Implication of Renewable Power Plants Allocation in Transmission and Distribution Grids

Monsalve, Cristian
Fraunhofer IOSB-AST
Ilmenau, Germany
cristian.monsalve@iosb-ast.fraunhofer.de

Kharboutli, Samir
Fraunhofer IOSB-AST
Ilmenau, Germany
samir.kharboutli@iosb-ast.fraunhofer.de

Nicolai, Steffen
Fraunhofer IOSB-AST
Ilmenau, Germany
steffen.nicolai@iosb-ast.fraunhofer.de

***Abstract*— This paper presents how the implication of allocation of renewable energies in transmission and distribution grids can be assessed with the aim to determine development strategies for the integration of these technologies. The scientific contribution of this paper is on the one hand, the definition of development scenarios for the allocation of renewable energies in Germany, considering political, technological and socio-economic factors and on the other hand, the assessment of the development scenarios in transmission and distribution grids, with focus on regions with high development of wind and PV power plants.**

Keywords—Energy balance, energy scenarios, renewable energy, reference networks, distribution grids, grid simulation

I. Introduction

The funding and development of renewable power plants have impacts on the transmission and distribution grids such as increase of grid congestion, reduction of grid stability, among others. Most of these impacts are associated with the highly fluctuating feed-in and widespread dispersion of some of these power plants. In order to overcome some of these effects, it is possible to balance energy supply and demand locally or regionally, which reduces the transported energy among the grid and may improve the dynamic stability. In this sense, common solutions are load and generation management, storage systems or grid expansions, which allow an enhanced energy balance along the grid [1].

This survey as part of the Fraunhofer project "Demand Analysis of Energy Storage 2 – BAES II"[1], addresses the problem from another perspective. Instead of balancing the energy demand locally by implementing additional control systems, it proposes the evaluation and determination of the impacts on transmission and distribution grids for different expansion scenarios. The results of this study are on the one hand, the determination of possible expansion plans for renewable power plants in different regions of Germany, which leads to a minimization of the energy unbalance and reduction of the impacts from integrating renewable energy power plants in each of these regions. On the other hand, the detailed assessment of reference regions with predominant supply from PV and wind power plants from high to low voltage levels illustrates an additional contribution of this paper.

This paper is organized as follows. The section II describes the development of the scenarios and their characteristics. The section III presents an assessment and comparison of effects of each scenario on the German high voltage grid. Subsequently, the section IV presents an assessment of the distribution grid in two characteristic regions in Germany. Finally, the section V concludes the results obtained in this study.

II. Scenario selection

As mentioned in section I, the main objective of this study is the assessment of implications from integrating renewable power plants on the transmission and distribution grids. It requires the development of different scenarios, which represent possible states of the grids for the year 2030. These scenarios represent the transformation of the grid in accordance to general strategies, considering the interdependency of energy distribution and social factors in Germany as well as climate protection goals and political targets.

The scenarios developed for this study are divided into three classes: explorative, normative and mixed. The explorative scenarios are based on expansion prognosis of power plants in accordance to trend analysis. The normative scenarios are strategy oriented and used for long-term decision-making. Their considered strategies attempt to minimize the ecological impact while maintaining cost efficiency. Finally, the mixed scenarios combine the explorative and normative scenarios allowing the consideration of different aspects (technological, political and economic). The review of methodologies used for developing future energy scenarios is out of the scope of this paper, however this review is detailed on the project report in [1].

It is important to emphasize that the regional model used in this study is based on [2]. This model groups the German municipalities into 146 reference regions based on demographic and electricity consumption and supply characteristics. The following sub-sections describe the characteristics of each scenario, which is the starting point for the assessment of the effects on transmission and distribution grids.

A. Development of scenarios

Since the funding of renewable power plants is influenced by politics and development plans on each federal state in Germany,

Project funded by the Federal Ministry for Economic Affairs and Energy
Project Reference: FKZ 03ET4016

978-1-5386-2910-9/18/$31.00 ©2018 IEEE

objectives and extension criteria must be established for the development of each scenario. The objectives for funding of renewable power plants are generally economic and ideological. On the one hand, economic objectives are influenced by operational costs of power plants and macro-economic aspects (e.g. resource quality), while ideological objectives are complex and depend on diverse factors such as ecological preservation, interest on specific technologies, sustainability, among others [3], [4]. The correlation between these factors and the distribution of renewable power plants is complex and may differ from state to state. For this reason, ideological objectives are not considered within this study.

