Berlin, 29 February 2016

Conclusion
Power Grid Development Plan 2025, Version 2015, 2ND Draft

Presented for the first time using its target year in the title and not the year of publication, the Grid Development Plan (GDP) 2025 deals with the expansion requirements of the German onshore energy transportation network and is based on the legal requirements as stipulated by the German Energy Management Act (Section 12a-d). The TSOs are planning, developing and building the grid of the future. The GDP is used to show how power generation in Germany can be successfully restructured and renewable energy can be integrated within ten and twenty years, respectively.

Scenario framework

By presenting the assumptions regarding the generation and consumption structure, the calculation method used and the resulting requirements for grid expansion on a public stage, the whole process of grid development planning is made very transparent. The GDP 2025 uses the same methodology as the Grid Development Plans for 2012, 2013 and 2014, as approved by the German Federal Network Agency. In terms of assumed energy generation capacity and the consumption situation in the future, the scenario framework, as approved by the Federal Network Agency on 19 December 2014, is used as a starting point for creating both the GDP and the O-GDP 2025 (in accordance with Section 12b and Section 17b of the German Energy Management Act). For the first time, the Federal Network Agency has included six scenarios in this scenario framework. The TSOs have no possibility to retroactively adjust the scenario framework that is approved by the Federal Network Agency. In this respect, the TSOs have not made any changes to the input data (e.g. capacity for renewable and conventional power, consumption, storage, European environment) between the first and second draft of the GDP 2025, nor have they carried out any new market simulations.

Grid connection points

Just like its predecessors, the GDP 2025 highlights the transmission requirements between start and end points. As a rule, starting points are located in regions with surplus energy generation, whilst end points are in regions with high levels of consumption or where energy is currently supplied by nuclear power stations, which are set to be closed down by the end of 2022. Like its predecessors, the present second draft of the GDP 2025 does not detail any specific routes for new transmission lines, but rather documents the levels of transmission demand required between grid nodes. A needs-based network is dimensioned.

Specifically named locations to denote start and end points are purely technical statements that serve to identify existing grid connection points. Exact line corridors or routes are not determined until later stages in the planning procedure (e.g. federal sectoral planning, planning permission). The GDP does not define locations for future power stations or renewable energy facilities, nor does it define the market design of the future or give recommendations or suggestions for optimisation.

Optimised combination of direct and alternating current

Alongside the expansion of the 380 kV alternating current system, high voltage direct current connections (HVDC or direct current connections) are also planned to handle the long-range transmission requirements from north to south as well as sometimes acting as an interconnector with neighbouring countries. These measures enable low-loss energy transmission over long distances and, thanks to the use of modern technology, help to stabilise the alternating current network. The otherwise necessary, far more large-scale, expansion of the alternating current network is thus avoided. Converter facilities are required for injection and withdrawal, significantly limiting the number of potential tension points for supplying cities and wider regions or for the intake of regionally-generated power along the route.

The combined use of direct current and alternating current technology as proposed in the GDP enables the collective optimisation of the transmission network to match with the development of supply tasks over time as well as changing future transmission requirements with regard to network stability, economic efficiency and spatial demands.

Developing the methodology

The transmission system operators are constantly working to further develop the methods and simulation tools used for network planning and running market simulations. This has allowed them to, for example, make improvements and enhancements to the methodology used in the GDP 2025 for the regionalisation of renewable energy sources compared to that used in the GDP 2014 (see Chapter 2).

Furthermore, the TSOs have taken the methodological approach for evaluating grid expansion measures used in part of the first draft of the GDP 2014 and developed this further to establish a set of evaluation criteria. A pilot project has been run in which the measures from Scenario B1 2025 have been subjected to an analysis with the aid of these evaluation criteria. These evaluation criteria can not only be used to provide an additional description and characterisation of the measures, but also to identify preferential measures from the overall set of necessary measures included in a GDP.

This process has not been applied in this GDP, but is described in an accompanying document (in German), which can be found online at www.netzentwicklungsplan.de/Begleitdokument_NEP_2025_Massnahmenbewertung.pdf. It is currently planned to use this process within the scope of the GDP 2030. This development is to be continued in close cooperation with the plan's stakeholders. As part of this, the TSOs plan on holding public experts workshops in the first half of 2016. Independently of this, the TSOs are also planning the imminent publication of a concept that will, among other points, include the redispatch amounts that are to be eliminated as a result of the grid expansion measures identified in the GDP 2025.

