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WIND ENERGY REPORT GERMANY 2013

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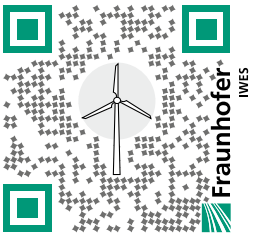

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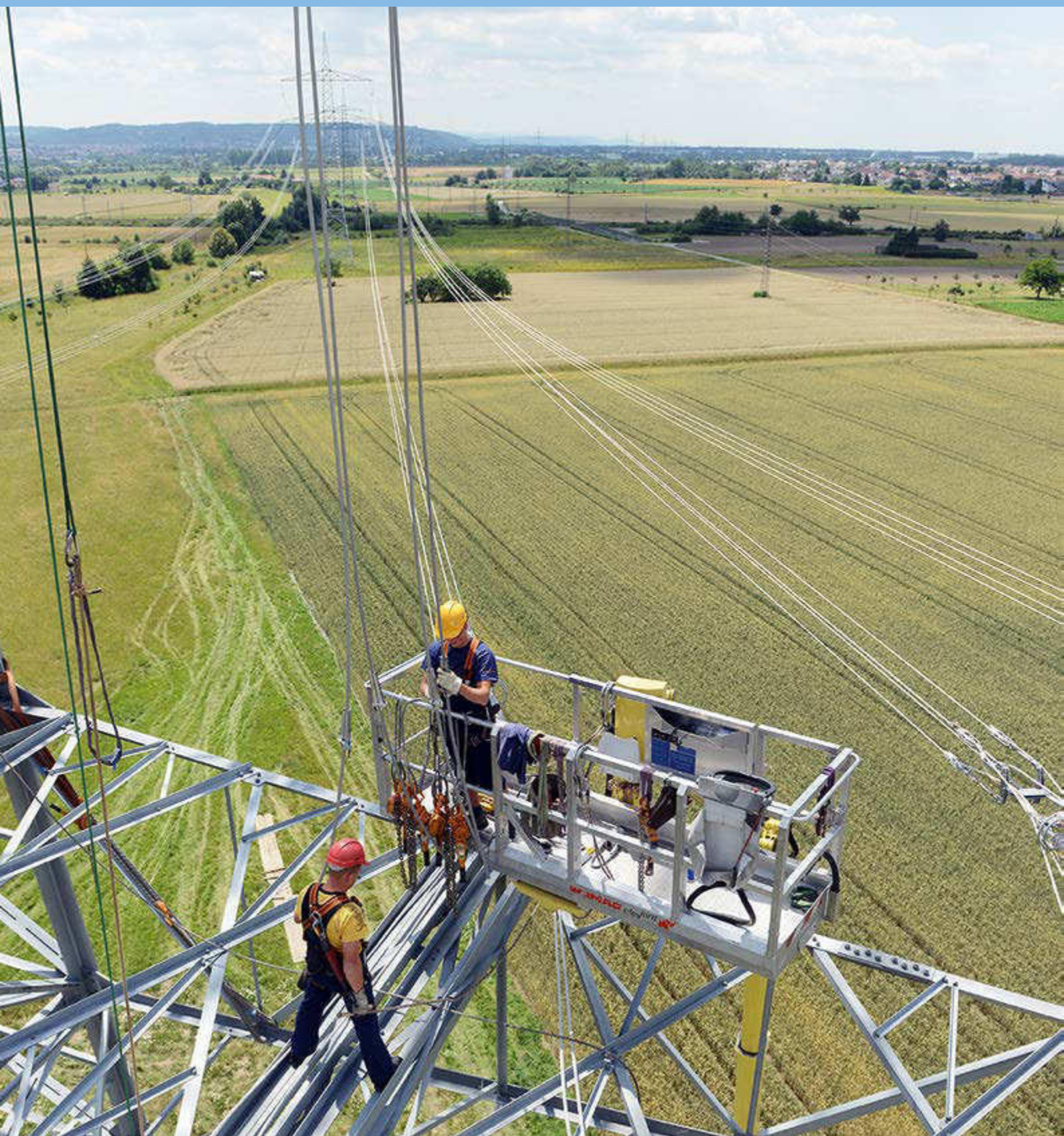

Special Report

TECHNICAL GRID ASSESSMENT BY THE FEDERAL NETWORK AGENCY

Dr. Swantje Heers, Thomas Dederichs und Achim Zerres

Challenges for grid planning and grid assessment during the switchover to renewable energy generation

The switchover to renewable energy generation requires major changes to the infrastructure for the transmission and distribution of electrical energy. For example, under EU Regulation 2009/72/EC and the amendment to the Energy Industry Act (EnWG) of 2011 a grid planning procedure was embraced which puts high requirements on transparency and accountability and is unrivaled. An annual grid development plan is drawn up by the German transmission system operators (TSOs) and then assessed by the Federal Network Agency (BNetzA). This is keenly monitored by market participants and the public.