The economic objectives used in this study are feasible operation cost and macro-economic cost reduction. For each objective different extension criteria were defined. Table I summarizes the reference objectives and extension criteria considered as a basis for the determination of the energy scenarios.

TABLE I. SCENARIOS OBJECTIVES AND EXTENSION CRITERIA

Objective	Extension Criteria	Description
Feasible operational costs	Yield from power plant	Concerning the economic feasibility of the power plant
	Resource Quality	Maximize the resource potential of each technology
Macro-economic cost reduction	Resource Quality	Cost reduction by means of use existent infrastructure (Scale effect)
	Consumption centers	Development of power plant close to large consumption center in order to reduce transported energy between regions
	Energy Balanced Demand (EBD[a]) reduction	Reduction of the energy unbalance overall the reference regions

[a.] EBD is the result from the energy supply minus the energy demand over a time interval

B. Definion of scenarios

In accordance to the objectives and extension criteria of the power plants, four scenarios were defined for the year 2030: business as usual (BAU), consumer oriented (Con-Or), onshore instead offshore (OsO), and EBD oriented (EBD-Or).

The scenario BAU corresponds to the reference scenario and has feasible operational cost of the power plants while increasing the resource quality as objective. This scenario considers the historical development trends of each technology and resource potential in each region. In this sense, the extension criteria of the power plants follows the evolution of each technology and optimal allocation in terms of maximizing the resource potential.

The scenarios Con-Or and OsO contain the macro-economic costs reduction which is designed to increase the efficiency of the grid and implementation cost reduction by means of using the existent grid infrastructure. However, the extension criteria differs in both scenarios. While Con-Or scenario attempts to locate the power plant close to the large consumption centers, the OsO scenario attempts to replace the offshore power plants with onshore power plants.

Finally, the EBD-Or scenario corresponds to an extreme case of the BAU, which allocation criteria is the reduction of the positive EBD. This means, this scenario attempts to reduce the supply gap on each reference region. The Table II summarizes the scenario objectives and allocation criteria.

C. Common assumptions

The evaluation and assessment of the different scenarios have to consider a common framework. This framework has regard to national targets for the development and funding of the different technologies in Germany, as well as the prognosis of energy consumption and production in 2030. These two factors are described as follows.

TABLE II. SCENARIOS OBJECTIVES AND EXTENSION CRITERIA

Scenario	Objective	Extension Criteria
Bussines as usual	Feasible operational costs (Refererence scenario)	Resource quality
Consumer oriented	Macro-economic costs reduction	Consumption centers
Onshore instead Offshore	Macro-economic costs reduction	Resource quality
EBD-Oriented	EBD reduction	Positive EBD in reference scenario

1) Energy consumption

The energy consumption used in this study is based on [5]. This reference study states that in 2030 the gross energy consumption will be 558 TWh/y. From this consumption, renewable energies will produce more than 50% of the gross consumption [6]. However, the gross consumption in this study will not consider electro-mobility and storage consumption. This leads to a net gross consumption of 450 TWh/y distributed in four consumption groups: households (26%), agriculture (2%), commercial (26%) and industrial (46%).

With help of the *Model for Estimation of Local Energy Balancing Demand* – MELENA developed by Fraunhofer UMSICHT [2], the energy consumption was calculated on each reference region considering geographical and demographical characteristics. Fig. 1 illustrates the annual energy demand on each reference region. This distribution is the base case used for all the energy scenarios explained previously.

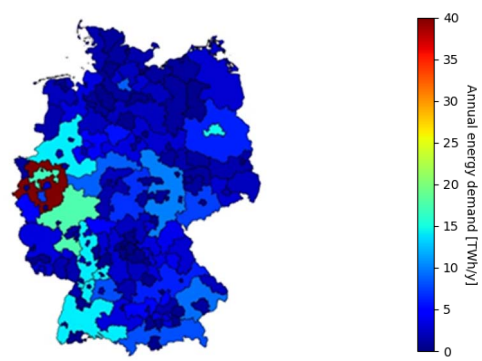


Fig. 1. Annual energy demand [TWh/y] in the model regions in 2030

2) Energy production

The last common assumption of the scenarios is related to the installed capacity and produced energy by renewable energies, which values are based on the scenario A from [5]. The prognosis of these assumptions takes account in the quantitative target of the national government, as well as, demographic, structural and

economic developments. For example, it considers no energy produced by nuclear power plants in 2030. Table III illustrates the installed capacity by technology in 2030.

