1 km away, and thereby to their four clients, the transmission system operators (TSOs) 50Hertz, Amprion, TenneT and Transnet BW.

The purpose of the plant is to supply the TSOs in the German control area with ancillary services in the form of positive and negative operating reserve in the event of imbalances in the transmission grid caused by unforeseen incidents in electricity generation (power station failure, meteorological events, general planning uncertainty), as well as in electricity demand (important television programmes, meteorological events).

Within the synchronous integrated electricity grid in Europe (ENTSO-E), power fluctuations are equalised in a three-stage control procedure, involving primary balancing capacity, secondary balancing capacity and minute operating reserve.

By using the Vanadium Redox Flow technology, the storage system is able to cover all three areas of control. However, it is mainly suited for the secondary balancing capacity field, and therefore will be the first storage system in the secondary balancing capacity.

The Vanadium Redox Flow storage system will go into service in the first quarter of 2018. This will initiate the next step in storage systems of this size. Up to now, battery storage systems have only been found in primary balancing capacity.

If the switch to renewable energy sources is to be successful, we must be in a position to disconnect conventional power stations entirely when sufficient renewable energy is input,' says Patrick von Hertzberg, Founder and CEO of WWF Solar. The Eberswalde-based company has undertaken the development of the battery storage in partnership with the manufacturers of the storage system, and now delivers the plants ready for use.

The supplier, UniEnergy Technologies from Seattle, guarantees the performance of the Vanadium Redox Flow storage systems employed for the next 20 years.

**Dr. rer. nat. Frank Wiegandt**
CTO, WWF Solar GmbH

**Contact:**
WWF SOLAR GmbH
Mühlenstrasse
16227 Eberswalde, Germany
Tel.: +49 (0)3334 55 29 00
Email: info@wwfsolar.de

**www.wwfsolar.de**

## Best-practice projects

# Mitnetz: Reactive power management – a key component of ancillary services

Ancillary services are essential requirements for secure and reliable grid operation. In the past, they were to a large extent derived from conventional power stations. For example, these power stations contributed to the voltage control of the grid by means of variable reactive power generation or reactive power voltage regulation.

The transition to renewable energy sources is leading to a change of granularity, to a marked inhomogeneity of power generation in terms of space and time, and therefore is having radical effects on the provision of ancillary services.

This challenge can be met by means of a reactive power management system. The opportunity exists to provide the reactive power generation needed for voltage control largely from decentralised sources. The key requirement is that the range of controllable reactive power sources on offer should be as wide as possible. With the growth of decentralised power generating plants, but also with the constant development of decentralised storage technologies and new technologies on the consumer side, the potential for reactive power is constantly expanding.

MITNETZ STROM has already integrated an actively controllable reactive power potential of -280 MVAR (cap) to 230 MVAR (ind.) into the active reactive power management system. The reactive power generation of plants is varied from the central grid control centre according to the current load situation.

In this way, not only is compliance with operational limits coordinated between the voltage levels of the distribution grid, but also measures for static voltage control at the points of connection with the ultra-high voltage grid are organised on a superregional basis. This procedure can also be carried out analogously for subordinate grid levels, e.g. by aggregating available potential from the medium voltage grid at the point of connection with the high voltage grid.

In the ARGE programme of the Local Grid Operators East, all distribution system operators have united under one control zone and adopted a common solution for these problems. Processes for active reactive power management have already been agreed in partnership with the transmission system operator 50Hertz Transmission, thereby guaranteeing a unified and collectively coordinated procedure. In this way, it was possible to realise an important precondition for effective use of the ancillary service potential available from decentralised sources.

**Contact:**
Mitteldeutsche Netzgesellschaft mbH
Industriestrasse 10
06184 Kabelsketal, Germany
Tel.: +49 (0)345 216-0
Email: info@mitnetz-strom.de

**www.mitnetz-strom.de**

## Best-practice projects

# Siemens: Wildpoldsried – how decentralised energy supply works

### Microgrid with added value

Around the world, the proportion of renewable sources in the energy supply is increasing. Expanding their use further depends not just on economic and political factors, but on technological ones as well. In the long term, the proportion of fossil fuels – mostly centralised – will have to fall. Demand will be met more and more by renewable facilities – mostly decentralised. At the same time, the high levels of security and cost-efficiency of supply will have to remain constant.


**Contact:**
Dr Michael Metzger
Siemens AG CT REE ENS
80200 Munich, Germany


This is why, in Wildpoldsried in the Allgäu region, the IREN2 research project is investigating innovative grid structures that are dominated by distributed power generation, and the economic and technical aspects of controlling these systems.

**The key objectives of the project are:**

- Operating a microgrid as an autarchic standalone network – disconnected from the superordinate distribution grid
- Using a microgrid as a topological power station to provide ancillary services
- Stabilised, economically optimised grid operation

Besides Siemens, Allgäuer Überlandwerk GmbH/Allgäu-Netz GmbH & Co. KG, RWTH Aachen University, Kempten University and ID.KOM Networks GmbH are all involved in the project. It is being funded by the Federal Ministry for Economic Affairs and Energy.

The local community of Wildpoldsried in Allgäu generates five times as much energy from renewable sources as it consumes itself – from biogas, solar power and wind power. The local grid, therefore, must cope with bidirectional energy flows and major fluctuations.

