Network Development Plan 2040

Electricity Transmission Grid

creos

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Introduction

The mission of Creos is to ensure the security, the stability and the quality of supply of the energy transport and distribution networks and to serve the customers in a non-discriminatory way at transparent and regulated tariffs in the Grand Duchy of Luxembourg. This role is executed equally with respect to all suppliers and by respecting the company's public service and environmental protection obligations. Aware of the economic, social and environmental issues at stake, Creos has a long-standing commitment to the principles of sustainable development. The Corporate Social Responsibility policy is focused on the company's mission and values, and aims to make an effective contribution to changing the society we live in. The cornerstones of the day-to-day work of the company are respect, team spirit, commitment and excellence.

The planning of a sustainable, future-proof electrical infrastructure becomes more and more challenging due to the uncertainties of the future economic, social and environmental developments.

That targeted decarbonisation in the European Union and Luxembourg will surely lead to a general shift towards electrification for heating purposes and for public and personal transportation and the growing digitalization in our society will further impact the energy grids of tomorrow. In order to stay in line with the EU-targets of a reduction of greenhouse gas emissions, an expansion of the use of renewable energies, and an improvement of the energy efficiency, the electrical grids must be adapted consequently.

The European Network of Transmission System Operators for Electricity, the ENTSO-E also acknowledged the Clean Energy Package as a priority and calls for stronger cross-border cooperation, in order to distribute and resorb the highly variable electricity flows from the renewables and to avoid congestions. To avoid possible constraints, it is therefore appropriate to increase the cross-border transmission capacities, where needed.

The current trend in Luxembourg indicates that the shift towards a much higher percentage of volatile electricity generation from renewable energy sources may happen as fast as the increase of the electricity consumption, thus intensifying the need for a strong electrical transport and distribution grid. A volatile, uncontrollable generation and a high consumption will stress the electrical networks on all levels during the peak times.

Due to the publication of the National Energy and Climate Plan (NECP) by the Ministry of Energy and Spatial Planning and considering recent developments, new forecasts have been established for demand, supply, and import needs in the related document "Scenario Report 2040" in order to prepare for future necessities. The Scenario Report 2040 provides an outlook on the developments in Luxembourg's electricity sector, specifically those that are relevant for the high voltage grid of Creos Luxembourg.

The present document, the "Network Development Plan" aims to provide an understandable view of the existing electricity infrastructure, its current loading in normal supply condition and in degraded state. The limits and risks of the existing infrastructure are shown in relation with the projected increase of the power demand and of the intended electricity generation. Thereafter, the planned modifications and improvements of the high voltage grid of Creos Luxembourg are presented with the help of illustrations of the different completion phases of the intended reinforcement project.

Guideline values from the Scenario Report 2040

The dimensioning of the electrical grid is dictated by the moments the highest operational currents occur and those currents occur during the following situations:

- *When there is a high power demand and a low electricity generation*
  During those times, the high power demand has to be mainly supplied with the help of electricity imports, which will grow to maximum values then.
- *When there is a low power demand and a high power generation*
  Indeed, at the moment the generation grows higher than the consumption, the excess generation has to be transported to other consumption sites and it could even be exported to neighbouring countries. From that moment on, the decisive factor for the grid dimensioning will be the excess of power generation and no longer the consumption.

Peak demand and peak import

In the Scenario Report 2040, a prospective ordinary load that took into consideration different possible scenarios for the future growth of the industrial, tertiary and residential sectors has been determined. Additional trends such as the increased power demand for e-mobility and for other consumers, have been analysed considering their specific characteristics, modeled in detail and added separately to the ordinary load. Several growth scenarios for the e-mobility were used. The domestic electricity generation has also been thoroughly analysed and its future development forecasted. The estimated power contribution during peak demand was subtracted from the total peak load projection in order to obtain the forecast curves of the future peak import.

The installed national generation capacities, especially from renewable energy sources, are continuously increasing and will continue to do so in the coming decades. This fast-growing renewable energy generation will reduce the yearly amount of imported electricity. However, the guaranteed domestic power generated during the peak demand does not contribute enough to reduce the maximum electricity import needs for consumption purposes. This was illustrated in the report with the help of statistics showing that the share of the national power generation during peak consumption times has not grown over the last ten years, despite a doubling of the installed power of renewable energies. The power generated by those units is variable and subject to fluctuations; its contribution during peak demand times is therefore not guaranteed.

Consequently, in order to ensure the security of supply, the import capacities must be dimensioned in a way to withstand longer periods of reduced domestic power generation since the adequacy between the generation and the consumption cannot be met otherwise.

According to this, the **future peak import on the high voltage grid** could reach the following values, which is representing our best assessment for the future power demand (cf. ‘Scenario Report 2040’ pages 4, 66, 67):

Year	*2025*	*2030*	*2040*
Peak import	*900MW*	*1200MW*	*1700MW*

**without the additional power need of the industrial load ‘SOTEL’*

Peak generation and excess generation

On the opposite, as the future installed generation capacity is expected to rise over the actual total transport capacity of the high voltage grid, it is necessary to analyse the grid situation which might occur, when there is a high generation during a period of low power demand.

The Integrated National Energy and Climate Plan for Luxembourg (NECP LU) gives some major indications about the future electricity generation capacities. For both scenarios, the reference scenario and the target scenario of the NECP, the following assumption values can be found for the installed generation capacities:

NECP LU Reference	*2025*	*2030*	*2040*
inst. power targeted	***850MW***	***1200MW***	***1600MW***
*RE power targeted**	*750MW*	*1100MW*	*1500MW*
NECP LU Target	*2025*	*2030*	*2040*
inst. power targeted	***1000MW***	***1550MW***	***2535MW***
*RE power targeted**	*950MW*	*1500MW*	*2500MW*

** installed power of renewable energy units / reference and target scenario*

Today, about 60% to 75% of the total installed capacity is effectively generated at a maximum. A higher rate of effective generation is quite possible, but not probable due to the mix of the different generation technologies and the various geographical locations of the generation units. With the same assumption for the future, the NECP reference scenario with about 1600MW of installed generation in 2040, could lead to an effective power generation of 1200MW then. The highest expansion scenario, the NECP target scenario with about 2500MW of installed generation in 2040, could lead to an effective power generation up to 1900MW.

Today, on the 220kV high voltage grid there is always a minimal power consumption of about 375 to 400MW, which has to be considered. However, on the downstream grids, the respective minimal consumptions can be much smaller. For example on the 65kV regional grids, the minimal power demand can vary between 10 and 30% of the maximum power demand; on the 20kV distribution grids the minimal consumption varies between 5 and 15%, and on various low voltage grids, the minimal consumption can fall back to nearly 0%. The impact of the power generation greatly depends of the analysed voltage level and the specific grids. The generated power circulating on the concerned grids must be examined in detail on the respective voltage levels.

Assuming a future minimum power consumption of 400MW on the 220kV grid at the time of highest future generation, most of the remaining generated power would have to be transported and eventually exported over the high voltage transport grid. Even if it cannot be predicted with certainty how the generation will correlate with the consumption profiles in the future, **the future peak excess generation on the high voltage grid** might reach the following values, which are representing our best assessment for the future excess generation during the times of low consumption:

*Excess generation**	*2025*	*2030*	*2040*
NECP LU reference	***250MW***	***500MW***	***800MW***
NECP LU target	***350MW***	***800MW***	***1500MW***

** estimated excess generation on the high voltage transport grid (currently 220kV)*

Methodology

An optimal grid planning, which has to be technically and economically balanced, must be based upon a detailed analysis of the existing infrastructure and its remaining power reserves. Major weak points or grid congestions have to be identified for every possible switch and supply states.

Measured load profiles from the years 2019 and 2020 were used for the subsequent load flow calculations of the present grid during the day and the time of the highest import from Germany.

According to the previous explanations, the following values during times of high consumption and low generation have been used in order to scale up the load profiles of today and to simulate the future peak import on the high voltage transport grid (cf. 'Scenario Report 2040' pages 4, 66, 67):

Year	*2025*	*2030*	*2040*
Peak import	***900MW***	***1200MW***	***1700MW***

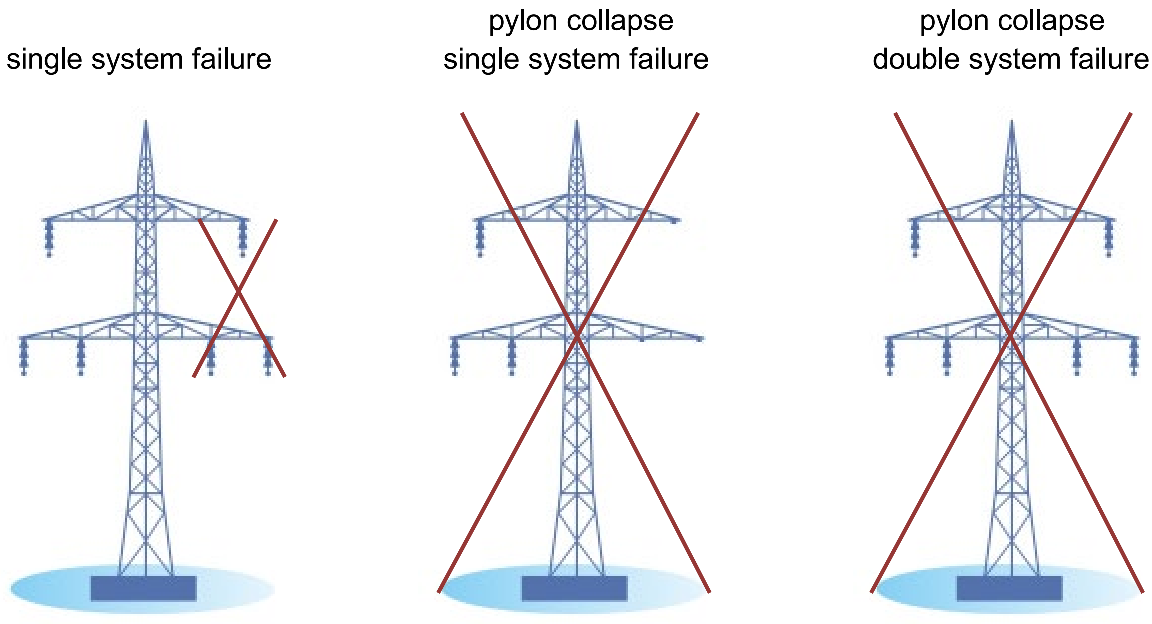
**without the additional power need of the industrial load 'SOTEL'*

For the future peak excess generation on the high voltage transport grid, the following values during the times of low consumption and high generation have been used:

