Resource Adequacy Methodologies – future flexibility options added to Austria's generation fleet and its impact on adequacy

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Abstract

Since the overall generation system in Europe is undergoing drastic change, away from big thermal generation units towards high volatile generation from Renewable Energy Sources (RES), the incorporation of future flexibility options is of outmost importance to ensure security of supply within the European transmission system. Transmission System Operators (TSOs) perform regular assessments to provide information on security levels of supply, by executing resource adequacy assessments. By performing those assessments a probabilistic approach is used, which enables to take into account stochastic uncertainty resulting from RES generation. Not only the change on the generation side needs to be closely monitored, but also the increase in demand due to additions like heat pumps, electronic vehicles or data centres needs to be observed. Within this paper, the development on the demand side and its impact on adequacy indicators is assessed by performing calculations using a tri-lateral test model. This model is also used to get a first insight on result development when adding possible flexible sources like batteries and Demand Side Response (DSR) to the generation system. First results of these additions are discussed within this paper, but it needs to be highlighted that future fine-tuning of the modelling approach is needed to properly reflect flexible sources in future adequacy models.

1 Introduction

Ensuring security of supply is one of the key tasks of a Transmission System Operator (TSO). Since the overall electricity generation mix in Europe will drastically change in the upcoming years, TSOs are forced to elaborate and execute processes, which are capable to determine future levels of security of supply per country. The Clean Energy Package for all Europeans especially the Regulation 943/2019 [1] foster the European Network for Transmission System Operators for Electricity (ENTSO-E) to perform the European Resource Adequacy Assessment (ERAA). European TSOs deliver input data for this once a year-executed process as well as for seasonal processes like the Winter or Summer Outlook, which are also executed following a probabilistic approach. This probabilistic approach started with the Mid Term Adequacy Forecast 2017. Since 2021, this process is named the European Resource Adequacy Assessment (ERAA). The probabilistic approach uses Monte Carlo Simulations, which help to take into account uncertainties due to climate dependent input variables like renewable generation or temperature dependent demand.

1.1 Input Data – installed Capacities in Austria

For the analysis carried out in this paper, the base case model of the Mid Term Adequacy Forecast (MAF) 2020 was used. The MAF 2020 focused on the target years 2025 and 2030. Figure 1 shows the overview of the installed generation fleet for Austria for the years 2025 and 2030.

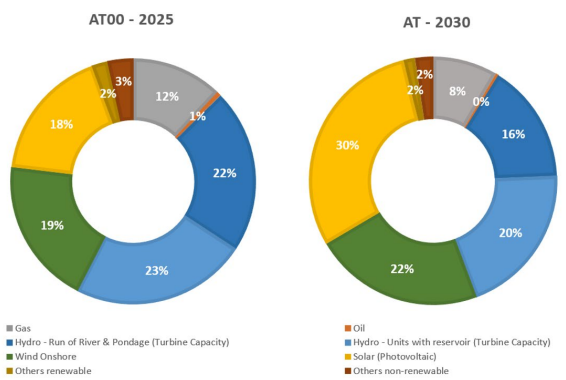

Figure 1 – Austria - installed Capacities in MAF 2020 [2]

Figure 1 highlights the fact that Austria, next to being a very hydro dominated country, will have >50% of its installed generation being provided by wind and solar in 2030. Wind and solar units show a very volatile production behaviour, fully dependent on climate conditions.

1.2 Development of renewable generation in Austria

Following the goals provided by the government back in 2018, when Austria's position paper #mission2030 was released, a total of 9 GW wind and 12 GW photovoltaics were assumed to be installed by 2030 [3], and thus placed as input data for the Mid Term Adequacy Forecast (MAF) 2020.

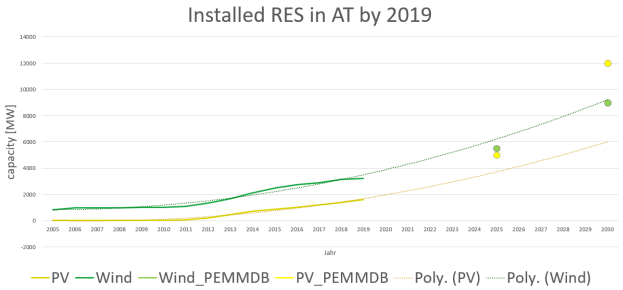

Figure 2 – RES development in Austria [4]

Figure 2 shows the development of wind and solar installed capacities of the recent past and an approximation for future, in case the development proceeds with the same pace (dotted line) as well as the goals provided for 2030, namely 12 GW of installed PV capacity and 9 GW wind. The thick lines provide real installed capacities according to the Austrian regulatory authority and the dots in 2025 and 2030 indicate the goals given by the governmental goals. The thin lines indicate the values APG assumed following a polynomial development.