Objectives of energy provision and grid assessment

There is wide consensus today that the construction of electricity grids is vital for efficient and environmentally compatible energy provision. However, both the construction and assessment of grids is not without controversy. Due to the associated costs, the utilization of land, and the actual or feared impact on the quality of life and assets of residents, grid expansion is far more than just an engineering issue.

The demands of the public with regards to grid planning have thus changed enormously in recent years. Driven by a classical attitude of "as much as necessary, as little as possible", other factors have now come to the fore. For example, when planning grids there are a series of competing goals including:

- Appropriateness with regard to the negative impact on other legal assets
- Effectiveness for reaching the objectives
- Realization in the prescribed time period
- Objectivity
- Transparency
- Comprehensiveness
- Robustness with regards to future energy industry developments that differ from the expected plans

Differences between grid planning and assessment

According to § 12b paragraph 1 of the Energy Industry Act (EnWG), the grid development plan must specify the required grid expansion for the next 10 years. This task is being undertaken in a multi-step development process, which is being repeated every year and at the end of which will be the grid development plan [2,3]. Based on an approved scenario [4,5,6] for regionalization and market simulation, the inflow and outflow of electricity are determined for every hour of a year (e.g. for 2023 in the grid development plan 2013). The feed-ins from renewable energies and conventional power stations to the individual grid nodes, the electricity demand, and the in/out balances at the interconnections define each hour a so-called grid utilization case (GUC). Based on stationary grid analyses (namely load flow calculations), the load on the so-called starting grid can be determined for each GUC. The starting grid, by definition of the Federal Network Agency, is the current transmission system plus planned or ongoing construction measures and projects under the Electricity Grid Expansion Act (EnLAG).

The TSOs determine the necessary measures for the German extra-high voltage grid to alleviate bottlenecks and guarantee efficient grid operations. Their decisions are based on the loads on the starting grid as well as consideration of their responsibilities for the system and their planning principles [1].

Besides assuring electricity provision, the assessment of the Federal Grid Agency must also ensure that the grid expansion measures are proportional, economically viable, and robust. It must take account of the fact that the ten year forecasts for electricity production and demand may change. As such, the necessary grid expansion may change from one grid development plan to the next. It must also be avoided that measures fluctuate from one year to the next due to approval and then non-approval.

Assessment of the grid development plan by the Federal Network Agency

The Federal Network Agency assesses the grid expansion measures proposed by the TSOs to check whether the TSOs have correctly applied their own planning rules and to check the measures against the above-mentioned additional criteria. For the assessment, the Federal Network Agency have defined the criteria "effectiveness" and "required" as follows [7,8].

Effectiveness. A measure is classed as effective if:

a. it ensures the (n-1) reliable operation of the grid in accordance with the planning regulations [1];
b. it avoids disproportional work to relieve overloads in lower grid levels;
c. it leads to the desired increase in cross-border transport capacity to other countries;
d. it significantly reduces undesired physical loop-flows across other European countries.

Points (b) – (d) will not be discussed further in this report (see [7,8]).

To test the effectiveness of a measure in the sense of (a), it is determined to what extent efficient grid operation is possible with and without the measure. First of all the measure under test is removed from the grid planned by the TSOs ("target grid"), namely the grid expansion is assessed without the measure but with all other expansion measures. With the help of the base load flow and (n-1) failure cases, the resulting line loads are determined in the German grid.

If there are no line loads of > 100% (overloads) in either the base case or in the failure situations, then the necessity for the measure is not clear and it is consequently not effective for relieving an overload. The (n-1) cases under consideration generally include the failure of lines in the surrounding grid zones which have base utilization of more than 50%.

In contrast, if overloads are found, the same tests are carried out with the measure. The measure is effective if all the (considered) overloads are relieved or considerably reduced.

For assessing the measures, overhead electricity line monitoring was taken into account, namely the weather-dependent operation of extra-high voltage lines to increase the current carrying capacity, as laid down in the planning regulations of the TSOs [1]. Depending on the weather, the maximum permissible line load in the three wind zones can significantly increase, namely in central and southern Germany (up to a maximum of 115% of the line load), in the northern German lowlands (maximum 130%), and in the coastal regions (maximum 150%).

In addition, topology changes (namely switching measures) are allowed for alleviating possible breaches of hardware limit values and small breaches of the total exchange capacity with other countries are allowed. A detailed description can be found elsewhere [7,8,9].