Year	*2025*	*2030*	*2040*
Excess generation	***350MW***	***800MW***	***1500MW***

** estimated excess generation on the high voltage transport grid (currently 220kV)*

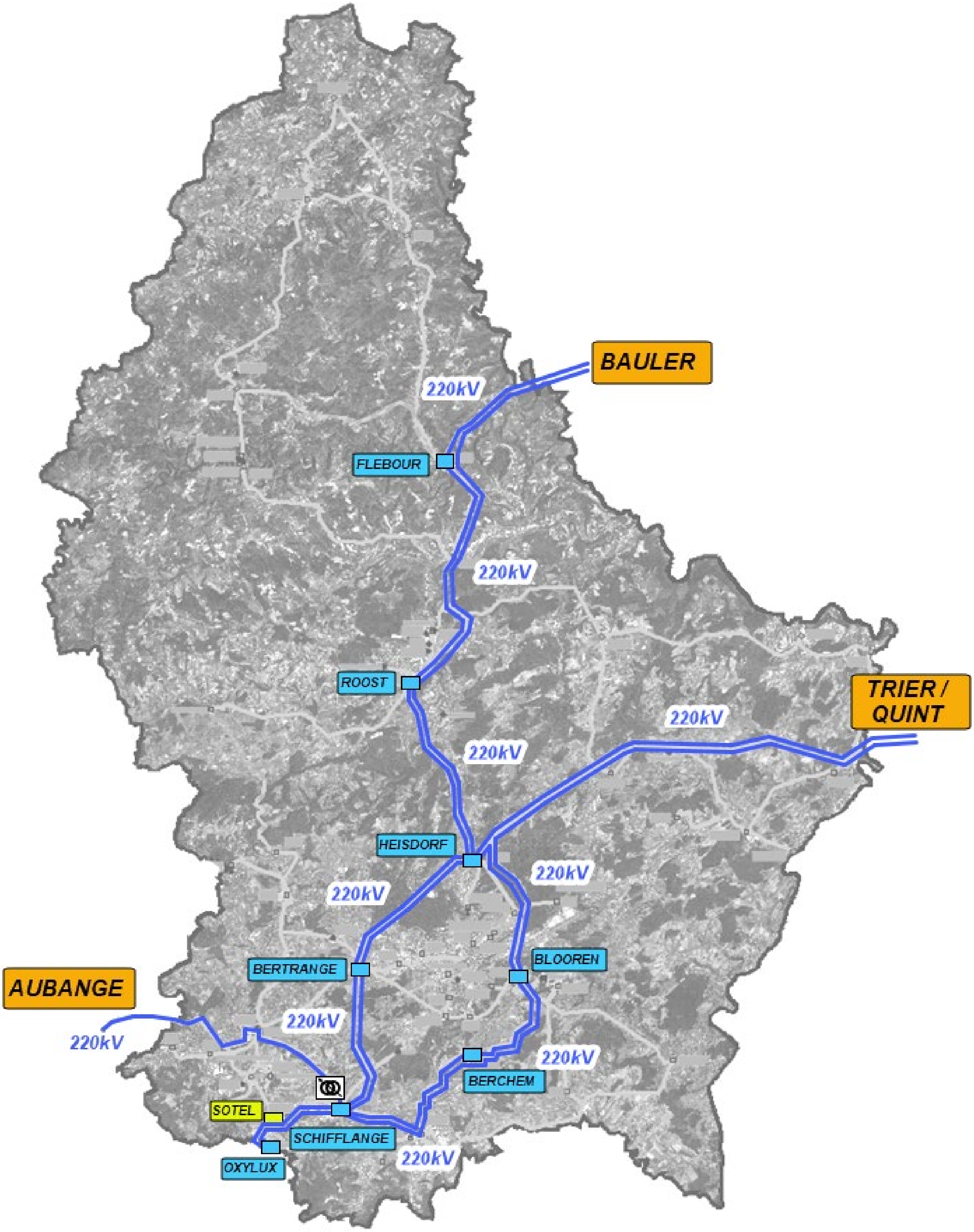
For the purpose of analysing possible outages, the failure cases depicted hereafter were simulated on the existing grid and the projected grid variants, and their effects and impacts were analysed:



High voltage transport grid
Analysis of the existing infrastructure

Grid Topology

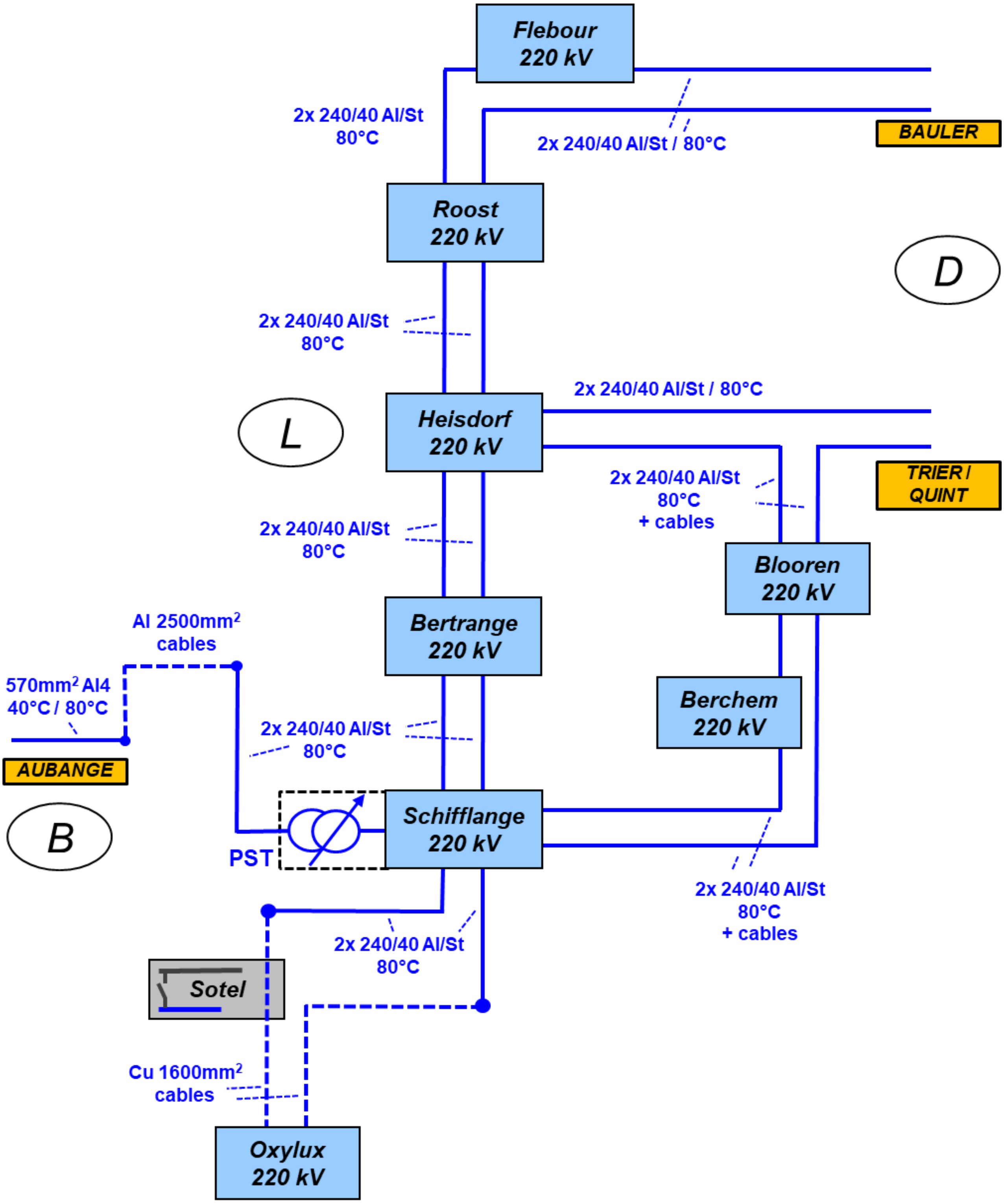
The current 220kV grid, which is mainly a transport grid, is supplied by two double power feeds from Germany (Bauler and Trier/Quint) and a backup connection with Belgium controlled by a phase shift transformer. Accordingly, the 220kV grids of Germany, Luxembourg and Belgium are interconnected and allow a certain amount of electricity transit in both directions.



Grid Schematic

As previously mentioned, two double lines from Germany (Bauler and Trier/Quint) are currently supplying the 220kV grid and the backup connection with Belgium, which has much less capacity, is controlled by a phase shift transformer.

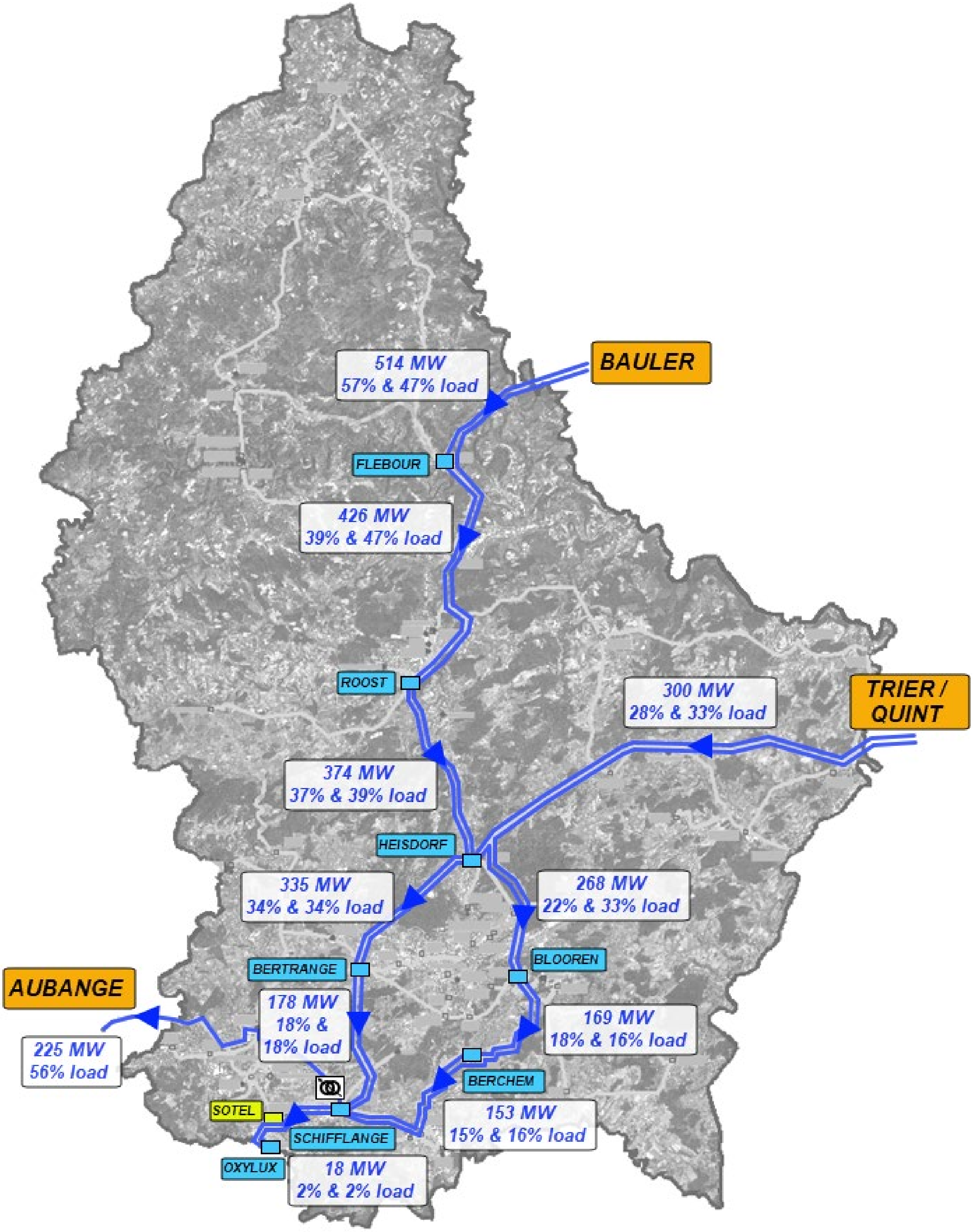
The 220kV grids of Germany, Luxembourg and Belgium are interconnected and allow a certain amount of electricity transit in both directions.



Load flow - Supply state without outage

The following illustration shows the line loads during normal operation without any outage. At the time of the highest import from Germany during the years 2019 and 2020, a power flow of 225MW circulated via Luxembourg to Belgium, over the 220kV high voltage grid. The highest import from Germany, totalling 814MW, has been on the 15th of January 2019 at 8 o'clock in the morning.