However, thanks to intelligent grid planning, implementation of measurement technology at critical points and controllable grid components such as local network stations, it was possible to avoid high investments in expansion of the power grid and comprehensive measurement technology.

The available structures form an ideal basis for further research. In collaboration with its consortium partners, Siemens plans to show that a grid of this type, incorporating a high proportion of renewable generating sources, can also run autarchicly. And, moreover, to demonstrate how it can even replace large-scale power plants for periods, by delivering ancillary services to the superordinate main grid.

## The solution

In Wildpoldsried, renewable and conventional generating sources form a hybrid structure. In the test area, photovoltaic roof installations and a biogas combined heat and power plant were supplemented by two diesel aggregates and a lithium ion storage system. The grid is equipped with a measurement and control infrastructure and controllable transformers. Siemens control technologies – Microgrid Manager and Hybrid Power Plant Control – are responsible for the central control and regulation of all units. Their main task is to keep the grid stable in real-time operation.

This includes voltage and frequency control, and providing short circuit power within the microgrid.

A particular challenge is stabilising the grid during black start, in other words grid restoration 'from below', and during resynchronisation with the main grid when the microgrid is reconnected after standalone operation. In addition to delivering internal stability, the Wildpoldsried microgrid is designed to function as a topological power plant, supplying services to secure system stability in the superordinate grid. By means of these ancillary services, for certain periods it can completely replace conventional power stations. For this purpose, the control technology enables the output of renewable generating sources to be authoritatively predicted and intelligently planned and controlled.

**What the microgrid carries out as a topological power plant:**

- It predicts the potential for ancillary services.
- If ancillary services are agreed upon, the microgrid must be able to deliver them at any time.
- A control system ensures that the divided facilities supply ancillary services in additional to normal operation.

## The benefits for Wildpoldsried and microgrids worldwide

The IREN2 research project in Wildpoldsried shows that supply grids incorporating a high proportion of renewable generating sources can be operated stably and cost-effectively.

# Environmental analysis

## Studies/research projects related to the topic of ancillary services

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| | SysDL 2.0 – ancillary services from local distribution grids | DREWAG NETZ GmbH (DREWAG. project management), TU Dresden – Chair for Energy Industry (EE2), TU Dresden – Institute for Electrical Energy Supply and High Voltage Technology (IEEH), ENSO NETZ GmbH, Siemens AG – Corporate Technology, Fraunhofer Institute for Wind Energy and Energy Systems Technology (Fraunhofer IWES), Mitteldeutsche Netzgesellschaft Strom mbH (MITNETZ), University of Kassel, Faculty of Electrical Engineering and Computer Science, 50Hertz Transmission GmbH (50Hertz), F&S Prozessautomatisation GmbH, Thüringer Energienetze GmbH (TEN, associated), DNV GL (associated) | Oct 2014 – Mar 2018 | goo.gl/gQ6vGc |
| | dena Study 'Ancillary Services 2030': security and reliability of a power supply with a high percentage of renewable energy.<br><br>Roadmap, dena Study 'Ancillary Services 2030' | dena (product management), TU Dortmund University, 50Hertz, ABB AG, Amprion GmbH (Amprion), BELECTRIC Solar Power Plants GmbH (BELECTRIC), E.DIS AG, ENERCON GmbH (ENERCON), EWE NETZ GmbH (EWE NETZ), MITNETZ, N-ERGIE Netz GmbH (N-ERGIE), Netze BW GmbH, SMA Solar Technology AG (SMA), TenneT TSO GmbH (TenneT), TransnetBW GmbH (TransnetBW), Westnetz GmbH (Westnetz), Younicos AG | Feb 2014 | bit.ly/2SQFJgn |

| | | | | |
|---|---|---|---|---|
| | | | ✓ completed | ongoing |
| ✓ | Conventional minimum generation – classification, current status and prospective treatment | Consentec, on behalf of the German TOS | Jan 2016 | goo.gl/HfE7rg |
| ✓ | REserviceS: Economic grid support from variable renewables | EWEA (Projektleitung), EPIA, 3E N.V., VIT, Fraunhofer IWES, acciona, UCD, DTU, EDSO, Mainstream, SMA, GE | April 2012 – Sep 2014 | goo.gl/rSvbZh |