Applying the NOVA principle

As with the previous Grid Development Plans, network optimisation and development measures were given priority over pure network expansion measures; this is referred to as the "NOVA principle". NOVA is a German acronym for the optimisation, enhancement and expansion of the grid [Netzoptimierung, -verstärkung und -ausbau]. This means that as a basic principle, it is always the existing network that is optimised or developed. The construction of a new route for a new power line is only proposed once all technical options for optimisation and development have been tested and proven to be insufficient. The "NOVA principle" (see Chapter 4.1.2) that forms the basis of the GDP is already guided by the usage of existing power line routes. Insofar as is possible, the line routes of the currently existing grid are also taken into account during the subsequent planning and approval stages of the GDP. However, in the GDP, it is not possible to make any prior decisions for the formal approval procedure. This can result in deviations from the existing route, e.g. due to protection of local residents or the environment, occurring in later approval stages, even in the case of a new line construction along an existing route.

Market simulation results

The market simulations for the GDP 2025 illustrate how much progress the transformation of the energy sector has already made. A large gap in terms of power generation within Germany can be seen in all scenarios with surplus generation in Northern Germany and a generation deficit in the south. The importance of renewable energy continues to increase: the source of energy with the largest share in the energy mix of Scenarios B1 2025, B2 2025 and C 2025 is wind energy (on and offshore). Additionally, Germany possesses the largest trade balance in Europe and is a transit country within the European energy network. The auxiliary conditions in the market modelling for emission controls in Scenarios B2 2025, C 2025 and B2 2035 result in Germany switching from its position as a net power exporter to becoming a net power importer.

Network analysis results

Thanks to the scope of six different scenarios, the network measures investigated cover a wide range of possible future developments. The GDP at hand contains all effective measures for the necessary optimisation, development and expansion of the energy grid as defined by Section 12b (1.2) of the German Energy Management Act. So-called "vertical point measures" (measures which are only required in electrical substations) are included in the data sets and only partially represented in the GDP report within the context of individual route construction measures. These are summarised in a separate accompanying document (in German), which can be found here: www.netzentwicklungsplan.de/Begleitdokument_NEP_2025_Punktmassnahmen.pdf.

Demand for grid expansion remains high

The results of the calculations in the GDP 2025 show that the scope of demand to develop the German energy grid is not fundamentally different to that seen in the GDP 2014.

As in the previous Grid Development Plans, the measures of the Federal Requirements Plan 2013 and moreover almost all measures from the Federal Requirements Plan 2015 prove to be robust, even in the face of the changed framework conditions. This is true both in regard to the changes between the GDP 2014 and the GDP 2025 (power plant complex, increase in renewable energy sources as a consequence of the new Renewable Energy Act and taking injection management into account) as well as within the scope of the scenarios contained in the GDP 2025 (scenarios with and without explicit targets for CO2 reduction).

The necessity of almost all measures from the Federal Requirements Plan 2015 can be seen both in the ten-year scenarios of the GDP 2025 as well as in the scenarios for 2035, which are used for the sustainability assessment. The combined use of direct and alternating current technology for ensuring a reliable supply of energy was once again proven to be necessary.

In addition to the measures stipulated in the Federal Requirements Plan 2015, almost all of the measures confirmed by the Federal Network Agency in the Grid Development Plans for 2013 and 2014 also prove to be necessary in all scenarios.

Relocation of the HVDC grid connection point to Isar and alternatives for disentangling Grafenrheinfeld

As a consequence of the key issues arising from the governmental coalition resolution of 1 July 2015 (see Chapter 1.3) and at the request of the Federal Network Agency, in the variations B1 2025 GI, the transmission system operators also investigated measures for disentangling the Grafenrheinfeld grid node. As the German Federal Parliament has meanwhile included Isar in the Federal Requirements Plan as the southern grid connection point for the HVDC connection line from Saxony-Anhalt to Bavaria, the second draft of the GDP 2025 does not cover the option B1 2025 GG – thereby forgoing a variation for the end site of the HVDC connection line.

As a consequence of this, Isar has been adopted as the southern grid connection point for DC5 and DC6 (referred to as DC5I and DC6I for the report) and the related AC connection between Oberbachern and Ottenhofen (P222) in all scenarios and their overview maps. These scenarios were not completely recalculated. However, plausibility investigations were used as a basis for reviewing the consequences of the changes identified in variation B1 2025 GI on individual measures within these scenarios. This showed that the changes identified by B1 2025 GI could also be accounted for in the grids depicted in the other scenarios.