Finally, Table IV summarizes the produced energy form renewable energies in 2030. These are the reference values for the location of the power plants on each energy scenario.

TABLE III. INSTALLED CAPACITY PER TECHNOLOGY IN 2030 [5]

Technology	Hard coal	Lignite	Biomass	Gas + Oil
Installed Capacity [GW]	14.4	6.3	9.88	5.9
Technology	**Hydro**	**Wind**	**PV**	**Geothermal**
Installed Capacity [GW]	4.9	6.7	6.1	1.0

TABLE IV. PRODUCED ENERGY FROM RENEWABLE ENERGIES IN 2030 [5]

Type	Biomass	Geothermal	Photovoltaic
Produced Energy [TWh]	56.9	6.5	55.1
Type	**Hydro**	**Wind Offshore**	**Wind Onshore**
Produced Energy [TWh]	23.4	89.4	100.5

D. *Comparison scenarios*

The extension criteria of the power plants and objectives of each scenario lead to variation of the generated energy from renewables respecting the common framework values shown in Table IV.

Fig. 2 shows that in scenario EBD-Or, the produced energy by wind energy plants is reduced and the energy from photovoltaic is increased compared with the rest of the scenarios. Furthermore, in scenario OsO the amount of energy produced by wind offshore is reduced and the energy from onshore is increased.

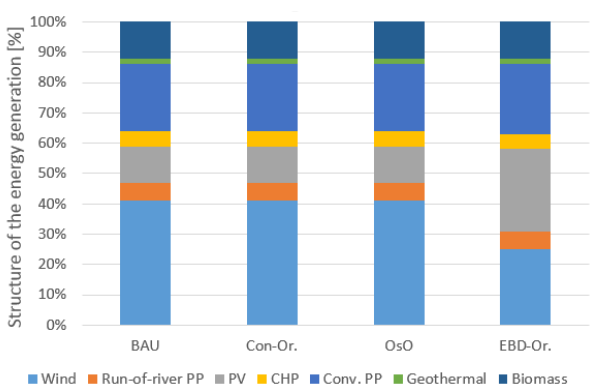


Fig. 2. Summary of produced energy in the evaluated scenarios

III. ASSESMENT OF GERMAN TRANSMISSION GRID

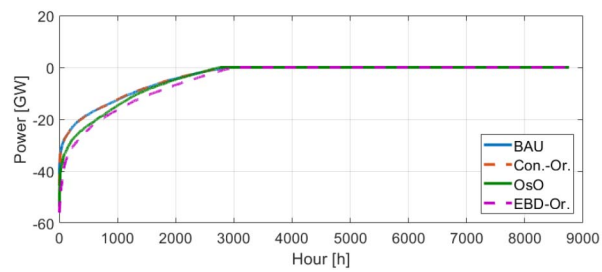
This section shows the comparison of the different scenarios from two perspectives. The first one assesses and compares the scenarios without grid restrictions, while the second one considers grid restrictions by means of power flow simulations of the transmission grid model developed in [2].

The first perstective aims to assess the scenarios from a strategical point of view and assess the performance in terms of the EBD. Subsequently, the second gives a general idea of which energy scenarios would require highest investment costs in grid reinforcements.

A. *Comparison without network restrictions*

As mentioned before, the comparison of the energy scenarios without restriction aims to evaluate them from a strategical perspective. In this sense, the first performance parameter is the EBD, which gives an overview of the scenarios that improve the energy balance in Germany, as well as, a general idea of the power flow. Furthermore, the second performance parameter is the amount of regions with balanced EBD.

Fig. 3 illustrates the EBD duration curve for the evaluated scenarios. It is possible to observe that the scenarios BAU and Con-Or present small differences and the minimum value of the negative yearly EBD, meaning that both scenarios reduce the energy imported to Germany. On the other hand, the scenario EBD-Or has the maximum yearly EBD in comparison with the other scenarios. However, this is the only scenario with a positive EBD.