Taking the assumptions for installed capacities of PV and Wind and scaling a load demand curve from 2018 to 2030, excluding thermal production, the following picture arises.

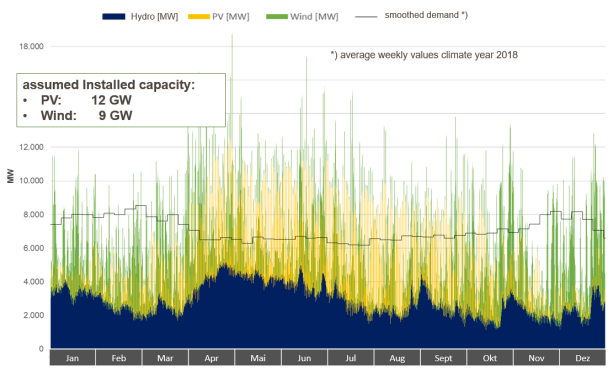

Figure 3 – supply demand curve estimate in 2030 (APG)

Figure 3 shows a clear seasonal behaviour of wind and solar production, which highly oversupplies Austria's demand during summer months and shows high import needs for the winter season. It is not granted that these import needs can be supplied by the given net transfer capacities (NTCs), thus Austria might end up in scarcity situations.

Given the development of installed renewable generation in Austria, the question of storage capabilities and flexible demand arises. Next to hydro storage capabilities of Austria's hydro fleet with a total of 2,5 TWh reservoir size and a pump capacity of 2,5 GW installed in 2020 the future growth of flexibilities in the grid will play an important role.

Most of this flexible behaviour of the system will be placed on the demand side. Therefore, for future adequacy assessments not only the development of a generation fleet of a country, but also the developments on the demand side need to be closely monitored. As part of those developments electronic vehicles, heat pumps, battery storages at the residential sites need to be accounted, as well as developments on the industrial sites need to be assessed.

To start with, the development of demand due to increased amounts of electronic vehicles and heat pumps in the operational process will be elaborated. In a later step the behaviour of additional load rising from data centres will be assessed, and finally investigations on demand side response and battery storage usage are explained.

2 Methodology

Based on the input data of MAF 2020, a trilateral model consisting of Austria and two additional country nodes was created. This trilateral model already served as basis for various investigations on input parameters, since it demands less computational power and thus less computational time.

2.1 Mid Term Adequacy Forecast – basic methodology

The methodology used for our demand investigation follows the MAF approach. The MAF methodology is based on a one node European model, meaning each country is represented by one country node, connected to its neighbours via predefined net transfer capacities (NTCs). For bigger countries like Italy, Norway and Sweden, several nodes are used for representation, but for the final report, the individual results of those country nodes are again aggregated.
For each node the full generation fleet is represented, meaning each TSO provides his best estimates of installed generation capacities for the relative target year, as well as system reserve requirements, DSR and Net Transfer Capacities.

For wind and solar these capacities are then multiplied with load factors provided by the pan European climate database (PECD), leading to 35 time series for input data of renewables. Since MAF 2020, also 35 time series for

historical hydro inflows are used to represent the stochastic behaviour of hydro units.

Next to the representation of the generation fleet, also the demand time series need to be prepared to serve as input for the calculation. Chapter 2.2 will elaborate in more detail on the demand time series creation.

When time series for all input data are available, a Monte Carlo approach is used to merge input data of 35 historic time series for renewables with random draws for unplanned outages to end up with several hundreds of market simulations which are then executed one after another or in parallel (depending on the system architecture).

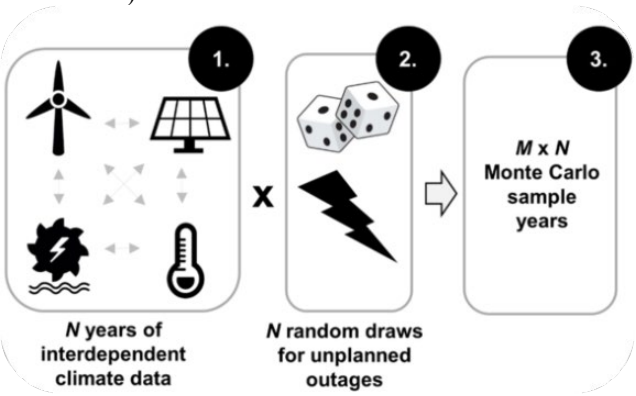

Figure 4 – Monte Carlo sampling [5]

Each of the Monte Carlo sample years follows a Unit Commitment and Economic Dispatch (UCED) approach, assuming perfect market foresight.

