Berlin, 30 October 2015

Conclusion
Power Grid Development Plan 2025, Version 2015, 1. 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 Economy Law (Section 12a-d). The transmission system operators 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 how renewable energies can be integrated within the next ten and twenty years.

Process and methodology

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 transparent. The GDP 2025 uses the same methodology as the Grid Development Plans for 2012, 2013 and 2014 and as approved by the German Federal Network Agency (Bundesnetzagentur, BNetzA). 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 Grid Development Plan and the Offshore Grid Development Plan 2025 (in accordance with Section 12b and Section 17b of the German Energy Economy Law [EnWG]). For the first time, the Federal Network Agency has included six scenarios in this framework.

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 by the end of 2022. Like its predecessors, the present Grid Development Plan 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.

Alongside the expansion of the 380 kV alternating current network, high voltage direct current (HVDC) connections are also planned to handle the long-range transmission requirements from north to south as well as sometimes acting as interconnectors 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.

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 Grid Development Plan 2025 for the regionalisation of renewable energy sources compared to that used in the Grid Development Plan 2014 (see Chapter 2).

Furthermore, the transmission system operators 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, which can be found online at www.netzentwicklungsplan.de/Begleitdokument_NEP_2025_1_Entwurf_Massnahmenbewertung.pdf.

As with the previous Grid Development Plans, grid optimisation and enhancement measures were given priority over pure grid expansion measures. This means that as a basic principle, it is always the existing network that is optimised or enhanced. The construction of a new power line is only proposed once all technical options for optimisation and enhancement have been tested and proven to be insufficient. The "NOVA principle" (a German acronym encapsulating the prioritisation of network optimisation over enhancement and expansion, see Chapter 4.1.2) that forms the basis of the Grid Development Plan 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.

Network analysis results

Thanks to the scope of six different scenarios, the network measures investigated cover a wide range of possible future developments. The Grid Development Plan presented here contains all effective measures for the necessary optimisation, enhancement and expansion of the energy grid as defined by Section 12b (1.2) of the German Energy Economy Law. 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.

The results of the calculations 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 Requirement Plan (*Bundesbedarfsplan*) are proven 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 [*EEG*], taking feed-in management into account) as well as within the scope of the scenarios contained in the GDP 2025 (scenarios with and without explicit targets for CO_2 reduction). The necessity of all measures from the Federal Requirement Plan 2013 can be seen both in all 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 current 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 Requirement Plan, the measures confirmed by the Federal Network Agency in the Grid Development Plans for 2013 and 2014 are also proven to be necessary in all scenarios.

As a consequence of the key issues arising from the governmental coalition resolution of 1 July 2015 (see Chapter 1.3), in the variations B1 2025 GG and B1 2025 GI, the transmission system operators investigate both the option of alternative end points for the HVDC connection line from Saxony-Anhalt to Bavaria (DC5, DC6) as well as measures for deconcentrating the Grafenrheinfeld grid node.

As stated in the additional investigation for the GDP 2014 presented by the TSOs in August 2015, “The network calculations show that, in terms of electrical technology, Gundremmingen is better suited to being used as a grid connection point than Isar. The calculations also confirm the efficiency of the GDP 2014 grid. By increasing the transmission capacity between Ottenhofen and Oberbachern (approximately 40 km of grid enhancement), the Isar connection point can be made suitable for use as a southern grid connection point in Corridor D.” In addition to this, the analyses included in the GDP 2025 depict structural changes in the area surrounding the grid connection points in Gundremmingen and Isar, resulting in a reduction in grid expansion measures to a small extent in a number of places, as reported in the overview in Chapter 5.

With respect to reducing load from the Grafenrheinfeld grid node, both variations B1 2025 GG and B1 2025 GI verify that, in principle, it would be possible to replace the construction projects P43 Mecklar – Bergrheinfeld/West (previously Grafenrheinfeld) and P44 Altenfeld – Grafenrheinfeld with the reinforcement of existing 380 kV power lines

(P43mod Mecklar – Dipperz – Urberach and P44mod Altenfeld – Würgau – Ludersheim). By making changes to the routing, new lines no longer need to be constructed in either of these projects. Together, the two network enhancement projects P43mod and P44 mod are, however, around 75 km longer than the construction planned in projects P43 and P44. Furthermore, it can be seen that the regional network load in southern Germany is shifted in both network alternatives B1 2025 GG and B1 2025 GI. 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 interconnection in Grafenrheinfeld. The degree of East-West interconnection – 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 energy sources, it is likely that further additional grid enhancement and expansion measures are to be expected in the future if the construction projects P43 and P44 are not implemented.

The stability evaluation 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.

In Scenario B1 2025, the volume of grid enhancement along existing routes (recabling or circuit requirements, construction of a more efficient power line along existing routes) amounts to 5,900 km of line routes and 6,400 km in Scenario B2 2025. In Scenarios B1 2025 and B2 2025, the required level of expansion for new power lines is each calculated at 3,300 km respectively, 2,200 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 220 km. In both options B1 2025 GG and B1 2025 GI, the required scope of grid enhancement measures on existing lines is slightly higher than in Scenario B1 2025, with approximately 6,300 km and 6,400 km respectively. In return, the required level of expansion for new power lines in both alternatives is 3,100 km, slightly less than the 3,300 km in Scenario B1 2025. The transmission capacity for the HVDC connection lines in Scenarios B1 2025 and B2 2025 totals 10 GW, whilst totalling 8 GW in Scenarios A 2025 and C 2025.

The investment costs for the network measures are calculated in the Grid Development Plan on the basis of specific cost estimations and are of a provisional nature. Depending on the scenario, the total volume of investments over the next ten years ranges between 22 and 25 billion euro, assuming that overhead lines are used. The costs for completing the HVDC connection lines DC1 and DC3–6 using only underground cables are estimated to be between 31 and 36 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 Grid Development Plan 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 again show a comparably high demand from the energy industry 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 stabilisation and slight 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 between the GDP 2014 and the GDP 2025.
- Developed based on 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, that are turning Germany into a net energy importer in the scenarios with CO_2 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 west and south 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.

GDP 2025 grid efficiency

A comparison of the results of Scenarios A 2025, B1 2025, B2 2025 and C 2025 prior to the government coalition resolution on key issues from 1 July 2015 and the results of the two alternative scenarios B1 2025 GG and B1 2025 GI, which were derived from these key issues, shows that the TSOs' original calculations portray a robust energy network, which satisfies its transmission duties efficiently. Although the changes undertaken in both alternative scenarios do indeed represent a network that is fundamentally operative; however the efficiency of this grid is less good. The degree of interconnection is lower and east-west flows are harder to manage.