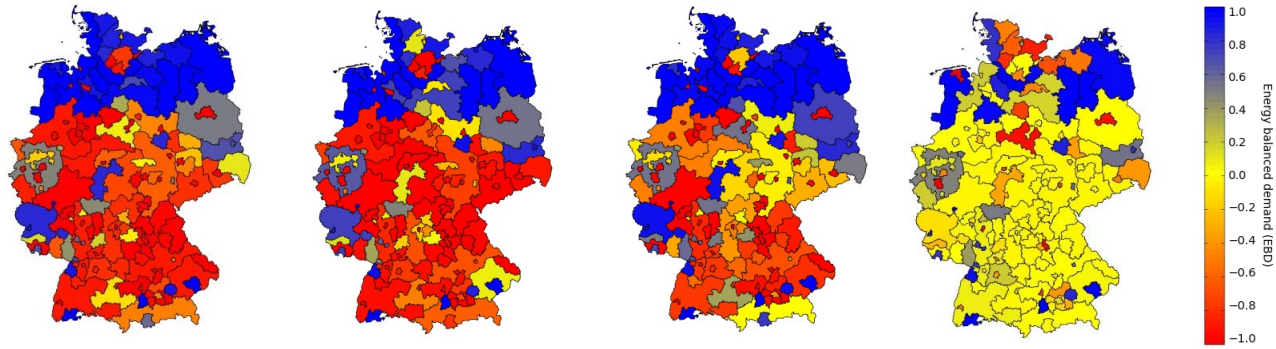
Type	BAU	Con-Or	OsO	EBD-Or
Sum. yearly pos. EBD [TWh]	0.00	0.00	0.00	0.01
Sum. yearly neg. EBD [TWh]	-29.20	-29.03	-34.40	-40.28
Max. pos. balanced power [GW]	0.0	0.0	0.0	2.80
Max. neg. balanced power [GW]	-44.40	-45.53	-53.68	-56.00

Fig. 3. Ordered EBD duration curve for each energy scenario and summary of main parameters

Nevertheless, the yearly EBD gives general information about the load during a year. In order to make a detailed assessment of the scenarios performance, the MELENA model calculate the EBD for each scenario in accordance to the objectives defined in the section II. Fig. 4 illustrates the normalized EBD results for each scenario. The regions with negative EBD (red) correspond to regions considered net energy importers while regions with positive EBD (blue) are net energy exporters. Finally, regions with an EBD close to '0' (yellow) are balanced region, which means the energy demand and production are comparable.

In Fig. 4, it is observed that the scenarios BAU and Con-Or have some specific differences in some regions, but in general the distribution of the EBD is similar. The regions with a positive EBD are located at the north while regions with negative EBD are often located in the middle and south of Germany indicating a power flow from north to south.

In the scenario OsO, regions with positive EBD concentrate at the north and regions with negative EBD concentrate at the south.



a. b. c. d.

Fig. 4. Summary of produced energy in the evaluation scenarios a) BAU b) Con-Or c) OsO and d) EBD-Or

Unlike BAU and Con-Or, the regions in the middle of the country have an EBD more balanced as consequence of the increase of the onshore wind generation in these regions. Finally, the scenario EBD-Or differentiate clearly from the other. This is caused by the definition of the extension criteria, which reduces the positive EBD in the region resulting in large amount of regions with balanced EBD.

Based on the assessment of the EBD, the regions were classified into five EBD classes: exclusive positive [-1, -0.8], predominant positive [-0.8,-0.2], balanced [-0.2, 0.2], predominant negative [0.2, 0.8], and exclusive negative [0.8, 1].

From the evaluation of the EBD in the regions, it may be possible to conclude that the more balanced region the lower energy transported on the grid, which at the same time may reduce the overloading of the transmission lines and other grid elements. Based on this performance criteria, the scenario EBD-Or is the one with higher performance as shown in Table V.

Nevertheless, this is not always the case, because even an EBD balanced region may have a considerable EBD variation during a day, which leads to lines overloading in short time periods. In this sense, the following subsection shows a detailed assessment considering network restrictions.

TABLE V. AMOUNT OF REGIONS PER EBD CLASS ON EACH SCENARIO

Type	BAU	Con-Or	OsO	EBD-Or
Exclusive pos.	76	69	52	7
Predominant pos.	21	16	27	24
Balanced	8	13	14	81
Predominant neg.	14	12	22	13
Exclusive neg.	30	36	31	18

B. *Simulation with grid coupling*

The assessment of the scenarios with grid coupling makes use of the transmission grid model developed in [2]. Each region represents a node in the high voltage (HV) grid level with consumption and generation. The parameters for the consumption and generation were adjusted in the grid model in accordance to the outputs from the MELENA model. Afterwards, quasi-dynamic simulations were performed in DigSilent PowerFactory.