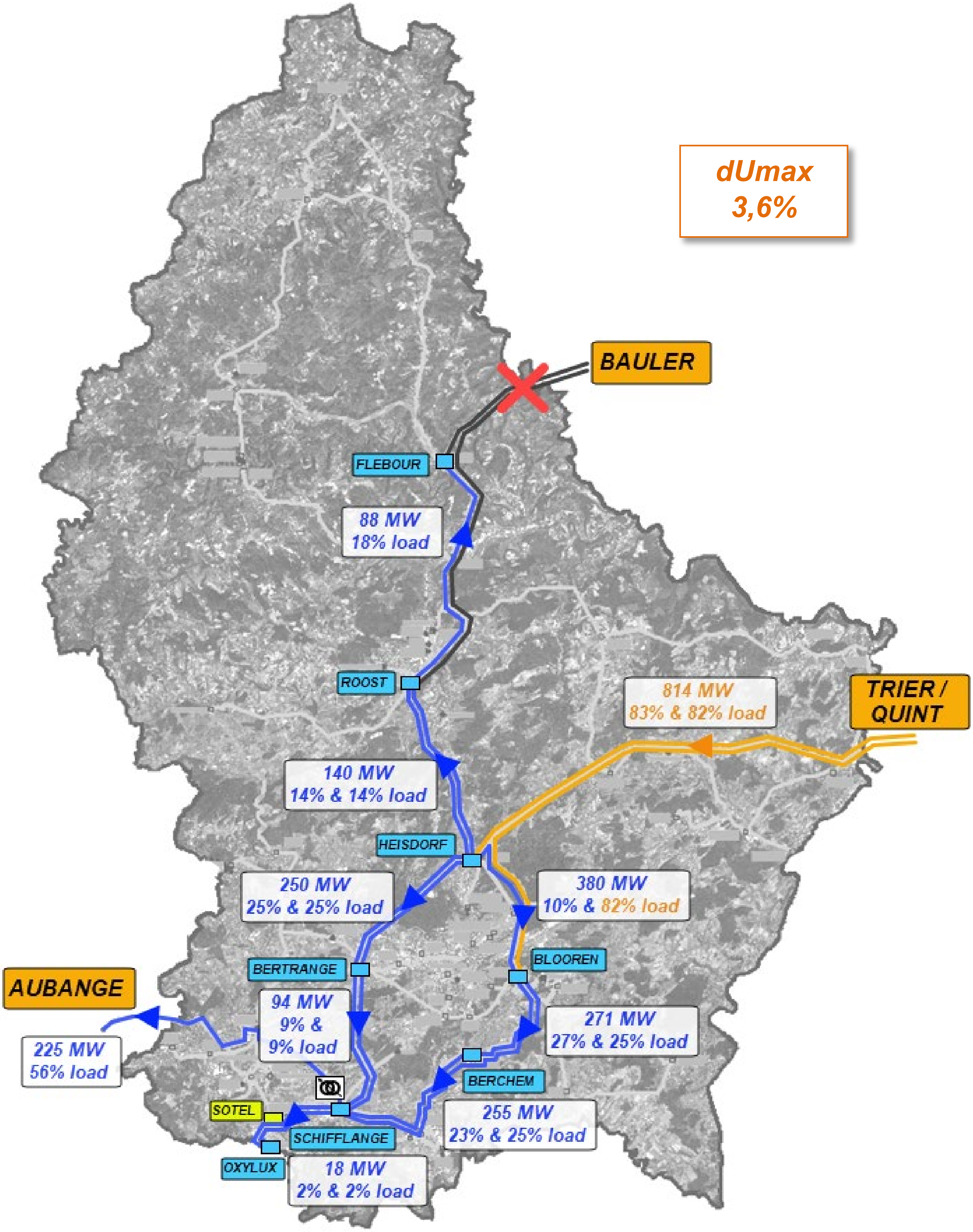
It is important to note that this normal supply state cannot be seen as relevant case for the grid dimensioning, the security of supply must be ensured in case of an outage.



Relevant contingency case 1

In a first relevant grid contingency case, it is assumed that the infeed from Bauler would suffer from a pylon collapse which implies a system failure of both lines on that pylon.

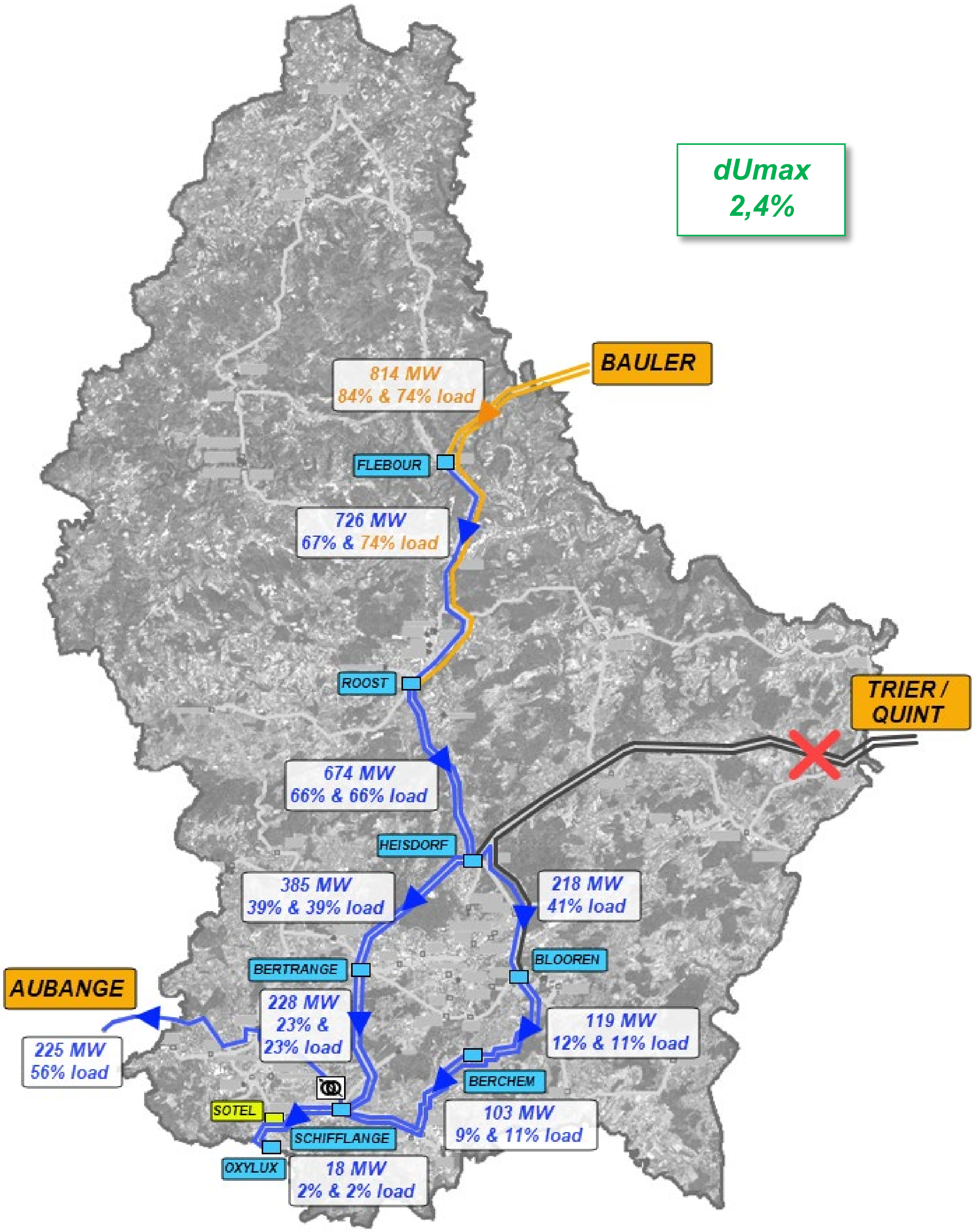
In this degraded grid situation, the entire load would have to be supplied by the double infeed Trier / Quint.



Relevant contingency case 2

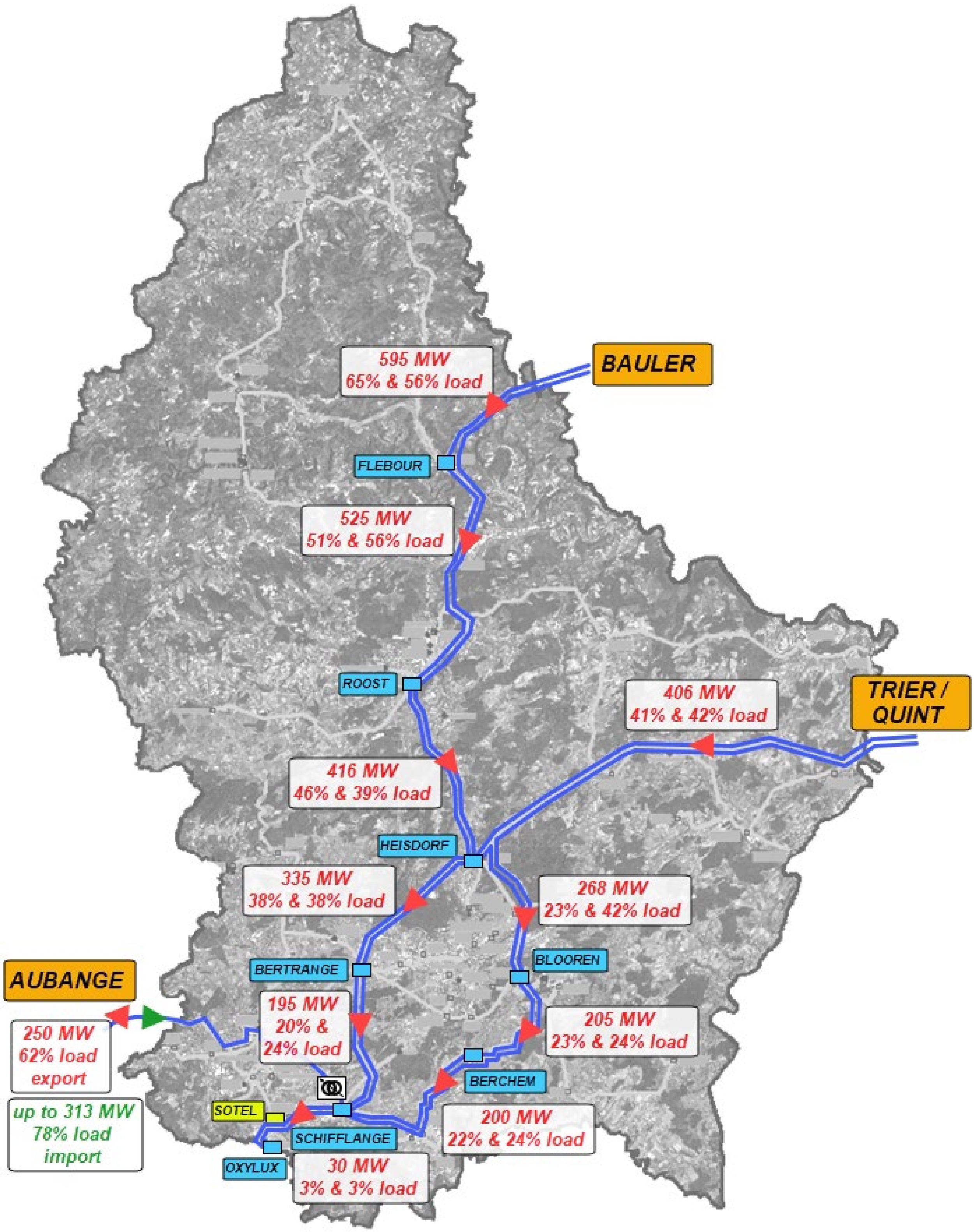
In this relevant grid contingency case, it is assumed that the double infeed from Trier / Quint would suffer a complete outage.

In this degraded grid situation, the entire load would have to be supplied by the double infeed from Bauler.