# Pilot facilities and demonstration projects for alternative provision of ancillary services

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| | 'Intelligent Energy Showcase' funding programme – digital agenda for the energy transition (SINTEG) | Federal Ministry for Economic Affairs and Energy (BMWi) | since Feb 2015 | goo.gl/KaZN7r |
| | Smart Country – intelligent grid concepts for rural areas | RWE Deutschland AG (RWE, project management), ABB AG, TU Dortmund University, Consentec | since July 2009 | goo.gl/m55wN5 |
| | SWARM – Storage With Amply Redundant Megawatt | N-ERGIE, Caterva | April 2015 – Dec 2017 | goo.gl/5LUXut |
| | Smart Operator – local, intelligent grid control | RWE (project management), Hoppecke, Horle Mann, University of Twente, RWTH Aachen University, Stiebel Eltron, PSI AG | 2012 – 2015 | goo.gl/AU3f1v |
| | Smart Area Aachen – innovative solutions and operating resources for the distribution grid of the future | Stawag (project management), RWTH Aachen University, ABB AG, Research Community for Electrical Installations and Electrical Industry (FGH), SPIE SAG GmbH (SAG), TU Dortmund University, MR, Kisters, Nexans Power Accessories Germany GmbH (Nexans), BET, PSI AG, DKE in VDE, ptj | 2012 – July 2016 | goo.gl/UoTcrT |
| | FLOW-R – flexible local grid voltage and active power controller | Pfalzwerke Netz AG (project management), TU Kaiserslautern, Power Plus Communications AG (Power Plus), Pfalzwerke AG, Walcher GmbH & Co. KG | Oct 2014 – Sep 2017 | goo.gl/MYHHfU |
| | Battery storage systems for stabilising the electricity grid/Statkraft | Statkraft | Feb 2016 | goo.gl/PFGKus |
| | Dresden Battery Park | Younicos AG, DREWAG, LG Chem und Nidec | June 2014 – March 2015 | goo.gl/5RmMTF |

✓ completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| ✓ | Provision of operating reserve from battery | Younicos AG, WEMAG Netz GmbH (WEMAG) | Sep 2013 – Sep 2014 (Expanded mid-2017) | goo.gl/rJDcNJ |
| ✓ | INEES – Intelligent grid connection of electric vehicles to provide ancillary services | Volkswagen AG (project management) Fraunhofer IWES, LichtBlick SE, SMA | June 2012 – May 2015 | goo.gl/g8EpcE |
| ✓ | iNES – Intelligent distribution grid management system | SAG (project management), University of Wuppertal (BUW), Mainova AG, Bilfinger Mauell GmbH (Bilfinger) | 2011 – 2013 | goo.gl/mNhriS |
| ✓ | IRENE: 'Integrating Regenerative Energy sources and Electromobility' | Allgäuer Überlandwerke GmbH (AÜW, project management), Siemens AG, Kempten University, RWTH Aachen University | 2011 – 2013 | goo.gl/GR5aj5 |
| ✓ | Combined power plant 2 – secure electricity supply from 100% renewable energy sources | Fraunhofer IWES (project management), Cube Engineering, DWD, ENERCON, Ökobit GmbH, Leibniz University Hannover, Siemens AG, SMA, Solarworld Agency for Renewable Energy Sources (Solarworld) | Sep 2011 – Aug 2014 | goo.gl/BVy1QL |
| ✓ | PV-integrated – Integrating large percentage of photovoltaics into electrical energy supply: new procedure for planning and operating distribution grids | Fraunhofer IWES (project management), SMA, Bosch Power Tec GmbH (Bosch), juwi Energieprojekte GmbH, Bayernwerk AG | Oct 2010 – Dec 2014 | goo.gl/swu1Ac |
| ✓ | SDL-Batt: Stabilising the grid by means of battery power stations | Brandenburg University of Technology Cottbus-Senftenberg (BTU Cottbus, project management), Energiequelle GmbH, 50Hertz | March 2013 – Feb 2016 | goo.gl/NU1Y1m |

# Studies/research projects focused on frequency control

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focused on balancing power** | | | | |
| | PV regulation – developing concepts and solutions for providing operating reserve from photovoltaic plants | SMA, TU Braunschweig (Elenia), Gewil AG, associated partners: Amprion, TenneT, TransnetBW, 50Hertz | Aug 2014 – July 2018 | goo.gl/yfFkcv |
| | ReWP – operating reserve from wind and photovoltaic parks | Fraunhofer IWES, ENERPARC AG | Aug 2014 – Dec 2016 | goo.gl/vMeoKb |
| | Reserve markets in transition – new concepts for greater supply security (ReWal) | IAEW/RWTH Aachen University, ZEW | Sep 2013 – Dec 2016 | goo.gl/RozgWu |
| | arrivee – wastewater purification plants as control units in intelligent distribution grids with renewable energy production | TU Kaiserslautern (project management), Wupperverbandsgesellschaft für integrale Wasserwirtschaft (WiW) mbh [Wupper association for integral water industry], Radevormwald Utilities Services GmbH, iGas GmbH, ITB gGmbH, Leibniz Institute for Regional Development and Structural Planning, University of Wuppertal | April 2014 – March 2017 | goo.gl/f2g4Yg |
| | Description of operating reserve concepts and operating reserve market | Consentec, on behalf of German TSOs | Feb 2014 | goo.gl/HfE7rg |
| | Dynamic provision of operating reserve requirements | Fraunhofer IWES (project management), TenneT | March 2013 – Feb 2015 | goo.gl/qdiwyJ |
| | Survey on Ancillary Services Procurement and Electricity Balancing Market Design, 2016 | ENTSO-E | May 2016 | goo.gl/9XeZHA |