The Federal Network Agency was given a grid data set for each measure. The grid data set contains the specific electricity feed-in and consumption for an hour of scenario B2023 (grid utilization case). Each data set contains the node-level topology of the entire German extra-high voltage grid and simplified models of the grids in neighboring countries and German distribution grids. The grid data were evaluated using Integral software. The grid comprises ca. 6600 grid nodes, 5500 circuits, and about 1850 transformers. Also included in the data set are line parameters, electrical data of the coupling transformers, generators, and extra high voltage direct current installations, busbar utilization and the switching states of the lines and active grid elements.

Example of effectiveness assessment for project 72, measure 50: Lübeck region – District of Segeberg. The measure involves the construction by the TSO of a 380 kV line along the route of the existing 220 kV line between Lübeck region and the District of Segeberg and is deemed necessary to enhance the grid. In the District of Segeberg the construction of a new 380 kV substation is also necessary.

The TSOs deemed the measure necessary due, amongst other things, to grid overload on failure of one of the lines between

Lübeck and Hamburg/Nord. It often arises that the Baltic Cable, connected in Herrenwyk, which connects the German and Swedish grids can either not be operated or not operated at full capacity.

The base load case was assessed with and without measure 50. In the hour that was assessed (3204, 13.05.2023, 12:00), the base case gave 71% utilization of the lines between Lübeck and Hamburg/Nord without the measure.

To simulate the (n-1) case, Figure 1 shows the Hamburg/Nord (HAMN) and Lübeck (LBEC) transformer stations in detail. If one of the two systems between Hamburg/Nord and Lübeck fails, the rest of the system is overloaded (118%). The overloading cannot be relieved by switching measures.

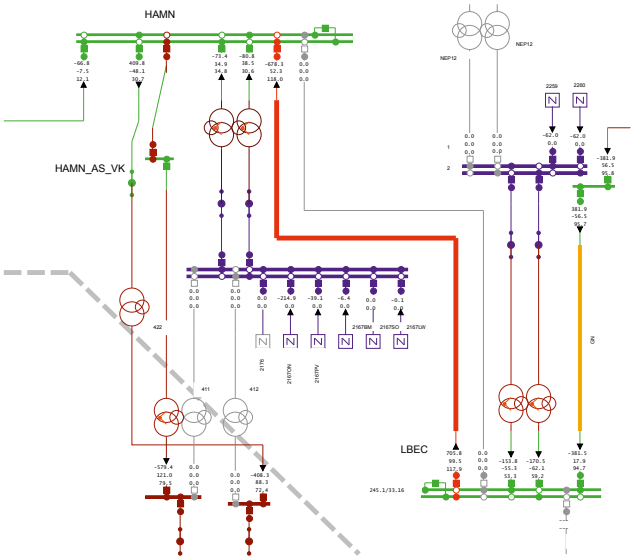

Figure 1: Lübeck (LBEC) and Hamburg/Nord (HAMN) transformer stations with (n-1) situation without measure 50.

The next step involves undertaking the same assessment but with the new planned measure. Figure 2 shows measure 50 in operation and the 220 kV systems between Lübeck and Hamburg/Nord switched off. If now one of the two 380 kV systems between Lübeck and the District of Segeberg fails, the parallel system is 45.5% utilized. Measure 50 enables the situation to be prevailed with (n-1) certainty, as assessment of other failures does not lead to overloads. Measure 50 was hence classed as effective.

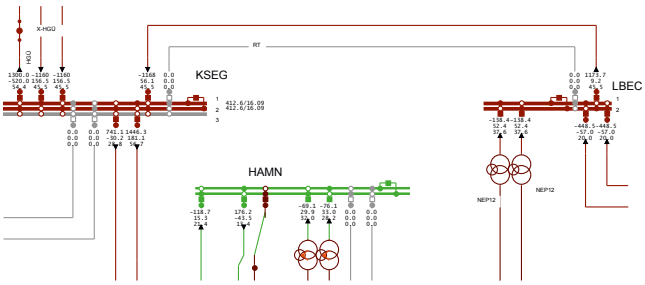

Figure 2: District of Segeberg (KSEG), Lübeck (LBEC), and Hamburg/Nord (HAMN) transformer stations with (n-1) situation. Measure 50 is active.

Necessity. Measures that are approved in the grid development plan must generate benefits for the grid even if the boundary conditions change. Examples of the latter are changes to the statutory requirements or assumptions in the scenario about the planning timescale. A measure is consequently necessary if it has a certain robustness to changes to the grid development plans, and even to changes to the starting parameters.