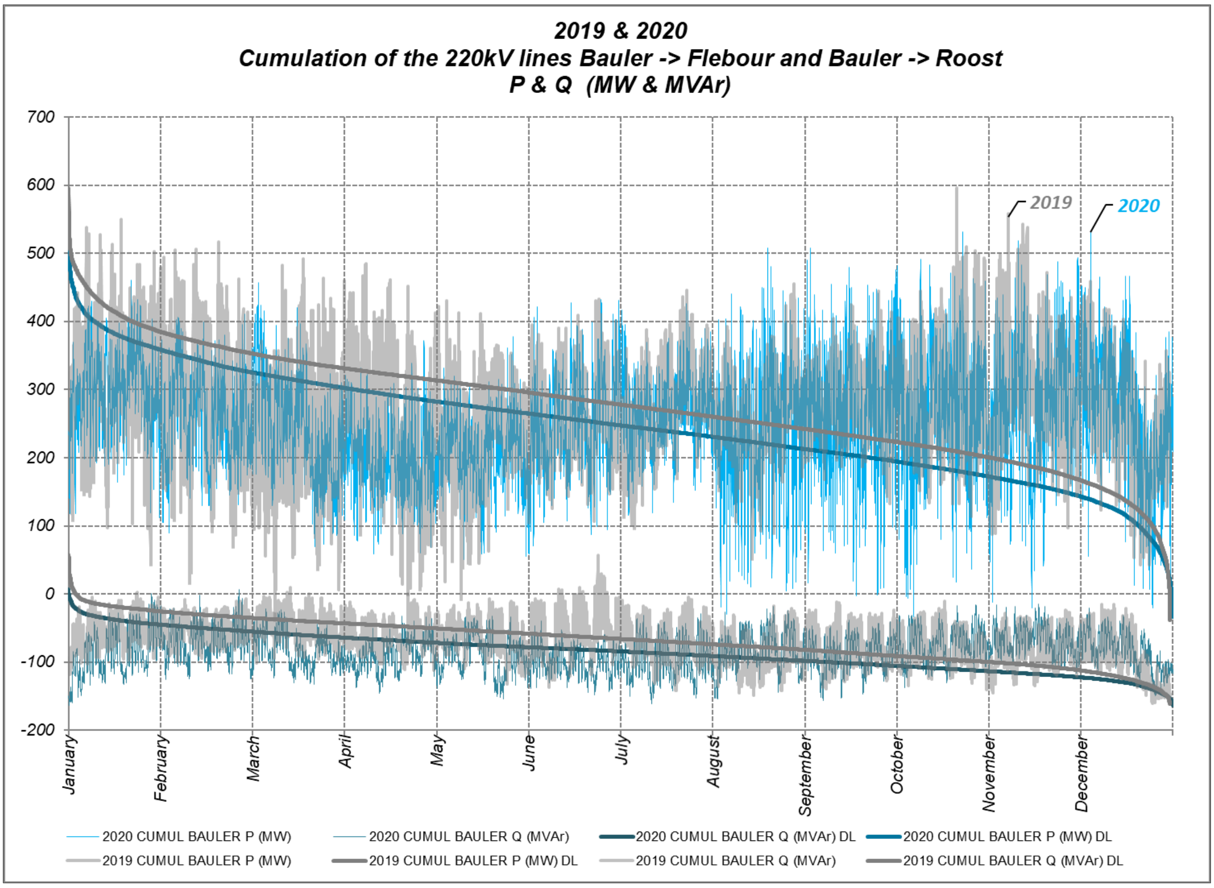


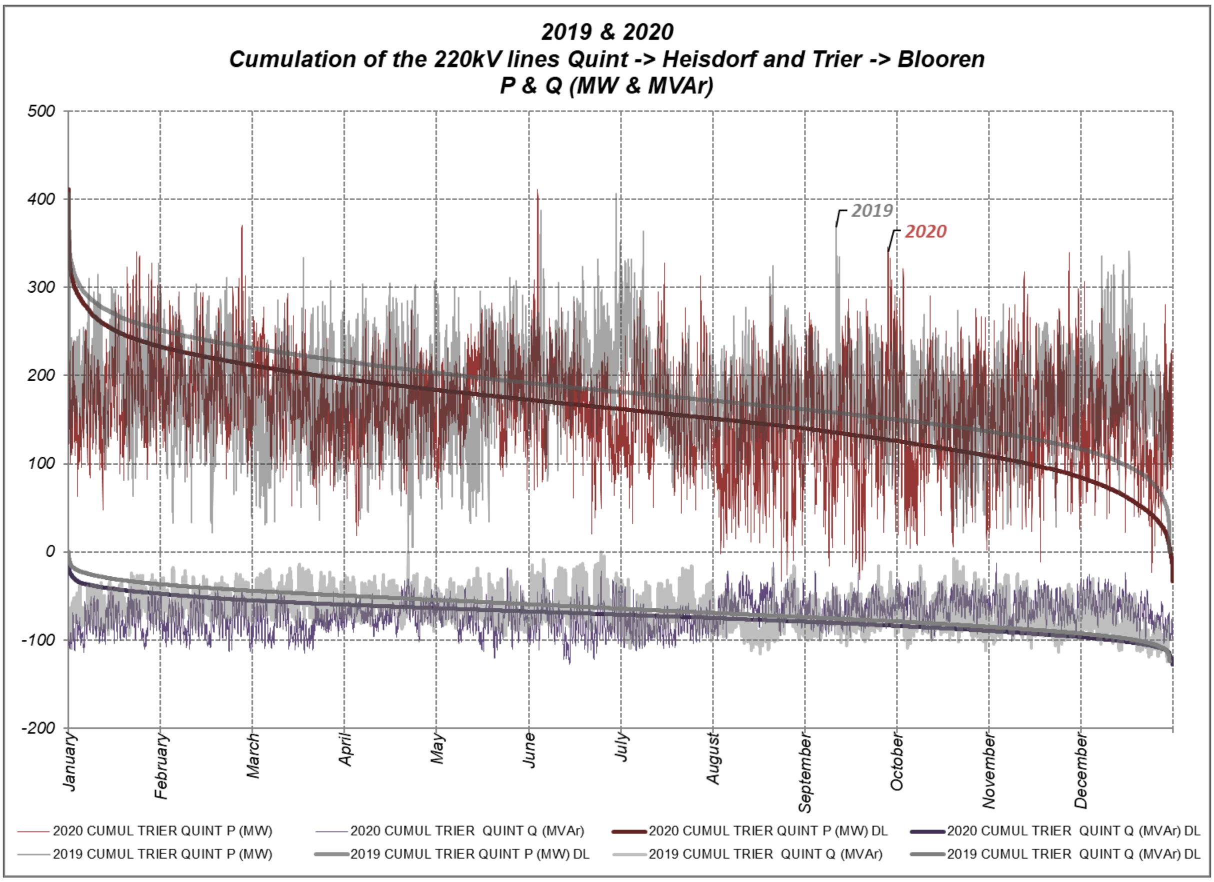
Highest individual line loads

The day of the highest import from Germany represents the highest load scenario in total, but the individual loads on the lines and cables of the 220kV grid can even get higher, just not simultaneously. The values depicted here below show the highest individual loads of the respective line sections.

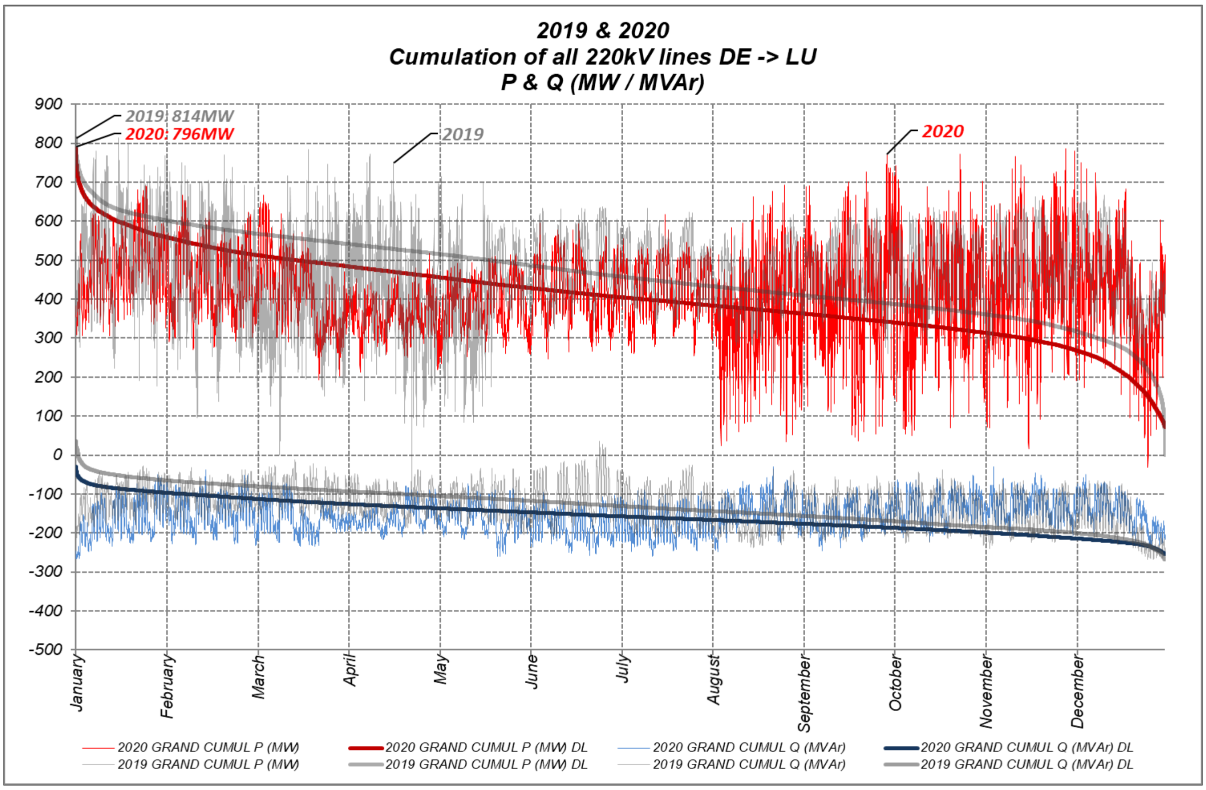


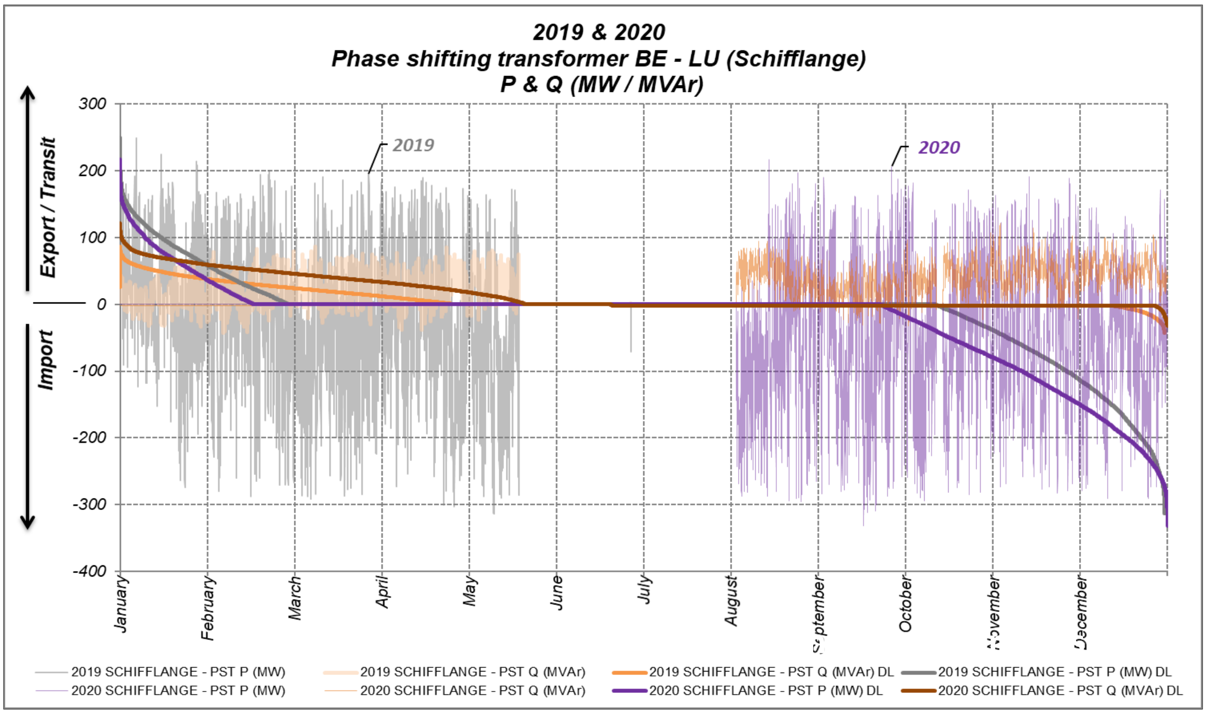
Line measurements Bauler and Trier / Quint