✓ completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focused on balancing power** | | | | |
| ✓ | Optimising the market conditions for operating reserve provision by means of renewable energy sources – a brief study | Fraunhofer IWES on behalf of BEE | April 2014 | goo.gl/pgBy7V |
| ✓ | Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity transmission system operators | E-Bridge, IAEW/RWTH Aachen University, 50Hertz, Amprion, Elia Group, TenneT | Oct 2014 | goo.gl/bc1fx9 |
| ✓ | Providing operating reserve from decentralised energy plants – an analysis of needs for further action by the dena ancillary services platform | dena ancillary services platform: dena, 50Hertz, Amprion, Bayernwerk AG, BMWi,E.DIS AG, E.ON AG, ENERCON, Energiequelle GmbH, EWE NETZ, Main-Donau Netzgesellschaft mbH (MDN), MITNETZ, RWE, Siemens AG, SMA, TenneT, TEN, TransnetBW, VDMA Professional Association of Power Systems (VDMA), VGB Power Tech e. V. (VGB), Westnetz, Younicos AG. | Nov 2015 | bit.ly/2Qvkrbh |
| ✓ | Balancing energy from wind power installations | Fraunhofer IWES (project management); ENERCON, Energiequelle GmbH, TenneT, Amprion | May 2012 – April 2014 | goo.gl/7dhmzH |

# Studies/research projects focused on frequency control

completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on instantaneous reserve** | | | | |
| ongoing | Grid regulation 2.0 | Fraunhofer IEE | from Feb 2018 | goo.gl/rooH3J |
| ongoing | MIGRATE – Massive InteGRATion of power Electronic devices | TenneT | Jan 2016 – Dec 2019 | goo.gl/8qtK3y |
| ongoing | Amses – aggregated models for simulating dynamic processes in electromechanical energy systems | Leibniz University Hannover (project management), Leibniz Research Centre for Energy 2050 (LiFE 2050) | Jan 2015 – March 2018 | goo.gl/9vcch1 |
| completed | Impact of reduced rotating centrifugal masses on grid operation | University of Stuttgart | Jan 2015 – Dec 2017 | goo.gl/LhFsMv |
| completed | Effects of reduced centrifugal masses on stable grid operation | 50Hertz, Amprion, TenneT, TransnetBW | April 2014 | goo.gl/kCuygd |
| completed | Demand for and provision of instantaneous reserve in 2030 | dena ancillary services platform: dena, 50Hertz, Amprion, Bayernwerk AG, BMWi, E.DIS AG, E.ON AG, ENERCON, Energiequelle GmbH, EWE NETZ, MDN, MITNETZ, RWE, Siemens AG, SMA, TenneT, TEN, TransnetBW, VDMA, VGB, Westnetz, Younicos AG. Specialist partners: WEMAG, STORNETIC | Feb 2016 | bit.ly/2RW8Cri |
| completed | Contribution of centralised and decentralised combined heat and power generation plants for grid support | bofest consult GmbH on behalf of Federal Association of Combined Heat and Power Generation e. V. | May 2014 | goo.gl/4Xw9Xs |
| completed | VISMA – virtual synchronous machine | TU Clausthal, EFZN | 2006 – 2011 | goo.gl/pLZwut |

# Studies/research projects focused on voltage control

✓ completed  ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| ongoing | IMOWEN: Integrating large quantities of wind energy from in- and offshore production into the electricity grid by means of intelligent grid analysis and cluster operational management | Fraunhofer IWES (project management), Avacon AG, Senvion | Aug 2014 – April 2018 | goo.gl/nvJsvP |
| ✓ | NEMAR – grid management as new market role | Fraunhofer Institute for Solar Energy Systems (Fraunhofer ISE), Fichtner IT Consulting, seven2one, University of Stuttgart | Nov 2014 – Oct 2017 | goo.gl/Ww3eQw |
| ongoing | SyNErgie – system-optimised grid and energy management for the distribution grids of the future | OTH Regensburg (project management), MDN, MFN Mainfranken Netze GmbH, FRAKO Capacitors and Plant Construction GmbH, KBR GmbH | March 2015 – Feb 2018 | goo.gl/N2cyzb |
| ongoing | U-control – technical and economic comparison between procedures for static voltage control | TU Braunschweig (project management), FGH, Technical University of Munich, RWTH Aachen University | Nov 2014 – Feb 2018 | goo.gl/J75YM8 |
| ongoing | Distribution grid 2020 – improving the carrying capacity and ensuring the grid quality of distribution grids | Technical University of Munich (project management), Grass Power Electronics GmbH, EMPURON AG, infra fürth gmbh, Power Plus, KACO new energy GmbH, Georg Simon Ohm Technical University of Nuremberg, A. Eberle GmbH & Co. KG, BMZ battery assembly centre GmbH | Aug 2014 – Jan 2018 | goo.gl/NCECCK |
| ✓ | Multi-PV-LVRT – verifying dynamic grid support by PV installations in the event of malfunctions in the medium voltage grid | Fraunhofer ISE, AEG Power Solutions GmbH, KACO New Energy GmbH, Kostal Industrie Elektrik GmbH, Bonfiglioli-Vectron GmbH, bes new energy GmbH, Lti REEnergy GmbH | May 2012 – Dec 2015 | goo.gl/uxmDWG |
| ✓ | LISA – guidelines on the integration of voltage-stabilising applications | Pfalzwerke AG (project management), Pfalzwerke Netz AG, IDS GmbH, FGH, Power Plus, A. Eberle GmbH & Co. KG, TU Kaiserslautern – Faculty of Energy Systems and Energy Management | Sep 2014 – June 2017 | goo.gl/Mgi3ii |