The results assessment used a developed software created for this project called GATES (GIS-Based Analysis Tool for Energy Systems). This tool reads the simulation results from PowerFactory and evaluates the operational state of grid and lines based on their loading. Table VI summarizes the performance criteria from the simulations for each scenario.

The scenarios BAU and Con-Or are characterized by a power flow from north to south. In this sense, the lines in norther regions as well as lines that interconnect norther with central regions have a high loading (> 50%). These scenarios have the highest loading of a line (360%), but at the same time, more lines are under normal operation (loading < 50%).

On the other hand, the scenario OsO is characterized by an increase of installed capacity of wind power plant in central regions of Germany. As consequence, this scenario increases the loading of the lines in central regions, reducing the amount of lines under normal operation in comparison with the scenarios BAU and Con-Or. Nevertheless, the power generation from wind power plants in this scenario is distributed in norther and central regions, reducing the maximum loading of the norther lines (max. line loading 197%).

Finally, the scenario EBD-Or reduces the installed capacity from wind power plants while increasing the installed capacity from PV power plants. As consequence, it increases the overall loading of the lines in the neighbor of the largest consumption centers and decrease the amount of critical lines (15 lines) in comparison with other scenarios. Furthermore, the maximum loading of a line is higher than in OsO but lower than in the other scenarios.

TABLE VI. PERFORMANCE CRITERIA FOR EACH ENERGY SCENARIO

Scenario	BAU	Con-Or	OsO	EBD-Or
Max. Line Loading (%)	360.19	360.17	197.96	213.06
Num. Lines with loading < 50%	131	134	118	119
Num. Lines with N-1 violation	41	41	51	58
Num. Critical Lines > 100%	20	19	23	15

IV. ASSESMENT SELECTED REGIONS

The previous section showed an assessment of the transmission level for each scenario. In order to have a complete assessment of the German grid, the energy scenarios were also evaluated in distribution levels of the grids. In this sense, two characteristic regions were selected for this purpose in accordance to the results

in [2]. The first region (R3) corresponds to a region in the north of Germany with a predominant energy generation from wind power plants. The second characteristic region (R126) corresponds to a south region of Germany with a predominant energy generation from PV power plants.

The detailed evaluation of the transmission and distribution grid in the characteristic regions requires a complete representation of the grid, which is not possible to obtain from public data. This study used a methodology for construction and parametrization of reference grids, which was developed in the context of this project [7]. Nevertheless, this methodology is out of scope of this paper.

Instead of assessing all the scenarios in the characteristic regions, the assessment consider the "extreme" scenarios and the BAU as reference scenario in each characteristic region. The term "extreme" corresponds to scenario with the minimum and maximum values EBD for each region [1].

The selected scenarios for R3 are BAU, OsO and EBD-Or and for R126 BAU and Con-Or. The similarities between the scenarios BAU and OsO and scenarios Con-Or and EBD-Or are the reason for the selection of just two scenarios in R126.

In R3, the energy generation from wind power plants in scenarios BAU and OsO is significantly, 75% and 82% respectively. Conversely, in scenario EBD-Or this value is reduced to 28% and the energy produced from PV power plants increased from 7% in BAU to 28% in EBD-Or. Similarly, in R126 the energy generated from wind power plants is reduced from 56% in BAU to 44% in Con-Or, while the energy generated from PV plants increased from 14% in BAU to 26% in Con-Or.

After evaluating the scenarios for each characteristic region, the assessment is performed in the HV (110 kV), MV (20 kV) and LV (0.4 kV) levels. In the first evaluation, each characteristic region were divided into supplied areas and the EBD is analyzed on each supply area as well as the performances criteria described on section IV. In case of the MV distribution grids, the evaluation considers three types of supplied areas: municipality, town and city. Each supply area type characterizes itself in terms of population density, load distribution, among others [7].

In R3, the scenarios BAU and OsO have some predominant positive supplied areas, due to the large amount of energy generated by wind power plants. The decrease of the generated energy from this source in scenario EBD-Or reduces the amount of predominant positive supplied areas and increases the predominant negative supplied areas. The Table VII shows the obtained simulation results.

Furthermore, the region R126 does not present any difference from both analyzed scenarios in terms of classification of the supplied areas. In this characteristic region, the exclusively and predominant positive regions correspond to regions with hydroelectric power plants, which do not differ in the evaluated scenarios. Due to the high energy demand in R126, the increment of generation from PV power plants in scenario Con-Or is not enough to change the distribution of supplied areas.