Line measurements Total Import from Germany and Belgium



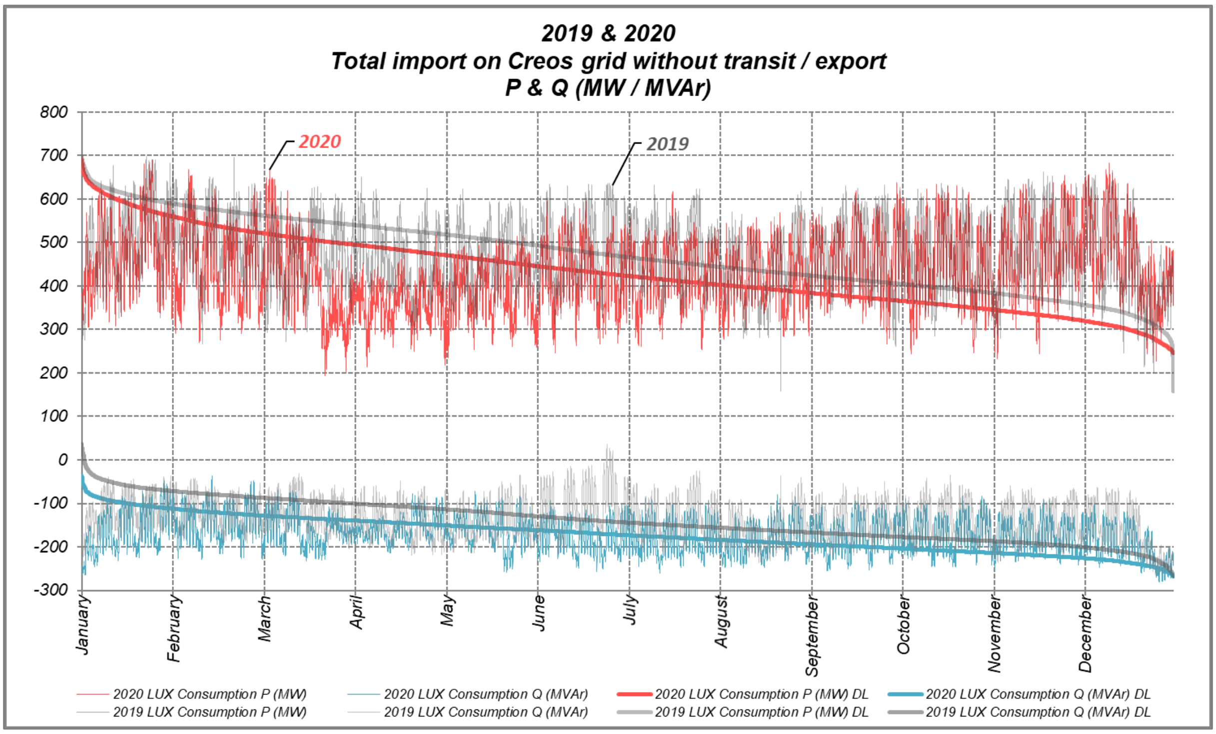


An unfortunate series of external and internal incidents caused a larger high voltage grid failure in May 2019, including the discharge of a transformer at Blooren site that has been replaced by December 2019.

Due to this event and to avoid any further burdening load on the 220kV high voltage grid, the power flow over the phase shifting transformer has been inhibited. Additionally, on 9th August 2019, Creos' interconnection to Belgium has been affected by a tornado, severely damaging several pylons of the infrastructure owned by SOTEL, the industrial grid operator. Despite some difficulties in the authorization processes, the capacity of this line has been recovered during summer 2020 and since then the interconnection is operational again.

Because of the limited transmission capacities for energy trade purposes between the different bidding zones of Belgium, France and Germany, the interconnection with Belgium via the phase shift transformer cannot not be considered as an additional permanent infeed for Luxembourg. The full availability of that electrical energy supply cannot be guaranteed at any time. However, the grid connection with Belgium can be seen as a support connection, although with a minor capacity, which increases the overall security of supply of Luxembourg and it is mostly useful in case of a major unplanned unavailability on the German side.

The subtraction of the electricity transit and the addition of the different imports from Germany and Belgium result in the following total import curves. Those curves represent the total net consumption on the Creos grid.



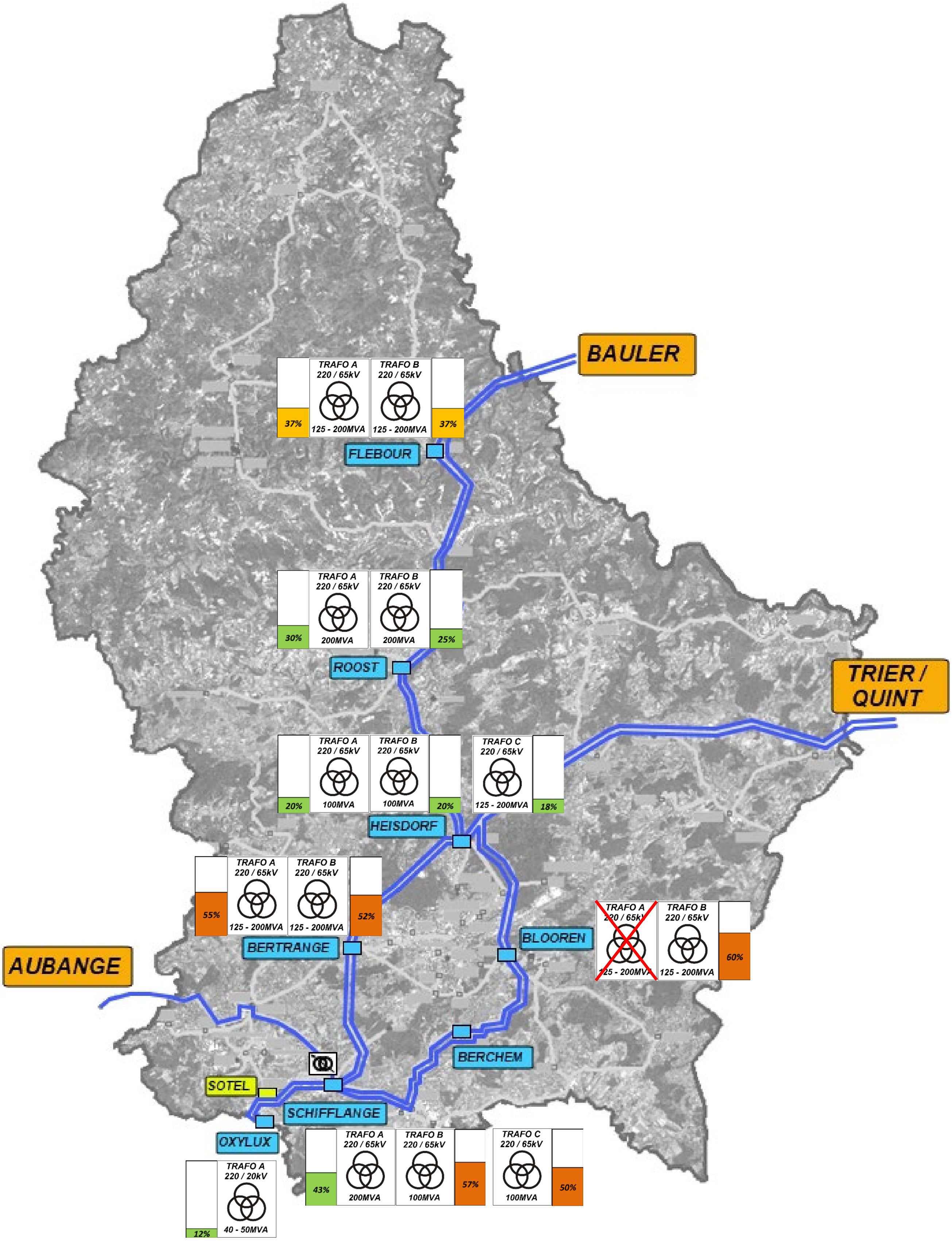
For the years 2019 and 2020, the total peak import on the Creos grid reached about 700MW.

The secured import and transmission capacity of the existing supply lines coming from Bauler and Trier / Quint in Germany is currently 980MW. Today, about 75% of the total import and transmission capacity is already used during peak import, even more if energy transit occurs from Germany to Belgium.

Highest individual load of the transformers 220kV / 65kV

The illustration hereafter represents the highest individual loads of the high voltage 220/65kV transformers during the years 2019 and 2020. The station "Berchem" is a customer station.

it should be mentioned that in case of a failure of a transformer, the cumulative load on the involved station would be less than the addition of the individual loads because of the simultaneity of those loads.



Cumulative and individual load of the transformers 220kV / 65kV

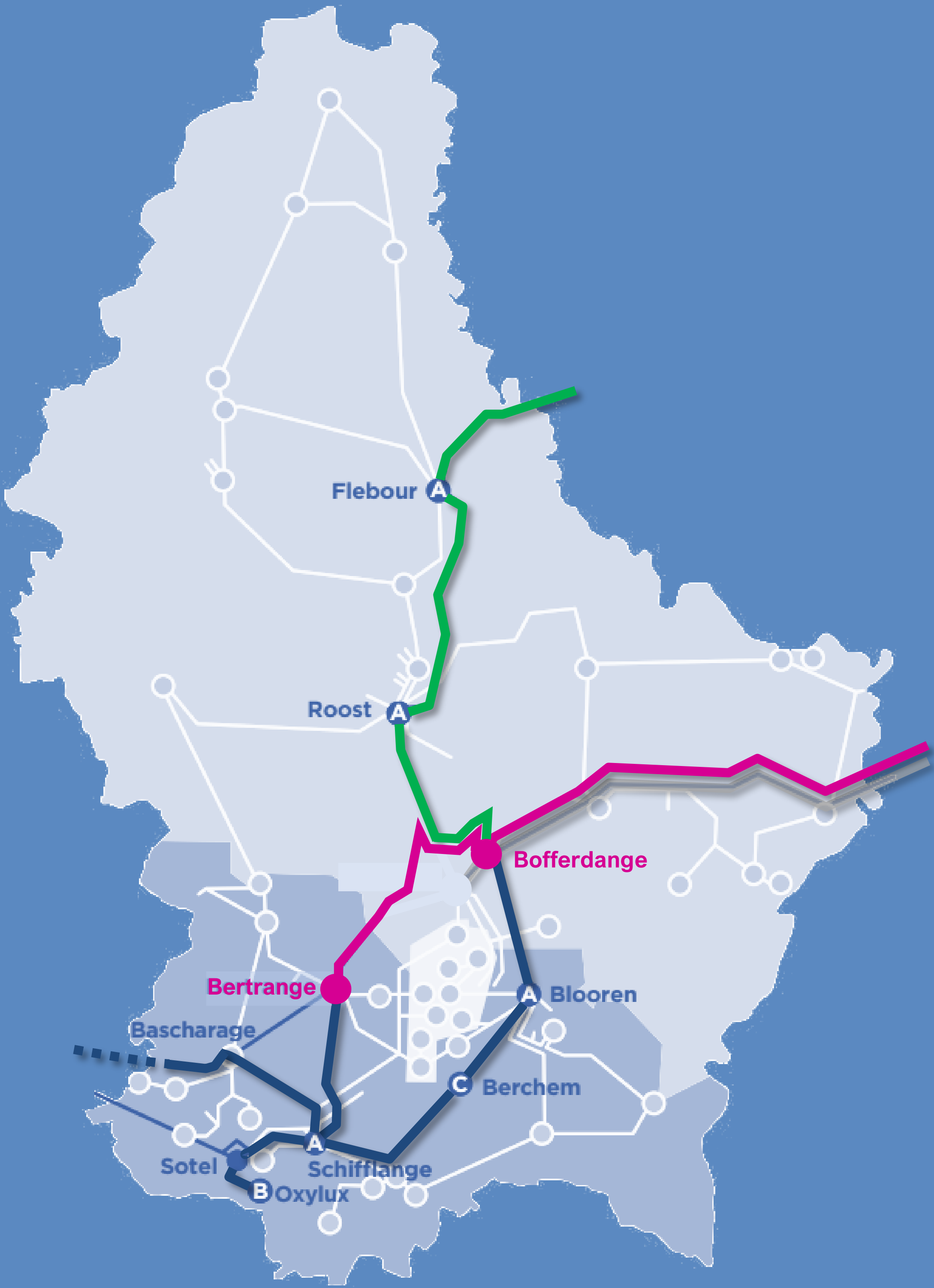
Station	Transformers (3-Winding)* 220 / 65kV	Highest cumulative load 2019 /2020	Highest individual load of each transformer (200MVA max)	Highest cumulative load '19'20 (N-1)
Flebour	125-200MVA, 125-200MVA	125MW	37% / 37%	63%
Roost	200MVA, 200MVA	110MW	30% / 25%	55%
Heisdorf	100MVA, 100MVA, 125-200MVA	71MW	20% / 20% / 18%	36%
Bertrange	125-200MVA, 125-200MVA	200MW	**55% / 52%**	**100%**
Blooren	125-200MVA, 125-200MVA	110MW	out of order / **60%**	60%
Schifflange	200MVA, 100MVA, 100MVA	171MW	43% / **57% / 50%**	**86%**

*** 125-200MVA transformers have a nominal rated power of 125MVA during normal operation with natural cooling (ONAN) and a maximum power of 200MVA during operation with forced cooling (ONAF).**

The 220/65kV transformer A in Blooren was partly out of service in 2019. As only one transformer in service always represents a possible outage risk, a fast replacement was a priority. During the outage, the load of the Station Blooren was secured with the help of the stations of Bertrange and Schifflange and the subordinated 65kV grid between those stations. A replacement transformer was installed and put in service during December 2019.