# Studies/research projects focused on voltage control

✓ completed   ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| ✓ | Future provision of reactive power and other measures for ensuring grid security | OTH Regensburg on behalf of the BMWi | Nov 2013 – Sep 2016 | goo.gl/7ccDxv |
| ✓ | The contribution of industrial reactive power compensators and consumers to an innovative reactive power management system in German power supply | OTH Regensburg – Institute for Grid and Applications Technology (INA), on behalf of ZVEI | Sep 2013 | goo.gl/TbavAA |
| ✓ | Behaviour of power generating plants during malfunctions | TU Delft, on behalf of the Network Technology/ Network Operation Forum (FNN) at VDE | Aug 2014 | goo.gl/GUez5j |
| ✓ | FNN study: Static voltage control | Network Technology/Network Operation Forum (FNN) at VDE | Dec 2014 | goo.gl/Vu7EE2 |

# Studies/research projects focused on operational management

completed · ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on grid operation** | | | | |
| completed | FNN connection rules: technical rules for grid operators' operation and planning – Part 1: Interface between transmission grid and distribution system operators | Network Technology/Network Operation Forum (FNN) at VDE | Oct 2017 | goo.gl/Em61z2 |
| ongoing | ENSURE – New energy grid structures for the energy transition | Karlsruhe Institute of Technology (KIT), RWTH Aachen University, Schleswig-Holstein Netz AG, TenneT, Siemens AG, ABB AG | Sep 2016 – Aug 2019 | goo.gl/eTQd7O |
| ongoing | Green Access – intelligent distribution grid automation to increase access for renewable energy sources | EWE NETZ GmbH (project management), University of Wuppertal (BUW), BTC Business Technology Consulting AG (BTC), DLR – Institute for networked energy systems e. V., Fraunhofer ISE, OFFIS e. V. Institute for Information Technology (OFFIS), PHOENIX CONTACT Energy Automation GmbH, SMA, SAG | Jan 2015 – Dec 2018 | goo.gl/rdnqSX |
| ongoing | Advanced decentralised grid control | EnBW AG, Information Technology Research Centre (FZI), Landis+Gyr, Fichtner IT Consulting, seven2one, ads-tec, University of Stuttgart, PREdistribuce | July 2015 – June 2018 | goo.gl/5u9QvE |
| ongoing | High penetration of PV-systems in electricity grids (second work period) | Fraunhofer IWES (Institute of Wind Energy and Energy Systems Technology) | Jan 2015 – Dec 2018 | goo.gl/jsrdV9 |
| ongoing | IREN2 – Sustainable grids for the integration of renewable energy systems | Siemens AG (project management), AÜW, Kempten University, RWTH Aachen University, IDKOM Networks GmbH | July 2014 – May 2018 | goo.gl/TYKvaK |
| completed | The proactive distribution grid – resource-efficient, optimised platform for RES integration and smart market tasks using condition-based load production and information management | RWE (project management), TU Dortmund University, RWTH Aachen University, OFFIS, BTC, Venios | Dec 2014 – Nov 2017 | goo.gl/AvD6SX |

# Studies/research projects focused on operational management

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on grid operation** | | | | |
| | REStable | Armines, Artelys, ENERCON, Fraunhofer IWES, Hespul, Hydronext, INESC TEC, Maia Eolis, Solarworld | April 2016 – March 2019 | goo.gl/hfKgGb |
| | ROSVS – Robust optimisation of electricity supply systems | ProCom GmbH (project management), RWTH Aachen University | Oct 2014 – Dec 2016 (but still ongoing) | goo.gl/Xd7YJ5 |
| | Transstabil-EE – Controls for large wind and solar farms to maintain transient stability in future integrated grids | Fraunhofer IWES (project management), SMA, University of Rostock, University of Kassel | April 2014 – March 2018 | goo.gl/hHzsff |
| | PolyEnergyNet – resilient polygrids for secure energy supply | Saarlouis Utilities Services GmbH (project management), Technical University of Berlin, German Research Centre for Artificial Intelligence GmbH, B.A.U.M. Consult GmbH, TU Darmstadt, Scheer Management GmbH, Urban Software Institute GmbH & Co. KG, VOLTARIS GmbH, KIT – Steinbuch Centre for Computing (SCC), VSE Distribution Grid GmbH | Sep 2014 – Aug. 2017 | goo.gl/hq9qMS |
| | NiVeAu – Grid intelligence for distribution grid automation | University of Wuppertal (BUW) (project management), SAG, Bilfinger, Mainova AG | 2013 – 2016 | goo.gl/vTpe3w |
| | FNN study: Identification of microgrids in the low voltage supply | Network Technology/Network Operation Forum | Dec 2015 | goo.gl/YuEGZh |
| | Investigation of the need for more extensive system control to maintain system balance | Consentec and Ecofys on behalf of the BMWi | Dec 2013 | goo.gl/ZEvY3c |