With respect to reducing load from the Grafenrheinfeld grid node, the variation B1 2025 GI verified that, as an alternative to the P43 Mecklar – Bergrheinfeld/West (previously Grafenrheinfeld) and P44 Altenfeld – Grafenrheinfeld construction projects, in principle it would be possible to develop the existing 380 kV power lines (P43mod Mecklar – Dipperz – Urberach and P44mod Altenfeld – Würgau – Ludersheim). By making changes to the cable routing, new lines no longer need to be constructed in either of these projects. Together, the two network development projects P43mod and P44mod are, however, around 76 km longer than the construction planned in projects P43 and P44. Furthermore, it can be seen that, with these alternatives, the regional network load in Southern Germany is shifted in the B1 2025 GI scenario version. The compensatory measures for relieving the load from Grafenrheinfeld redirect the power flow from the north, bypassing Grafenrheinfeld, resulting in the load being reduced at the River Main connection point between TenneT and TransnetBW. In comparison with Scenario B1 2025, this option results in a deterioration in the degree of meshing in Grafenrheinfeld. The degree of East-West meshing – and thereby also the connection with states in Eastern Germany – is reduced. If current flows continue to increase, e.g. as a result of the greater expansion of renewable sources of energy, it is likely that further additional grid development and expansion measures are to be expected in the future if the construction projects P43 and P44 are not implemented.

Network stability

The system stability evaluation included in the second draft of the GDP 2025 clearly shows that the levels of network load occurring in the GDP 2025 are comparable with those in the Grid Development Plans for 2012, 2013 and 2014. In general, no changes can be seen in the indication of problems regarding transient stability and voltage stability (see Chapter 4.3). In the event of a fault occurring, the cause of which is in accordance with the concept, the results of the dynamic studies indicate a robust and stable system behaviour with no risk of the fault spreading more extensively.

In certain load situations, extended periods of down time may lead to a loss of angle stability within the Northern German transmission network. In certain network usage situations, depending on the actual development of the grid, the development of the power generation structure and other constraints (e.g. network connectivity), it may be necessary to reduce the network load in order to maintain transient stability. This can be achieved by relocating electricity feed-in, also known as redispatch.

Level of demand to modify and expand the extra-high voltage network

In Scenario B1 2025, the volume of network developments along existing routes (recabling or circuit requirements, construction of a more efficient power line along existing routes) amounts to 5,300 km of line routes and 5,800 km in Scenario B2 2025. In Scenarios B1 2025 and B2 2025, the required level of expansion for new power lines is calculated at 4,300 km respectively, 3,200 km of which are HVDC corridors. This also includes the German share in the direct current interconnectors between Germany and Belgium, Denmark, Norway and Sweden with an overland length of approximately 330 km. In the variantion B1 2025 GI, the required scope of network development measures on existing lines is slightly higher than in Scenario B1 2025, with approximately 5,800 km needed. In return, the required level of expansion for new power lines in this alternative is 4,100 km, slightly less than the 4,300 km in Scenario B1 2025. The transmission capacity for the HVDC connection lines in Scenarios B1 2025 (including the B1 2025 GI option) and B2 2025 totals 10 GW, whilst totalling 8 GW in Scenarios A 2025 and C 2025.

Investment costs

The calculations of investment costs for the network measures are calculated in the GDP are based on standard costs and are of a provisional nature. Depending on the scenario, the total volume of investments over the next ten years ranges between 27 and 30 billion euro, assuming that up to 50% of the HVDC connection lines DC1 and DC3-5 or DC3-6 respectively are to be constructed using underground cabling. The costs for completing the aforementioned HVDC connection lines using only underground cabling are estimated to be between 30 and 34 billion euro.

Expectations regarding the Grid Development Plan 2025: what are the causes behind the demand for grid expansion?

Several assumptions regarding the energy industry have changed since the publication of the GDP 2014, supposedly having a reductive effect on the need for grid expansion; the Renewable Energy Act was amended, peak capping was introduced for renewable energy in all scenarios and the conventional power plant complex size was reduced. The results of this GDP 2025 again show a comparably high need for grid expansion, as in previous years, even after these changes to the framework conditions have been implemented. This is due to a number of different factors:

- The overall data for renewable energy sources have changed considerably. The amendments made to the Renewable Energy Act in 2014 did not lead to a reduction in construction in the renewable energy sector, but rather to a stable and steady increase. A comparison of Scenarios B 2024* and B1 2025/B2 2025 gives the following results: the level of installed offshore wind capacity has been reduced by 2.2 GW between B 2024* and B 2025, whilst onshore wind capacity increases by 8.8 GW. In total, the installed capacity of energy from renewable sources in Scenario B has increased by 2.8 GW between the GDP 2014 and the GDP 2025.
- Developed on the basis of the amended Renewable Energy Act and used for the first time in Scenario B 2024* in the second draft of the

GDP 2014, the new method for regionalisation of renewable sources of energy was further refined in the GDP 2025 and extended to all other scenarios. As a result of this, the installed capacity of onshore wind energy has increased in Northern and Eastern Germany in particular. This further increases transmission demand in a north-south direction and thus lessens the curtailing effect of peak capping on renewable energy.