The highest cumulative load of the station Bertrange is already quite high. In case of a failure of a transformer of that station, the load would have to be secured with the help of the neighbouring stations and the related 65kV grid between those stations.

High voltage transport grid
Calculation scenarios - Planned reinforcements



Scenarios for the load flow calculations 2020 - 2040

With the forecasted values of the future peak import and the values for the expected excess generation, as described in the previous chapter “Guideline values and methodology” and in the Scenario Report 2040, various grid scenarios have been examined and the corresponding load flow calculations have been performed.

Different technical solutions for the storage of electrical energy may be of importance in the future. Smaller, decentralized battery storages or bigger seasonal “Power to X” storages may emerge in order to accumulate a surplus of generated electricity and to provide it when there is a consumption need. Electrical storage methods could indeed help reduce import peak demands. Still, it is a fact that, today, those solutions are not yet fully developed and not cost-effective. It would be highly speculative to consider them presently in the context of this study. Currently, no storage capabilities for electricity are planned, and that means that the future grid has to be dimensioned to satisfy both extreme scenarios, a maximum load scenario with minimal generation and a maximal generation scenario with a minimal load.

A demand side flexibility on the consumption and the generation side could certainly help reduce those extreme values, although to a certain restricted extent. Eventual rule based mechanisms, reward incentives and/or a viable inducement for a potential market are currently under examination but have not yet been implemented.

As the expected cumulative excess generation is slightly lower than the projected peak import values, the future peak import values have been identified as the most critical ones to be examined on the 220kV high voltage grid.

First of all, several load flow calculations have been made using the load profiles of 2019 and 2020 on the existing 220kV infrastructure, in order to show its upper limits and constraints.

In order to understand why the enumerated grid alternatives hereafter were chosen for further analysis and why those specific variants have been deemed the best solutions for the future, it is useful to explain the following circumstances:

Raising the import and transmission capacity of the existing high voltage grid due to the future developments is a necessity, and in theory, the most simplest way to do so would be the reinforcement of the existing 220kV infrastructure, for example by replacing the existing conductors of all the 220kV supply lines with high temperature conductors (HTLS). However, this would have certain disadvantages, such as the necessity of replacing several pylons of those lines and the general problem of the planned dismantlement of the upstream 220kV grid infrastructure in Germany in the future.

In our opinion, a connection to the 380kV grid in Germany is currently representing the best reinforcement option for the future. Besides offering a high transmission capacity solution, 380kV voltage supply lines have lower current heat losses and lower magnetic fields during operation. To ensure the security of supply, it would be best to create a 380kV loop connection, as stub line connections are generally representing a risk in case of a major failure. Although that solution represents the long-term solution to strive for, it is not feasible on short or mid-term for different reasons.

Based on open exchanges and discussions with the grid operator in Germany, the immediate area of Aach in the district Trier-Saarburg has been pinpointed as the most judicious connection point to create a first link with the 380kV network. Additionally to a new 380kV double line between Aach, Bofferdange and Bertrange, it is planned to install a 380 / 220kV transforming station in Bofferdange in order to realize the first connection between the 380kV voltage level and the subordinated national 220kV grid.

A prerequisite for the construction of a new 380kV double line between Aach, Bofferdange and Bertrange is the decommissioning of the existing 220kV double line Trier / Quint – Heisdorf. Of course, the construction of the new 380kV double line must be completed before the decommissioning of the existing 220kV double line. As a consequence of the decommissioning of the existing 220kV double line Trier / Quint – Heisdorf and because the creation of a 380kV loop is not yet possible, the 220kV supply lines coming from Bauler have to be reinforced to guarantee the security of supply in the future. The existing 220kV supply lines coming from Bauler do not have the necessary transmission capacities in case of a major failure of the future 380kV infeed.

In this case, reinforcing the 220kV supply lines coming from Bauler with the help of high temperature conductors (HTLS) is the most viable solution. Calculations have shown that most of the electrical energy will be circulating over the 380kV grid, coming from Aach, during normal operation.

In a next step, due to the projected load concentration in the center and south of Luxembourg, the installation of a second 380 / 220kV transforming station will become necessary to supply those areas. The existing 220kV station of Bertrange has been deemed the most suitable for an expansion to 380kV due to its grid connections and geographical location.

As already mentioned, it would be best to create a 380kV loop connection on the long term in order to have a secure high capacity grid solution. However, that loop connection has not been thoroughly analysed and specifically projected so far.

The potential switch of the industrial load presently connected to Belgium and France via the SOTEL grid, representing a total of 280MW, has also been examined in the calculation scenarios.

Proceeding from these considerations, the following grid scenarios were selected and the consequent load flow calculations performed in case of a normal supply and in relevant outage situations:

- ***Existing 220kV grid (2020)***
  with the load profiles of 2019 and 2020
  with the projected load profiles of 2025
- ***Reinforced 220kV grid with high temperature conductors (HTLS)***
  (only on supply lines Bauler – Flebour / Roost)
  with the projected load profiles of 2027
- ***380kV infeed with the existing 220kV grid***
  (220kV lines Trier / Quint – Heisdorf decommissioned)
  with the projected load profiles of 2027 and 2030
- ***380kV infeed with a reinforced 220kV grid with HTLS***
  (220kV lines Trier / Quint – Heisdorf decommissioned)
  with the projected load profiles of 2030
  with and without the additional industrial load of SOTEL
- ***380kV extended grid with a reinforced 220kV grid with HTLS***
  (220kV lines Trier / Quint – Heisdorf decommissioned)
  with the projected load profiles of 2040
  with and without the additional industrial load of SOTEL
- ***380kV loop connected grid***
  (220kV lines Trier / Quint – Heisdorf decommissioned)
  with the projected load profiles of 2040
  with and without the additional industrial load of SOTEL

Summary of the results of the grid calculation scenarios

The detailed load flow calculations have not been included in this document, but the results have been summarized in this spreadsheet. All the 380kV reinforcement solutions here analysed suppose a decommissioning of the double line Trier / Quint -> Heisdorf.

Voltage level / solution	Existing 220kV		220kV HTLS (only Bauler – Flebour)	380kV infeed + existing 220kV (no HTLS)	380kV infeed + existing 220kV (no HTLS)	380kV infeed + 220kV HTLS (mid term)		380kV extended grid + 220kV HTLS (long term)		380kV loop connected grid (long term +)	
Scenario	2019 / 2020	2025	2027	2027	2030	2030	2030 + SOTEL	2040	2040 + SOTEL	2040	2040 + SOTEL
Existing / Projected import (or limit)	700 - 814MW	900 - 980MW	1000 - 1125MW	1000 - 1125MW	1200MW	1200MW	1500MW	1700MW	2000MW	1700MW	2000MW
N-1+ secure (pylon collapse) Max power available (DE)	YES 980MW	YES 980MW	YES 980MW	Only with import BE 980MW	Only with import BE 980MW	YES 1500MW	YES 1500MW	Only with import BE 1700MW	Only with import BE 1700MW	YES >2000MW	YES >2000MW
Transit / export possible	YES	YES	Conditional	Conditional	Conditional	YES	YES	Conditional	Conditional	YES	YES
Additional import needed from BE (in N-1+ case) (220kV)	NO	NO	YES 200MW N-1+ Bauler	YES 200MW	YES 300MW	NO	Recommended due to voltage levels in N-1+ situation	YES 200MW N-1+ Bauler	YES 300MW	/	/
Comments		limit of existing 220kV infrastructure			limit of existing 220kV infrastructure			limit of projected infrastructure	probability of constraints and curtailments		

Summary of the results of the grid calculation scenarios

Time horizon 2020 - 2025

The line measurements and the load flow calculations show that today and in the near future, the total power demand can be supplied securely by the existing infrastructure, even during a major failure case on the grid.

Time horizon 2025 - 2030

There is a risk that the existing 220kV infrastructure may reach its limit between 2025 and 2030, depending on the actual growth of the power demand and of the generation. That means that from 2025 on, the peak import values may rise over the import and transmission limit of 980MW during occasional hours. In case of a major failure of one of the two double supply lines coming from Germany during those hours, the remaining circuit would be overloaded and the security of supply would be at risk. The complementary supply from Belgium over the phase shift transformer is helping to reduce that risk, but it should be noted that the availability of that additional supply cannot be guaranteed at any time.

In order to increase the import and transmission capacity, a connection to the 380kV grid in Germany, in combination with the use of high-temperature conductors (HTLS) on a part of the 220kV structure, is offering the best grid reinforcement option for the future.

As can be seen from the summary table, superposing a 380kV double injection line with its corresponding 380 / 220kV transforming station on top of the existing 220kV structure would increase the import capacities, but would not guarantee a secured supply, as the maximum transmission capacity falls back to a maximum of 980MW in case of a major failure of the 380kV infeed. This is due to the fact, that the dismantlement of the existing 220kV double line between Trier/Quint and Heisdorf, after the construction of the new 380kV double line, is a prerequisite to build the new 380kV infeed in that line corridor. In consequence, to ensure the electrical supply in case a major failure of the 380kV infeed, the reinforcement of a part of the 220kV structure with high-temperature conductors (HTLS) will be necessary. That reinforcement is needed in any case because of the projected load increase. For practical reasons, it is planned to do the replacement of the conductors with high-temperature conductors and the adaptation of the concerned line before the project of the 380kV infeed.

The completion of the 380kV infeed and the HTLS reinforcement enables the possibility of switching the industries currently connected to the industrial grid of SOTEL on the planned grid infrastructure of Creos. Several industries are currently regrouped in that total load, so that a load split up could also be conceivable. Before the switch, the impact on the supply quality should be thoroughly analysed to ensure that the resulting perturbations remain low and acceptable.

It should be mentioned that different reasons prohibit a connection between the Creos grid and the currently existing direct line between the SOTEL system and France. It is clearly not planned or intended to make a connection between the Creos grid and the electricity grid in France.

Time horizon 2030 - 2040

Most of the electricity is currently consumed in the south and the central part of the country. Because of the expected rising electricity demand in those regions and in order to guarantee the security of supply in the future, the installation of a second 380 / 220kV transformer station in the south / central part of the country is currently considered the best option for the time period 2030 - 2035.

The existing 220kV station of Bertrange would be the most suitable for an expansion to 380kV and to supply that station, the 380kV grid would have to be extended between Bofferdange and Bertrange.

At the end of the forecast period between 2035 and 2040, the reinforced 220kV grid connection Bauler - Flebour may reach its limit during a major failure of the 380kV infeed, depending on the actual growth of the power demand and of the generation.

Grid reinforcement steps

In consideration of the results of the grid calculations and the related explanations, successive grid reinforcement steps have been compiled for the purpose of setting up an appropriate and secure electrical energy supply infrastructure capable of satisfying the future electrical energy demands and facilitating the energy transition.

The interrelated steps depicted hereafter are planned for the future development of the high voltage transport grid.

It is intended to carry out the step 2 and 3 of the grid reinforcement plan with the related project “PROJET 380” which is representing a future-oriented replacement construction that provides a better cross-border connection between Luxembourg and Germany.