✓ completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
| --- | --- | --- | --- | --- |
| **Focus on grid operation** | | | | |
| ✓ | Stable DEA – decentralised power generating units | Fraunhofer IWES (project management), ENERCON, TenneT, DERlab e. V. | April 2013 – March 2016 | goo.gl/J24TWS |
| ✓ | In2VPP – Integrating technologically and economically optimised virtual power stations | Siemens AG (project management), infra fürth gmbh, OFFIS, Technical University of Munich | May 2013 – Aug 2016 | goo.gl/pTDTm7 |
| ✓ | NEmo – Integrating electromobility and renewable energy inputs into the grid with the help of an intelligent local grid station | University of Wuppertal (BUW) (project management), SAG, Bilfinger, WSW Netz GmbH | May 2013 – Dec 2015 | goo.gl/EuBwzQ |
| ✓ | REStabil – Security and stability of operation for energy distribution grids through use of aggregated decentralised grid components | Fraunhofer Institute for Factory Operation and Automation (Fraunhofer IFF, project management), Otto von Guericke University Magdeburg, MITNETZ, GETEC AG, ABO Wind AG, Sachsen-Anhalt Centre for Renewable Energy Sources e. V. | March 2014 – Dec 2014 | goo.gl/BSnAFq |
| ✓ | SECVER – Security and reliability of distribution grids on the path to a future energy supply system | Fraunhofer IFF (project management), Otto von Guericke University Magdeburg, Siemens AG, Harz Renewable Power Stations GmbH & Co. KG, Fraunhofer IWES, Avacon AG | Dec 2013 – May 2016 | goo.gl/2hC15R |
| ✓ | Smart North – intelligent grids in North Germany | University of Oldenburg, OFFIS, Leibniz University Hannover, TU Braunschweig, TU Clausthal, Next Energy, EFZN | March 2012 – Feb 2015 | goo.gl/CZ2gpc |
| ✓ | SPIDERS – Smart Power Infrastructure Demonstration for Energy Reliability and Security | Collaboration of partners in the US, lead by the Department of Defense (DOD) partners include Department of Energy (DOE), Department of Homeland Security (DHS), and individual military services (army, marines, and navy). | 2011 – 2015 | goo.gl/DPkSps |

# Studies/research projects focused on operational management

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on grid operation** | | | | |
| ✓ | Twenties project – final report: Transmission system operation with a large penetration of wind and other renewable electricity sources in electricity networks using innovative tools and integrated energy solutions (TWENTIES) | RED Electrica de Espana (project management), 50Hertz, ABB, Alstom, Elia Group, coreso, DONG energy, DTU Wind Energy, EDF, ENERGINET.DK, EWEA, Fraunhofer IWES, Gamesa, Iberdola, INESC TEC, KU Leuven, RSE, RTE, Siemens AG, SINTEF, TenneT, UCD Dublin, Université de Liège, Comillas, University of Strathclyde Glasgow | June 2013 | goo.gl/8Yi753 |
| ✓ | UMBRELLA – Optimization of Network Operation | TenneT, IAEW/RWTH Aachen University, Amprion, CEPS, Eles, TransnetBW, PSE, Swissgrid, APG, TU Delft, ETH Zurich, University of Duisburg-Essen, FGH | Jan 2012 – Dec 2015 | goo.gl/m6Z32c |
| ✓ | BDEW roadmap Data and market communication 2015 – 2018 | BNetzA, German Association of Energy and Water | Jan 2015 | goo.gl/RJZ4wJ |
| ✓ | Working Group of Local Grid Operators EAST (Arge OST) – ten-point programme for secure electricity supply in Eastern Germany | MITNETZ ELECTRICITY, Avacon AG, E.DIS AG, ENSO NETZ GmbH, HSN Magdeburg GmbH, Magdeburg Utilities Services GmbH, TEN, WEMAG, 50Hertz | Sep 2014 | goo.gl/5Cyuw9 |
| ✓ | Further development of feed-in management for wind-powered installations – an assessment of approaches | Ecofys, on behalf of the Federal Association for Wind Energy (BWE) | July 2015 | goo.gl/auD51H |

completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on measurement technology and communication** | | | | |
| completed | Sensors in the grid – developing new, economical ways to record grid status and detect malfunctions by using broadband power line (BPL) infrastructures as the basis of future grid system control | University of Wuppertal (BUW) (project management), Power Plus, Leverkusen Energy Supply, Nexans | Nov 2014 – Oct 2017 | goo.gl/87hDVi |
| ongoing | ENSURE – New energy grid structures for the energy transition | Karlsruhe Institute of Technology (KIT), RWTH Aachen University, Schleswig-Holstein Netz AG, TenneT, Siemens AG, ABB AG | Sep 2016 – Aug 2019 | goo.gl/eTQd7O |
| completed | Harmonising the grid – optimised efficiency and grid tolerability during integration of power generating plants from a harmonic perspective | FGW e. V. – Association for the promotion of wind energy und other decentralised energy sources (project management) | Jan 2015 – Dec 2017 | goo.gl/LbgL6P |
| completed | ENERGIE – Recording low voltage-side grid status values in real time | SWK GRIDS GmbH (project management), Janitza Electronic GmbH, Devolo AG - Strategic Positioning, Düsseldorf University of Applied Sciences, University of Duisburg-Essen | Sep 2014 – Aug 2016 | goo.gl/nXuqSG |