As stated in section IV, the scenario performance assessment makes use of the elements loading. Table VII summarizes the performance parameters for each characteristic region and evaluated scenarios. In R3, the increase of the maximum line loading in scenario OsO is explained by the increase of energy generation from offshore power plants in this region, but it does not clarify the increase of the maximum line loading in the scenario EBD-Or. In this case, the overloading is caused by power flow from neighbor regions, specifically power flow from south regions to supply the norther regions. Furthermore, overloading of transformers happens only in the scenario OsO, as effect of the generation from offshore wind power plants in periods of low demand.

The Table VII shows also the same analysis for the characteristic region R126. In this region, the overall performance of the grid decreases in the scenario Con-Or in comparison with the scenario BAU. This is a result of the location of PV power plants in the R126. The highest potential areas for PV are areas with relative low energy demand (e.g. municipalities). This is reason why the energy flows to higher demand areas (e.g. cities) lead to higher lines loading and in overall reducing the grid performance.

TABLE VII. PERFORMANCE ANALYSIS FOR HV GRID IN SUPPLIED AREAS

Region	**R3**			**R126**	
Scenario	**BAU**	**OsO**	**EBD-Or**	**BAU**	**Con-Or**
Exclusive pos.	0	1	0	0	0
Predominant. pos.	3	4	0	4	4
Balanced	8	7	8	38	38
Predominant neg.	3	2	4	3	3
Exclusive neg.	0	0	1	1	1
Num. Lines	17	17	17	0	0
Max. Line Loading (%)	84	113	118	98	70
Num. Lines with loading < 50%	9	7	9	0	0
Num. Lines with N-1 violation	8	8	7	4	14
Num. Critical Lines > 100%	0	2	2	0	0
Transformer	5	5	5	6	6
<50%	1	0	1	5	3
<100%	4	4	4	1	3
>100	0	1	0	0	0

In the MV level, the evaluation depends on the demand characteristics of the supplied area in accordance to the results form [7]. In this sense, the performance evaluation was performed in municipalities, towns and cities bellowing to the characteristic regions. Table VIII shows the performance parameters obtained for each supply area type.

In Table VIII, it is possible to observe that in R3 all the MV lines operate in normal conditions (loading <50%) independent of the supply area type. Nevertheless, the performance of municipalities and towns is considerably reduced in scenario OsO. In this case, the low energy consumption sums up with high generation from wind power plants increasing the power flow from the MV to HV level and creating overloading in the substation transformers up to 103% in municipalities and 75% in towns.

In R126 the performance in both scenarios is very similar but for two parameters: lines number of n-1 violations and average transformer loading. First, the municipalities decrease their performance in scenario Con-Or as cause of the power feeding

back given by the increment of PV power plants and low demand in these areas, which has as consequence an increase of the HV/MV transformer loading. Finally, in cities the average loading of the HV/MV transformer is reduced but the amount of lines with n-1 violations duplicates in scenario Con-Or. This is explained by the feed-in from PV power plants in the proximity to the MV/LV substations, which leads to a power flow distribution and reverse power flow in short time intervals.

The last part of the performance and effects assessment corresponds to the evaluation of the LV level. However, in LV there is not a representative difference between the evaluated scenarios. This is explained by the fact that in LV networks most of the generated energy comes from PV installations and the variation of installed capacity in this voltage level is smaller in comparison with higher voltages levels [1].

TABLE VIII. PERFOMANCE ANALYSIS IN MV GRIDS. VALUES FOR EACH SUPPLIED AREA TYPE (MUNICIPALITY/TOWN/CITY)

Region	**R3**			**R126**	
Scenario	**BAU**	**OsO**	**EBD-Or**	**BAU**	**Con-Or**
Num. Lines	47/47/47	47/47/47	47/47/47	47/47/47	47/47/47
Max. Line Loading (%)	22/13/17	22/13/17	35/15/28	46/51/63	48/52/61
Num. Lines with loading < 50%	47/47/47	47/47/47	47/47/47	47/47/47	47/47/47
Num. Lines with N-1 violation	0/0/0	0/0/0	0/0/0	0/2/3	0/2/6
Max. Transformer Loading [%]	75/55/36	103/75/50	50/29/36	49/51/65	57/51/65
Average Transformer Loading [%]	15/18/8	9/11/7	11/15/14	26/30/24	28/27/22

V. CONCLUSIONS AND FINDINGS

This paper addresses the effects of the renewable energies integration in transmission and distribution grids under different expansion scenarios. The expansion scenarios introduced in this paper consider political and economic targets as well as different expansion criteria based on economical optimization functions (e.g. use of existent infrastructure).