2020-2025

Step 1
HTLS Reinforcement

Reinforcement of a part of the existing 220kV infrastructure with high temperature conductors (HTLS)

2025-2030 creos 380

Step 2
380kV Infeed

Construction of a grid connection to the 380kV high voltage transport grid in Germany

2030-2040 creos 380

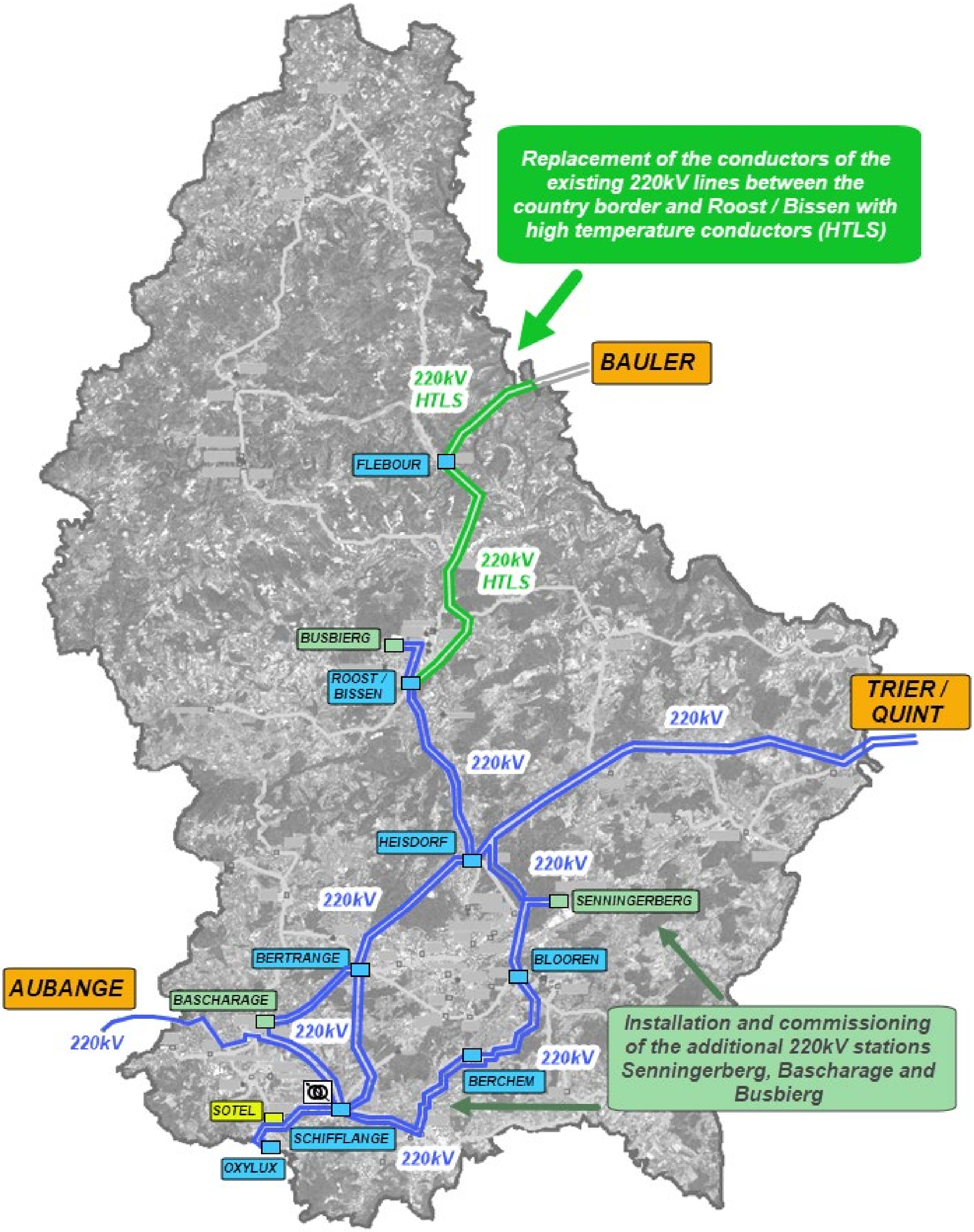
Step 3
380kV Extension

Extension of the 380kV high voltage transport grid within Luxembourg

Grid reinforcement - Step 1 (HTLS Reinforcement)

To prepare for the future energy demands and to secure the energy supply, it is planned to conduct the reinforcements depicted hereafter in **step 1**.

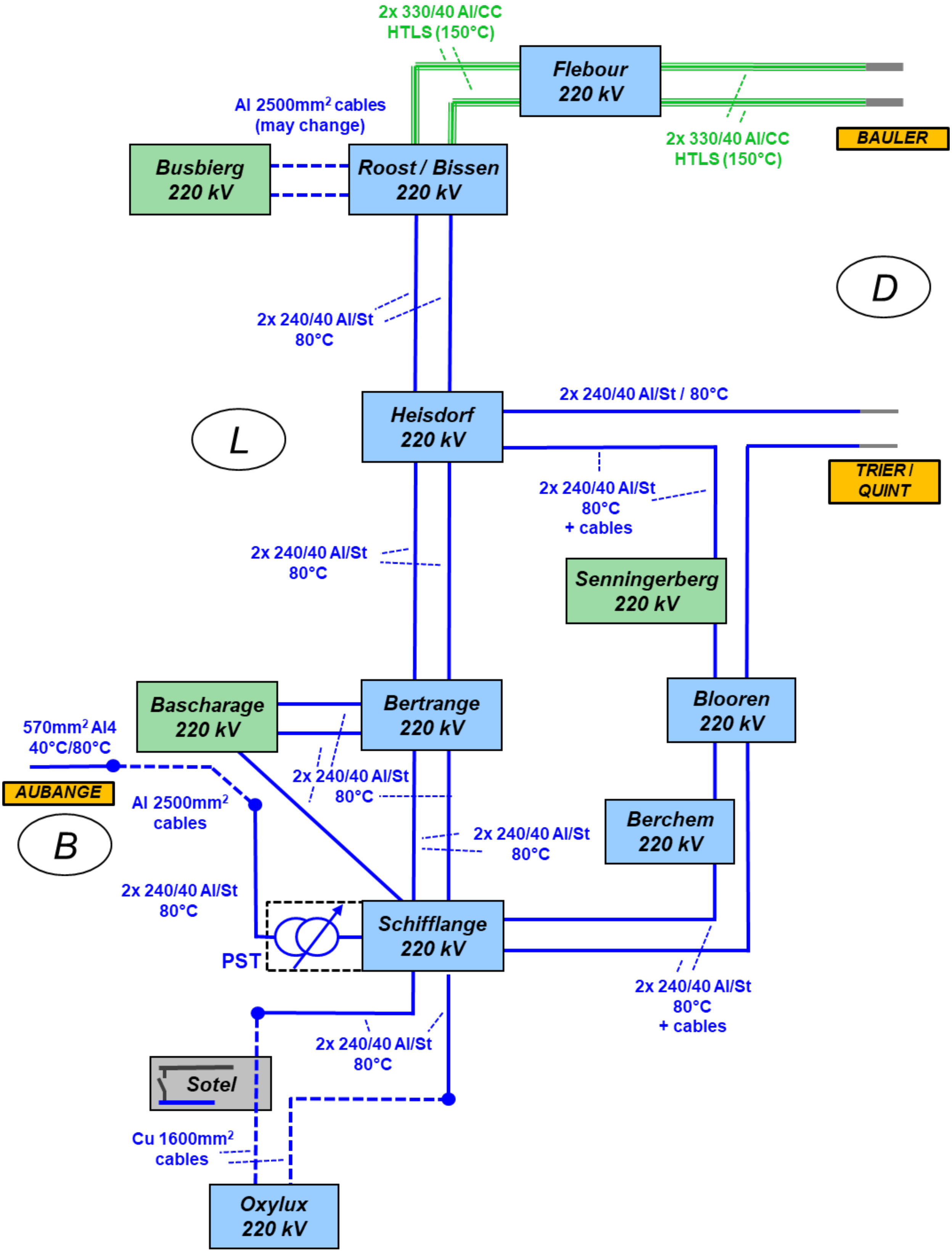
In order to improve the current and future security of supply and in order to cope with the future energy demands, it is necessary to install and commission further 220 / 65kV (110kV) stations. In a first step at Senningerberg and Bascharage.



The upstream grid operator Amprion has to be involved in this reinforcement process and has to commit itself to an overall higher import limit. The transmission capacities of the concerned grid sections between Niederstedem, Bauler and Luxembourg must meet the necessary requirements.

Grid reinforcement - Step 1 Schematic

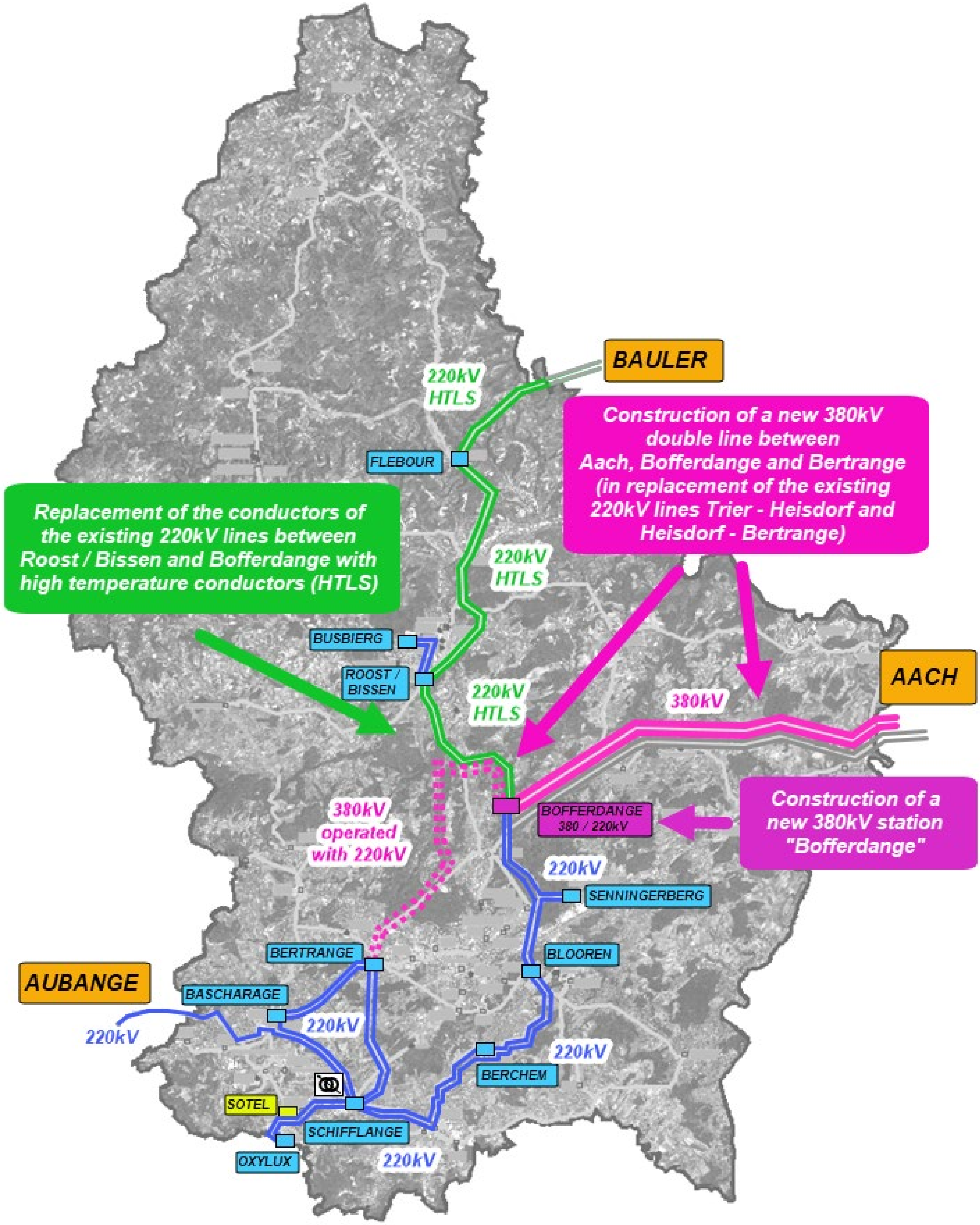
During the works of the first reinforcement step, the replacement of the conductors of the existing 220kV lines between the country border and Roost / Bissen with high temperature conductors (HTLS / ACCC conductors), the two circuits of the line coming from Bauler will be looped in and connected to the station of Flebour.



Grid reinforcement - Step 2 (380kV infeed)

Furthermore, for the purpose of ensuring the electrical energy supply in the mid and long term, it is necessary to conduct the following reinforcements in **step 2**.