# Studies/research projects focused on operational management

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on pooling and flexibilisation of power generating plants** | | | | |
| ↻ | Flex4Energy: managing flexibility intelligently | Partner StoREgio, HSE, ads-tec, Fraunhofer ISE, Darmstadt University of Applied Sciences | April 2015 – March 2018 | goo.gl/UnGeQZ |
| ✓ | Renewable electrical energy system | Otto von Guericke University Magdeburg Siemens AG, Fraunhofer Institute for Optronics, System Technologies and Image Exploitation – Applied System Technologies (Fraunhofer IOSB-AST), Fraunhofer IFF, TU Ilmenau | Jan 2015 – Dec 2017 | goo.gl/ZK5Uts |
| ✓ | Smart Grid Solar | Bavarian Centre for Applied Energy Research ZAE (project management), IBC Solar, Areva, Bayernwerk AG, Fraunhofer Institute for Integrated Circuits (Fraunhofer IIS), Fraunhofer Institute for Integrated Systems and Device Technology (Fraunhofer IISB), Friedrich Alexander University Erlangen-Nuremberg (FAU), HEW HofEnergie+ Wasser GmbH, Hof University of Applied Sciences, Rauschert, Rehau ES, SMA | Nov 2012 – Nov 2017 | goo.gl/K9LWHk |
| ↻ | SwarmGrid – secure operation of energy sources through user-swarm ancillary services | RWTH Aachen University | Aug 2015 – July 2018 | goo.gl/2DyAo2 |
| ✓ | PV as future power station – enabling PV power plants to take part in a holistic energy supply system in combination with fossil producers and storage systems | BELECTRIC, Fraunhofer ISE, BTU Cottbus – Faculty of Power Station Technology, Adensis GmbH, GE Energy Power Conversion GmbH, Jurchen Technology GmbH, MTU Friedrichshafen GmbH, Padcon GmbH | Nov 2014 – Oct 2017 | goo.gl/7erzGB |
| ✓ | INE-VES – innovative energy storage systems in networked photovoltaic hybrid systems | Fraunhofer IWES (project management), SMA, Vaillant GmbH, Saft Batteries | Oct 2013 – Sep 2017 | goo.gl/Y6Tqfi |
| ✓ | The city as storage system | TU Dortmund University (project management), Bittner+Krull Software Systems GmbH, Bosch, Fraunhofer UMSICHT (Institute for Environmental, Safety and Energy Technology), University of Duisburg-Essen, Hertener Utilities, SWW Wunsiedel GmbH | Dec 2013 – Nov 2017 | goo.gl/HfzGj1 |

✓ completed ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| **Focus on pooling and flexibilisation of power generating plants** | | | | |
| ✓ | E-Energy – smart energy made in Germany | BMWi (sponsor), 6 pilot regions with 42 companies and scientific installations | May 2014 | goo.gl/diyjCR |
| ✓ | Impact of increasing volatility in production and consumption on security of supply | VGB (project management), University of Rostock, University of Stuttgart | June 2011 – March 2014 | goo.gl/2RtmyB |
| ✓ | metaPV – Metamorphosis of Power Distribution: system services from photovoltaics | 3E N.V. (project management) Austrian Institute of Technology (AIT), Infrax cvba, Limburgse Reconversie Maatschappij N.V., SMA, University of Ljubljana | Oct 2009 – March 2014 | goo.gl/WwGzrw |
| ✓ | Partner steam power station for renewable electricity generation | VGB (project management), EWI, E.ON AG, RWE, Steag, Vattenfall | Sep 2013 – Feb 2015 | goo.gl/PmuJrH |
| ✓ | SolVer – storage system optimisation in local distribution grids | HSE, Darmstadt University of Applied Sciences, ads-tec | March 2013 – May 2015 | goo.gl/Egx53a |

# Studies/research projects focused on system restoration

✓ completed   ongoing

| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| ongoing | Kickstarter | WEMAG, Younicos AG, University of Rostock – Faculty of Electrical Energy Supply, Schwerin Utilities Services GmbH (SWS), Schwerin Energy Supply GmbH & Co. Power Generation KG (EVSE) | Dec 2015 – Nov 2018 | goo.gl/oejbzj |
| ongoing | Linda: supplying local microgrids with renewable energy sources | LEW distribution grid (project management), BEW Bayerische Elektrizitätswerke, Augsburg University of Applied Sciences, Technical University of Munich, Stellba Hydro, marquis automation technologies, MTU, PSI AG | Aug 2015 – July 2018 | goo.gl/hQuBGu |
| ongoing | GRID:POWER – grid restoration in the light of future power station structures | Fraunhofer IWES (project management), 50Hertz, TenneT, Amprion, TransnetBW, EnergieNetz Mitte GmbH, MITNETZ, DREWAG, Avacon AG, Siemens AG, ENERCON, Energiequelle GmbH, SMA, ÖKOBIT GmbH, PSI AG, Dutrain GmbH, GridLab GmbH, FAU, University of Kassel, DERlab e. V. | Jan 2015 – June 2018 | goo.gl/mKdtys |
| ✓ | SORGLOS – Smart, robust, renewably fed, blackout-proof grid sections | TU Wien – Institute for Energy Systems and Electrical Drives (project management). Energy Institute at the Johannes Kepler University Linz, Energie AG Oberösterreich Netz GmbH, Vorarlberg Energienetze GmbH | March 2013 – Feb 2015 | goo.gl/Sy8Hrp |