As a result of these several hundreds of market simulations, averaged values for the following two adequacy indicators are provided for each country node:

Energy Not Supplied (ENS) [MWh/year] is the energy not supplied by the generating system due to the demand exceeding the available generating and import capacity [5].

Loss Of Load Expectation (LOLE) [h/year] is the number of hours in a given period (year) in which the available generation plus import cannot cover the load in an area or region [5].

2.2 demand time series creation

TSOs shall provide demand time series based on climate conditions from the above-mentioned 35 historic years, reflecting the demand growth including future developments for heat pumps (HPs), electronic vehicles (EVs), data centres (DCs), batteries, etc. Therefore, a regression method is used, which trains a model based on historic demand time series dating from 2012-2016 and climate variables from these training years comprising population weighted temperature, city temperature, irradiance, wind speed and a holiday calendar for the relative country. After successful training of the model, input data for the development of heat pumps, electronic vehicles including their daily load profiles as well as climatic variable profiles for the historical years are added in order to forecast the load time series of the target year [6].

Since each of this newly added load addition follows a certain behaviour, for the following analysis, each component was individually added to the standard load curve and the impact on the tri-lateral model was assessed in terms of Energy Not Supplied and Loss of Load Expectation. Since this is an experimental environment, the load curve was created based on latest available information available at APG and thus, differs from the load curve used in MAF 2020.

2.3 tri-lateral test model used for the study

For the analysis carried out within this paper a tri-lateral test model was used. This test-model was developed during a Master Thesis in 2019 and since then serves as academic test model within APG [7]. It includes Austria and two neighbouring countries. For the proper representation of the hydro fleet supplementary nodes for hydro production are added to each country node and for experiments with batteries, two supportive nodes are also part of the test system. For the calculation itself, the Antares simulator was used. Antares is an adequacy calculation tool, which was developed by the French TSO and is available open source [8].

The above described model served as basis for various test calculations, where the generation input data always stayed constant (same like in the MAF process), but the demand time series varied.

For the first investigations, electronic vehicles entering the market in 2025 increased the base demand, followed by heat pumps also added in 2025.

The second investigation assessed additional load due to demand centres, which will most likely enter the Austrian market in 2030.

Both developments were concluded by the investigation how flexible elements like batteries and DSR may affect the adequacy indicators.

3 Results

3.1 electronic vehicles and heat pumps added in 2025

For the first assessment the base demand was increased by electronic vehicles, secondly by heat pumps and in a third step both of these technologies were added to the existing demand curve. As basis for the calculation, the MAF 2020 model for target year 2025 was taken. This assessment was performed with the knowledge that in 2025 installed

capacities of PV and wind are still lower compared to target year 2030. Since the assumptions for thermal capacity in 2025 and 2030 stayed the same, the model for target year 2025 will show higher impact on additions to the demand than for target year 2030. Results of the first calculation assessing the effect of electronic vehicles and heat pumps are displayed in table 1.

Table 1 – EVs and HPs added to the standard load curve

	Base	EVs	HPs	EVs + HPs
LOLE [h/a]	9,59	10,71	35,62	79,11
ENS [GWh/a]	10,07	11,78	46,24	117,56

Table 1 clearly indicates a deterioration of the adequacy indicators ENS and LOLE when EVs and HPs are added to the system. This increase of course worsens the overall adequacy situation by up to 8 times higher than the initial amount of LOLE calculated by the base case scenario and 12 times higher in regards of EENS if both technologies are added to the standard load curve.
Again, it has to be highlighted that this tri-lateral system is in high scarcity situation and cannot be compared with real situation, like the full European model. Due to the fact that only two neighbouring countries exist and provide potential available generation that can be imported in case of scarcity this setup cannot be compared with real operation and thus only serves for methodology exploration. The results serve as indications on methodological improvements, but do not provide any value, which reflects real operation.

3.2 additional load due to data centres added in 2030

A calculation focusing on the target year 2030 is executed, which reflects an additional load for future installed data centres. Such load addition is in a way simply to model, but for real operational business also means a constant additional band load, which has to be covered every hour of the year. Thus, the demand is expected to increase by 2030, even though for target year 2030 the adequacy indicators for the base case do result in lower numbers. The very high numbers of renewables installed in 2030, which next to their volatile generation behaviour also accumulate a huge amount of energy over the year, can explain the lower adequacy indicators.