Subsequently, this paper presents an assessment of the transmission grid for all the introduced scenarios. From this part it is possible to conclude that the scenario EBD-Or has the best performance in term of amount of regions classified as balances as well as a reduction of amount of lines under critical operation. However, this scenario present two main critics/disadvantages: increase of imported energy from neighbor countries as well as overall increase of lines with loading between (50% – 100%).

In order to assess the complete distribution grid two characteristic regions were selected. The first region (R3) with predominant energy production from wind power plants and the second region (R126) with predominant energy production from photovoltaic power plants. The assessment on each characteristic region was divided per voltages levels.

In HV level, the assessment was similar to the German transmission grid. In this sense, the reference and "extreme" scenarios were analyzed in each supplied area. In accordance to the performance parameters, the scenario with the best performance in R3 and R126 is BAU. In general this scenario presents the lower lines loading and more supplied areas classified between predominant negative and predominant positive. However, as mentioned in section IV, the overloading of the scenario EBD-Or in R3 are cause of the power flow from neighbor regions. If this power flow is ignored the scenario EBD-Or have a similar performance as the scenario BAU.

The assessment of the MV depends of the demographic characteristics of the distribution area. In this sense, the distribution areas were divided in three types: municipalities, towns and cities. In the characteristic region R3, the scenario EBD-Or has the best performance since it decreases considerably the transformers loading even when the maximum lines loading increase with respect to the other scenarios. It is important to note that these results apply for all the distribution area types in region R3. Furthermore, in R126 there are not significant differences between the assessed scenarios. Nevertheless, the scenario BAU reduces the amount of lines with loading between 50% and 100% in cities.

Finally, this paper discuss implications of integration of renewable energies in terms of different performance criteria, which demonstrate that in overall the scenario EBD-Or has the best performance in most of the cases. Nevertheless, network reinforcement have to be performed in some cases as exemplified in region R3.

REFERENCES

[1] C. Beier et al., "Demand analysis of energy storage 2 - Bedarfsanalyse Energiespeicher 2 – Abschlussberich BAES II," Fraunhofer UMSICHT; Fraunhofer IOSB/AST, Oberhausen/Ilmenau, 2017.

[2] C. Beier and P. Bretschneider, "Regional model based demand analysis of energy storage for balancing fluctuating energy supply – Abschlussbericht Modellbasierte, regional aufgelöste Analyse des Bedarfs an netzgekoppelten elektrischen Energiespeichern zum Ausgleich fluktuierender Energien - BAES I," Oberhausen/Ilmenau, 2013.

[3] Agentur für Erneuerbare Energien e.V., "Acceptance and citizen participation in renewable energies - Akzeptanz und Bürgerbeteiligung für Erneuerbare Energien- Erkenntnisse aus der Akzeptanz und Partizipationsforschung. Renews Spezial Ausgabe 60. November 2012." Agentur für Erneuerbare Energien e.V, 2012.

[4] P. Schweizer-Ries, I. Rau, and J. Hildebrand, "Research acceptance and participation in energy sustainability - Akzeptanz- und Partizipationsforschung zu Energienachhaltigkeit," FVEE Themen, pp. 138–144, 2011.

[5] J. Kroh et al., "Supraregional potentials of local innovation impulses - Überregionale Potentiale lokaler Innovationsimpulse – Zur Diffusion sozio-technischer Innovationen im Bereich erneuerbarer Energien," Center for Environmental Systems Research, 2012.

[6] J. Nitsch, T. Pregger, T. Naegler, D. Heide, D. Luca deTena, and F. Trieb, "Longterm scenarios and strategies for development of renewable energies in Germany - Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global," 2012.

[7] J. Büchner, O. Flörcken, S. Dierkes, L. Verheggen, and M. Uslar, "Moderne Verteilernetze für Deutschland," no. 44, p. 209, 2014.

[8] C. Monsalve, S. Kharboutli, and S. Nicolai, "Methodology to generate MV and LV reference network models (RNMs) from public data," in NEIS 2017 - Conference on Sustainable Energy Supply and Energy Storage Systems, 2017.