# Studies/research projects focused on short-circuit current contribution

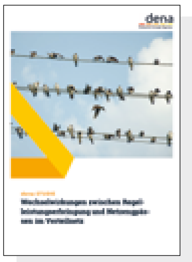
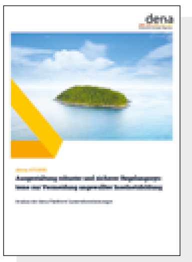
| Status | Title/ description | Responsible parties | Lifespan/ publication | Short link |
|---|---|---|---|---|
| ✓ | Voltage control with modern WEA technology | University of Duisburg-Essen, Repower Systems AG, Woodward SEG GmbH & Co. KG | 2009 | goo.gl/cyriKv |

# Annexes

A List of publications
B List of footnotes

# A List of publications

| Description | Document image | Title | Link |
|---|---|---|---|
| I |  | dena Study 'Ancillary Services 2030',<br><br>February 2014 | bit.ly/2SQFJgn |
| II |  | Roadmap of the dena Study 'Ancillary Services 2030'<br><br>July 2014 | bit.ly/2rydyqR |
| III |  | Providing operating reserve using decentralised energy facilities.<br><br>November 2015 | bit.ly/2Qvkrbh |
| IV |  | Challenges in the further development of coordination processes for operating reserve provision.<br><br>May 2016 | bit.ly/2LfPTEH |
| V |  | Analysis of need for action – monitoring ability and management in the energy system.<br><br>July 2016 | bit.ly/2Bf3K9G |

| Description | Document image | Title | Link |
|---|---|---|---|
| VI |  | Report – demand for and provision of instantaneous reserve in 2030.<br><br>February 2016 | bit.ly/2RW8Cri |
| VII |  | Sector opinions – economically affordable provision of reactive power<br><br>April 2017 | bit.ly/2Bk8Stc |
| VIII |  | Report – interaction between operating reserve provision and grid congestion in the distribution grid<br><br>November 2017 | bit.ly/2LdBgS8 |
| IX |  | Report – design of robust and secure control systems to avoid unintentional formation of microgrids<br><br>November 2017 | bit.ly/2QvU98C |
| X |  | Report – developing a procedure to quantitatively evaluate different options for providing reactive power<br><br>January 2018 | bit.ly/2zYyc8d |

# B List of footnotes

[1] In the present-day electric power system, instantaneous reserve arises as a result of the inertia of the rotating masses of conventional generators. Since the market share of conventional producers is constantly falling, research is needed to determine how much instantaneous reserve will need to be actively provided by frequency converters in the future.

[2] ‘Product time slices’ are periods of time in which a specific operating reserve must be provided.

[3] The term ‘system split’ refers to a separation in the grid caused by a malfunction. Examples in the past include a system split in Europe in November 2006, resulting in a power outage. Other examples are the blackouts in Italy on 28 September 2002 and in Turkey on 31 March 2015.

[4] For example, such concepts are being developed as part of the ARGE programme of the Local Grid Operators East, under the umbrella term ‘active reactive power management’.

# Imprint

**Publisher:**
Deutsche Energie-Agentur GmbH (dena)
German Energy Agency
Chausseestrasse 128 a
10115 Berlin, Germany
Tel: +49 (0)30 66 777-0
Fax: +49 (0)30 66 777-699
E-mail: info@dena.de
Website: www.dena.de

**Authors:**
Stefan Mischinger, dena
Hannes Seidl, dena
Elie-Lukas Limbacher, dena
Dr Sebastian Fasbender, dena
Frederik Stalleicken, dena

**Image credits:**
Cover page – thinkstock.de/Mawardibahar, p. 4 – istockphoto.com/SergBob, p. 6 – thinkstock.de/Eyematrix, graphic, p. 8 – freepik.com/Created by Harryarts, Graphic p. 10 – freepik.com/Created by Cornecoba, p. 17 – thinkstock.de/danielsbfoto, portrait p. 17 – EWE NETZ GmbH, p. 18 – shutterstock.com/giSpate, portrait p. 18 – ENERCON GmbH, p. 19 – WWF Solar GmbH, p. 20 – shutterstock.com/mycteria, p. 22 – shutterstock.com/Diyana Dimitrova, p. 24 – shutterstock.com/Pressmaster

**Concept & design:**
Heimrich & Hannot GmbH

Effective: 12/2018


This publication was compiled as part of the dena ancillary services platform.

**The project partners of the ancillary services platform are:**
50Hertz Transmission GmbH, Amprion GmbH, Bayernwerk AG, Federal Ministry for Economic Affairs and Energy, E.DIS AG, E.ON AG, ENERCON GmbH, Energiequelle GmbH, EWE NETZ GmbH, Main-Donau Netzgesellschaft mbH, Mitteldeutsche Netzgesellschaft Strom mbH, innogy SE, Siemens AG, SMA Solar Technology AG, TenneT TSO GmbH, Thüringer Energienetze GmbH, TransnetBW GmbH, VDMA Facbverband Power Systems, VGB PowerTech e. V., Westnetz GmbH, WWF Solar GmbH, Younicos AG

**Climate neutral**
Print product
ClimatePartner.com/11854-1812-1003

Printed on BalancePure, awarded the Blue Angel environmental label for paper and cardboard, as it is energy and water-saving and made from 100 % recycled fibres.

www.dena.de

9 783981 855845

German Energy Agency