Table 2 – additional load (DCs) added to demand in 2030

	Base	+ EVs, HPs, DCs
LOLE [h/a]	1,34	6,7
ENS [GWh/a]	1,64	9,7

Table 2 shows the overall increase of adequacy indicators when adding EVs, HPs and DCs in the test model for target year 2030. An increase of LOLE of about 5 times compared to the base demand can be seen. The increase of ENS is 6 times higher compared to the base case.

3.3 additional load in 2030 plus batteries and DSR

In chapter 3.1 and 3.2 the overall increase of demand due to additions like electronic vehicles, heat pumps and data centres was assessed. These additions are important to model in order to get an overall impression of the effect on adequacy indicators of such technologies entering the electricity market.

Also the options of curtailing or shifting demand by using demand side response or batteries installed is assessed in the following. Starting from the model in 2030 adding all above-mentioned technologies (EVs, HPs, and DCs) in a next step 5000 MWh of battery storage with installed capacity of 2500 MW and 500 MW installed DSR are added to the system.

What has to be noted is that the model until now was set up in a very basic approach for Austria. Meaning batteries do not yet respond to price signals and DSR is available for all hours of the day for an activation price of 500 €. Figure 3 shows adequacy indicators for 2030 when all above described additional demand plus batteries are added to the system.

Table 3 – base load + all additions + Batteries

	Base + all additions	+ batteries daily const.	+ batteries weekly const.
LOLE [h/a]	6,7	6,4	6,2
ENS [GWh/a]	9,7	9,5	8,9

Results presented in table 3 show a decrease of 0,3 hours of LOLE and 200MWh ENS when adding batteries being constraint on daily basis. Performing the same addition using weekly binding constraints the results differ compared to the base case by 0,5 hours of LOLE and 800MWh ENS.

Table 4 – base + all additions + DSR

	Base + addition	+500MW DSR 200€	+500MW DSR 100€
LOLE [h/a]	6,7	1,83	1,86
ENS [GWh/a]	9,7	2,3	2,3

Adding 500MW of DSR to the 2030 model, a decrease of 4,8 LOLE and 7,4 ENS compared to the base model including EVs, HPs and DCs can be seen. The difference in the price signal cannot be seen in this case, since the model is already very stressed and thus reacts in a similar way for both price bands.

500 MW of DSR added to the system shows a way higher impact on the results than adding the 2500 MW of batteries.
In this very first approach of adding these flexibilities to the system, DSR was added as a thermal generator reacting

to a price signal of 200 Euro or 1000 Euro, whereas batteries were added by an additional node using daily or weekly binding constraints and an efficiency of 90%. The charging and discharging of these additions might not be sufficient to follow the overall Unit Commitment and economic dispatch. Thus, more in-depth analysis on the hourly results are needed.
Since the tri-lateral model is already stressed by default, this test-environment might also not be the most suitable one for this type of investigation.

4 Conclusion

Results presented in this paper provide an overview of future additions to the load, which currently are modelled on the one hand side by adding them to the load time series using a regression tool to create the time series. These time series enter the model and are next to future generation profiles input to the Monte Carlo simulation. By adding these demand components, an overall increase of adequacy indicators can be seen when assessing results of the tri-lateral academic model.

The most significant increase of adequacy indicators due to additional load rises from heat pumps (4-times higher LOLE) as well as close to constant addition to the load due to data centres (5-times higher LOLE) values. In regards of improvement of adequacy indicators DSR plays an important role and needs to be investigated in more detail.

On the other hand, to reflect flexible behaviour of future components, those technologies need to be directly incorporated in the market model. For this investigation, additional country nodes were created for batteries, which act similar to closed loop pump storage units. For batteries an efficiency of 90% is used versus for pump storages 75% efficiency is assumed. Following the results presented in chapter 2.3 adequacy indicators are for this first investigation positively influenced by batteries and DSR.
Anyhow, during the investigations shown in chapter 2.3, it turned out that the simple assessment of behaviour of adequacy indicators on the tri-lateral test model seems not to be sufficient for in depth methodological investigation. In a future step, the details on hourly dispatch need to be investigated and a comparison using a different tool will be started.
The approach used by reflecting batteries adding an additional node and constraining the battery usage by daily or weekly boundary conditions might not be sufficient for future adequacy studies.

The investigations performed in this paper based on the simulation program Antares show on the one hand side, that new additions to the model of course influence the adequacy results. Furthermore, that the way of modelling influences the results and that the approach used within this tri-lateral model using the Antares simulator might not be sufficient for future usage of flexibilities in the adequacy models. Additional modelling approaches need to be explored, also using a different tools for proper reflection.

Finally, for future investigations, also the addition of possible entry into market of other flexibility options like electrolysers and electronic melting furnaces need to be assessed. This and further technology investigation is taken up in the ongoing research.

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