- On the one hand, the decline in domestic power station output compared with the GDP 2014 is compensated for with the increased construction in the renewable energy sector and on the other hand with energy production in foreign power stations, thus turning Germany into a net energy importer in the scenarios with CO2 restrictions.
- The number of grid expansion measures required is also higher than in the GDP 2014; in the ten year scenarios for the GDP 2025, the construction of two DC connections (Wehrendorf – Urberach and Segeberg district – Wendlingen) is not yet necessary under the new framework conditions. This means that several hundred kilometres of construction along new routes is not yet required in these scenarios. Instead, the network analyses show that further development work on the existing grid is necessary, thus increasing both the number of measures as well as the total cable length in kilometres identified for network development in comparison with the GDP 2014.
- Overall, the north-south divide in terms of generation and consumption in Germany – and all over Europe – continues to widen. The renewable energy sector is the main driver behind this. The level of long-range transmission demand thus remains the same between renewable sources of energy in the north and east and the load and consumption centres in Western and Southern Germany on the other hand.
- A cross-comparison of the scenarios shows that, for the most part, the difference between the installed generation capacity and the load or rather consumption is decisive in determining the demand for grid expansion. This is why the demand for grid expansion in Scenarios A 2025 and C 2025 is roughly the same, despite large differences between the input parameters. The same is true for Scenarios B1 2025 and B2 2025, whereby there is a significant difference in the

results of the market simulation (in B1 2025, Germany is a net power exporter and a net power importer in B2 2025). By comparison, the difference in terms of the demand for grid expansion is marginal. It even shows that the higher level of demand for grid expansion does not manifest in Scenario B1 2025, in which the German power stations produce significant volumes of energy for export, but rather in Scenario B1 2025, where the German power stations produce considerably less energy and Germany needs to obtain additional power from other countries.

GDP 2025 grid efficiency

With regard to the disentanglement of the Grafenrheinfeld grid node, a comparison of the results of Scenarios A 2025, B1 2025, B2 2025 and C 2025 and the results of the alternative scenario B2 2025 GI – which was derived from the key issues from the government coalition resolution from 1 July 2015 – shows that the TSOs' original calculations portray a robust energy network, which satisfies its transmission duties efficiently. Although the changes undertaken in B1 2025 GI do indeed represent a network that is fundamentally operative; however, the efficiency of this grid is worse. The degree of meshing is lower and east-west flows are harder to manage.

GDP 2025 consultation process

Numerous responses were submitted to the TSOs within the scope of the public consultation regarding the first draft of the GDP 2025. The statements primarily focussed on general questions about the assumptions and demands for grid development made in the scenarios as well as on regional concerns regarding the disentanglement of the Grafenrheinfeld grid node and the route of the HVDC connection line between Saxony-Anhalt and Bavaria.

The submitted statements were reviewed by the TSOs and incorporated into this second draft of the GDP 2025. This transparent process, which particularly focusses on open dialogue, ensures that all stakeholders interested in the GDP are given the opportunity to voice their opinion and that the GDP is the result of a process of mutual recognition and development.

Review and approval of the GDP 2025

The transmission system operators are building an energy network that will comply with the aims of the German Energy Transition and of networking across Europe to create an internal European energy market and that also facilitates the efficient and safe operation of the energy grid. In this context, the projects and measures stipulated in the Federal Requirements Plan 2013 and almost all of those in the Federal Requirements Plan 2015 prove to be a solid foundation for the development of the power grid over the next few years. They form the basis of the target networks detailed in every scenario of the GDP 2025.

From the perspective of the transmission system operators, it seems advisable to concentrate on approving the measures included in the Federal Requirements Plan as amended in late 2015 along with the measures already approved in the GDP 2014 and again identified as necessary by the TSOs in the GDP 2025.

In the course of the GDP 2030, which will be based on new scenarios, further measures, which have been investigated in the network analysis, are to be assessed and where appropriate, then prioritised in terms of their effectiveness. By the GDP 2030, the TSOs hope to further expand upon and apply the methods for evaluating measures outlined in the GDP 2025.

With regard to projects P43 and P44 as well as their alternatives P43mod and P44mod, the TSOs ask the Federal Network Agency to make a decision as to which project will be approved and subsequently pursued by the TSOs. Given that calculations for the GDP 2030 are expected to begin in summer 2016, the transmission system operators call for an early decision to be made, in order to assure that the projects and measures can be accounted for appropriately within the scope of the network analyses for the GDP 2030.