To quantity the necessity, the maximum utilization of a measure during a year was determined. The line utilization in an hour (hi) here is defined as the ratio of the electricity load ($I(h_i)$) to the nominal maximum load of the line (I_r) (see equation (1)).

$$p\%(h_i) = \frac{I(h_i)}{I_r} \cdot 100\% \quad (1)$$

For the assessment, a measure is deemed necessary if its maximum utilization was at least 20% (see (2)).

$$\max_{i=1}^{8760}(p\%(h_i)) \geq 20\%: \quad (2)$$

The choice of a limit load of 20% was made for the following two reasons:

The required minimum line load must not be chosen too high so as to be impractical for subsequent grid operation if there are operation-related shutdowns or other such events. High line loads are generally not able to absorb the failure of other operating systems.

The utilization limit must also not be chosen too low so as to make the measure necessary under changed boundary conditions. The value of 20% was chosen because below this value it is also possible for grid expansion in lower level grids or other technical variants. The necessity criterion only gives meaningful results for alternating current measures, because there the utilization follows from the physical principles of the network grid. For direct current measures (HVDC), the utilization can be set by controlling the converters. Here the Federal Network Agency has embraced the results of the expert report of TU Graz [10] for the grid development plan 2012 and the grid development plan 2013. The report comes to the conclusion that "the necessity and benefits of controllable transport corridors is evident", but that "assessment of the utilization of the four extra-high voltage corridors proposed by the TSOs shows that a solution with a fewer number of corridors would be preferable."

The assessment of the necessity was undertaken using a data set of the "target grid", which shows the planned expansion of scenario B2023 in the normal state of operation and which the Federal Network Agency received for assessment in addition to the individual grid utilization cases. Using the target grid, the annual utilization curves for the specific measures were determined by calculating all 8760 grid utilization cases and evaluating the necessity of the measures in the grid development plan. The line utilization for project P72 M50 Lübeck – District of Segeberg is shown in Figure 3. The maximum utilization is 30.6%. The measure is therefore necessary.

Further development of assessment methods

The Federal Network Agency will trial various improvements for grid assessment over the coming years. Some will have a major effect on the currently used procedures and are difficult to implement.

Selection of grid utilization cases and weather years. Despite increasing the grid utilization cases to 8760 hours per scenario, only a two-digit number of the (n-1) calculations is relevant for the design of the grid. It must be checked whether a selection of individual hours or selected time periods (e.g. weeks) from long weather time series is appropriate.

More scenarios / sensitivities. The procedure up until now puts the reference scenario to the fore, knowing however that the future will not be exactly like this. There is more uncertainty, however, in the range of the grid utilization cases and the choice of selection criteria. Various contributions to consultations and scientific studies [11] have urged greater consideration of further scenarios. This does not necessarily lead to greater legitimacy of the assessment results because no scenario can accurately forecast actual future developments. With regard to the comprehensiveness of the methodology demanded by the legislator, a compromise must also be found between complexity and manageability.

Time periods versus points in time. A further key point is the focus on a point in time 10 years hence (and also to a lesser extent on a point in time 20 years hence). The same studies [11] provide reason for more continuous assessment over shorter time periods. It is not disputed that procedures over short time periods, considering a lot of points in time, are more suitable for avoiding a so-called "lock-in". With regard

to transmission grid planning, however, there has up until now been no indication that local optima provide significantly lower efficiency with respect to technical or economic assessment standards.

Status-dependent assessment criteria. In order to be robust, an abnormal parameter set for already approved lines is also conceivable. Taken from control technology, the term hysteresis would be suitable for this. This was so prevent an often changing assessment result for lines whose necessity is only just justified. Instead, stricter requirements would be put on lines that are not (yet) approved. In principle, approved lines would only be subject to limited assessment in the following years.

In addition, there remain other considerations such as the dependence of the scope of the assessment on the size of the project (should the same criteria apply for a short AC grid expansion and an HVDC electricity highway) and the matter of procedural dependence of the solution (to what extent is a "very good" long-term solution overlooked because "good" solutions are approved in the short-scale iteration steps of the grid development plan).

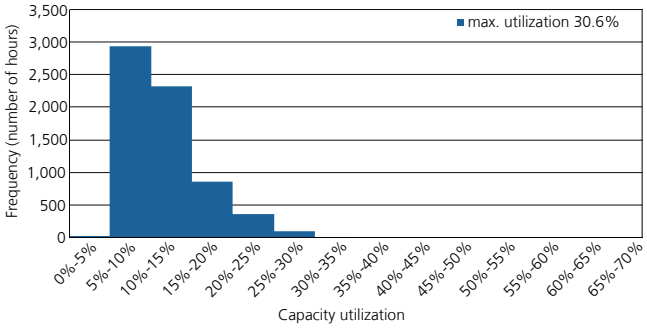

Figure 3: Line utilization for measure 50 over 8760 hours

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