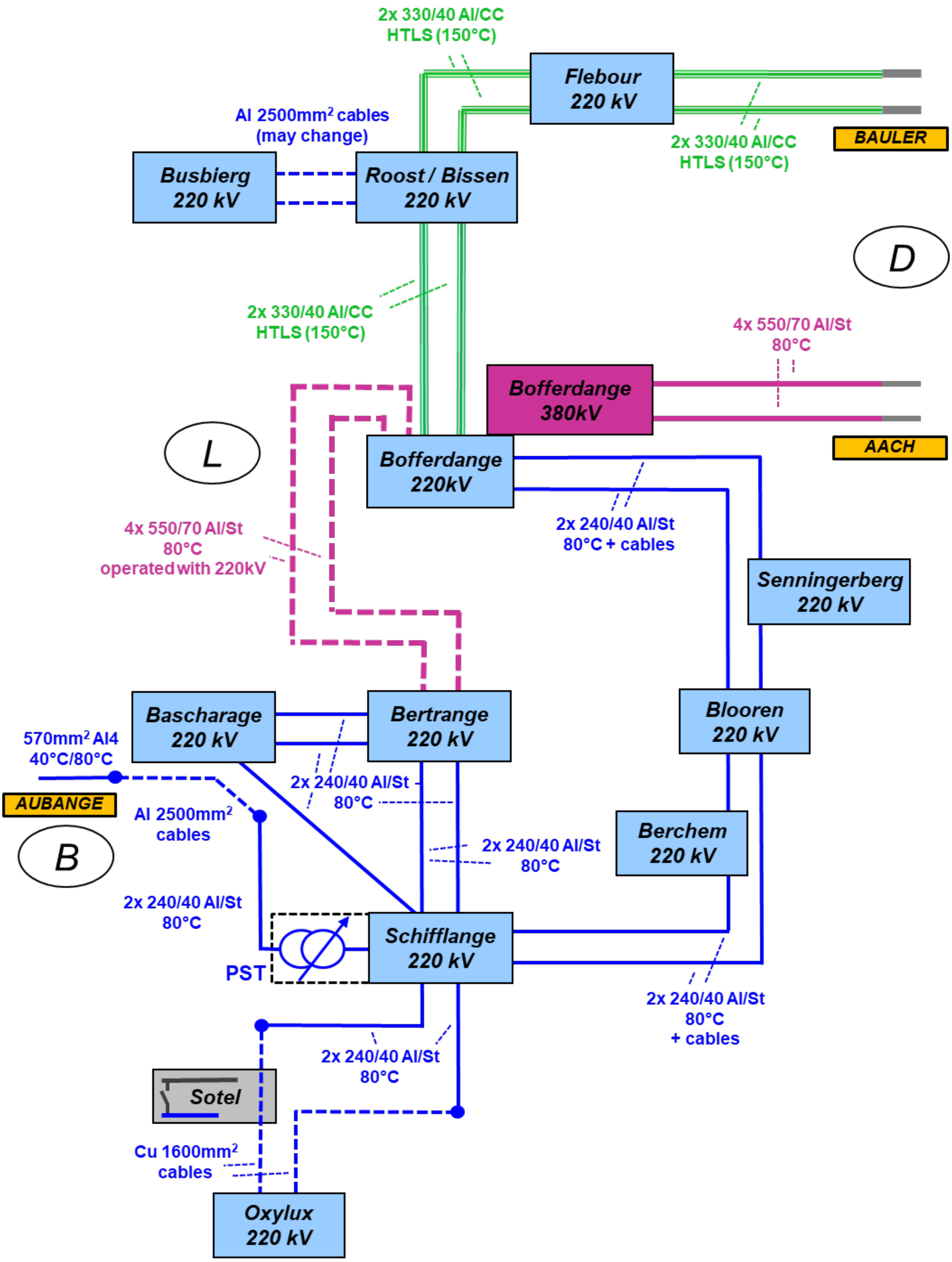
It is also intended to prepare the next step of the 380kV reinforcement with the replacement of the existing 220kV double line between Bofferdange and Bertrange with a new 380kV infrastructure, which will be operated with 220kV until the completion of the next reinforcement step.



The upstream grid operator Amprion has to be involved in this reinforcement process and has to commit itself to an overall higher import limit and to the necessary increase of the transmission capacities.

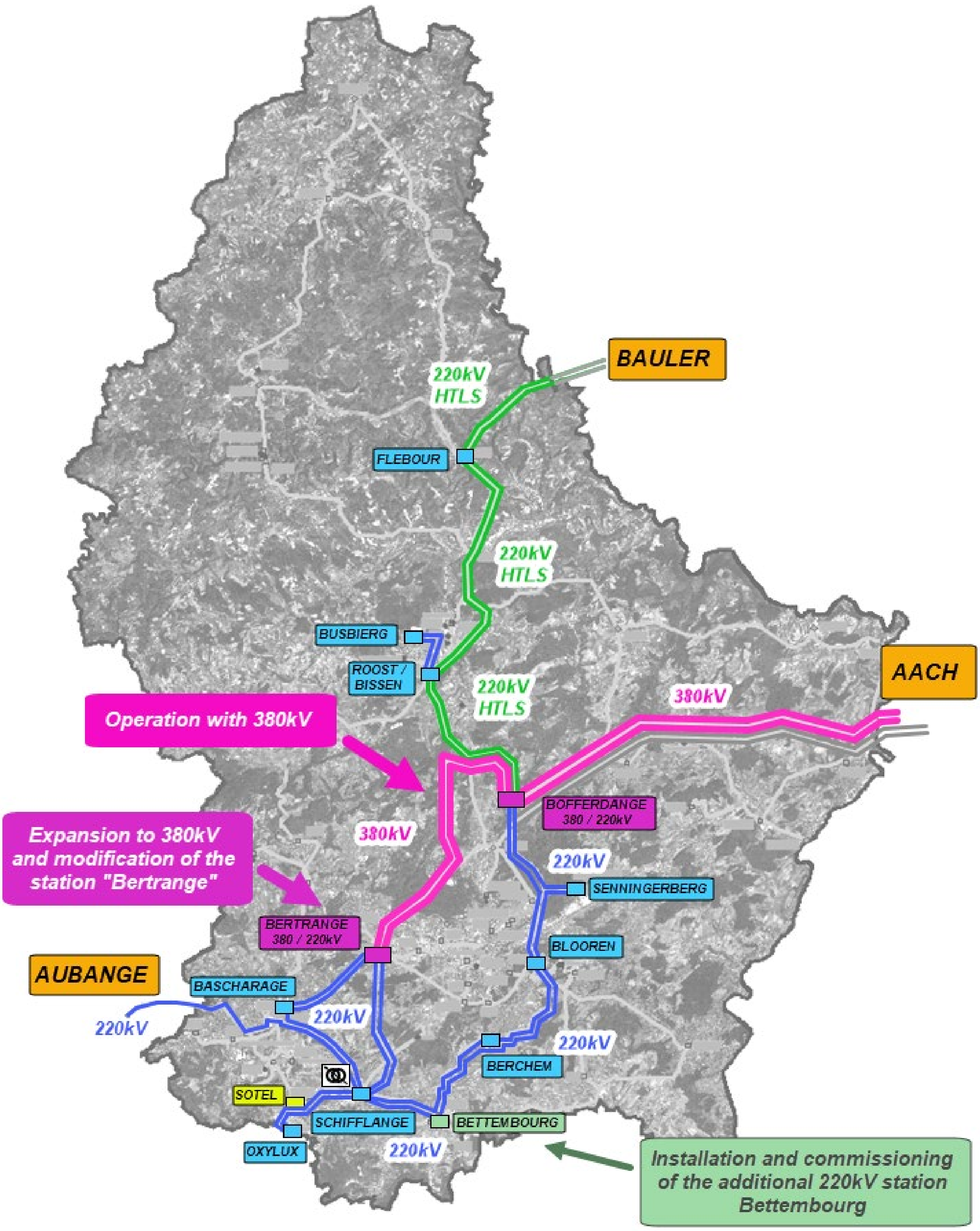
Grid reinforcement - Step 2 Schematic

After this step, the reinforcement of the 220kV infeed coming from country border / Bauler shall be completed with the replacement of the conductors of the existing 220kV lines between Roost / Bissen and Heisdorf / Bofferdange with high temperatures conductors (HTLS / ACCC conductors).



Grid reinforcement - Step 3 (380kV extension)

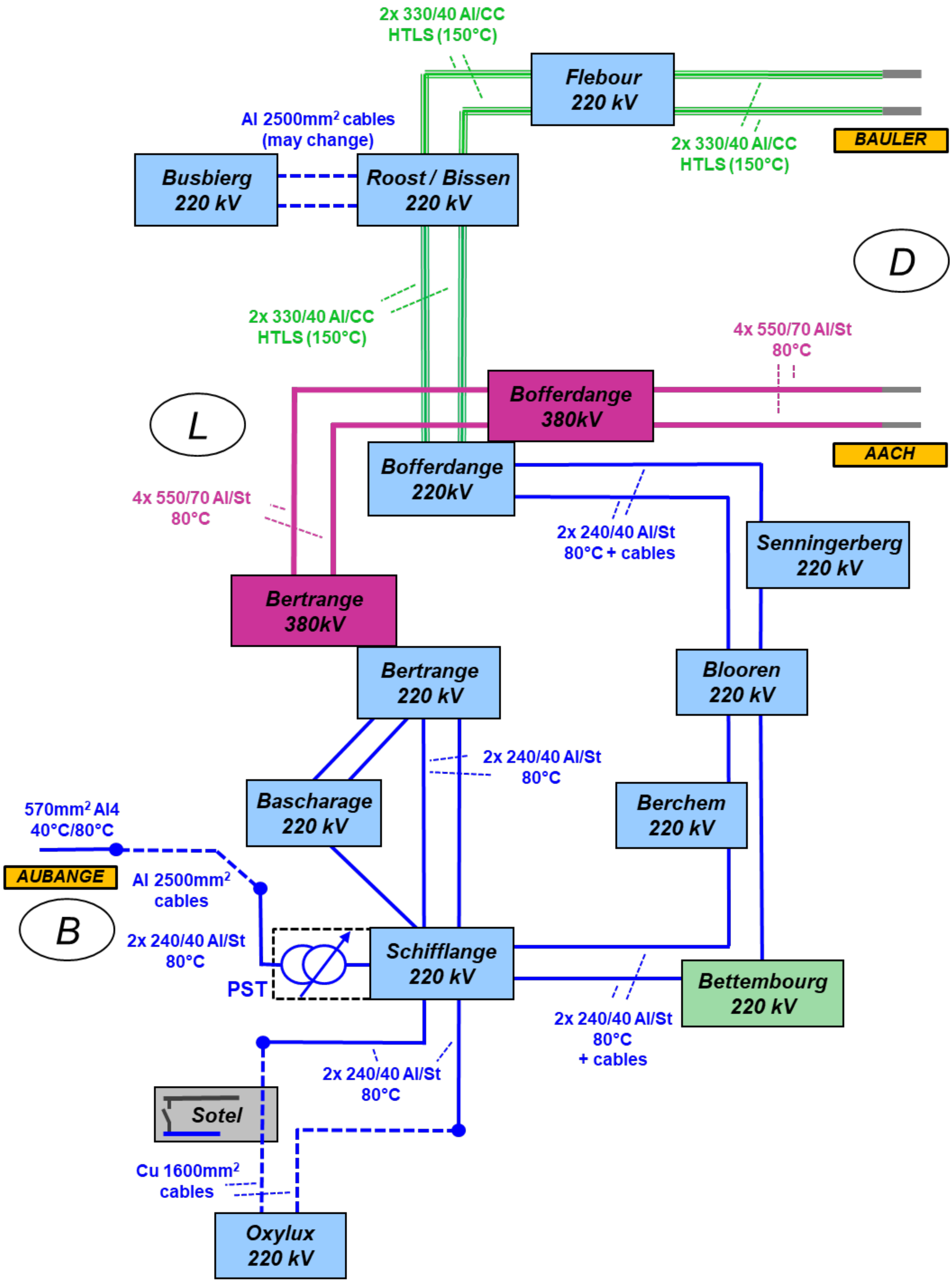
In order to guarantee the security of supply in the south and central region of Luxembourg in the future, the installation of a second 380 / 220kV transformer station is planned in that part of the country. The existing 220kV station of Bertrange is the most suitable for an upgrade to 380kV or a reconstruction. As the 380kV double line has already been constructed during the second reinforcement step, it will only be necessary to operate the double line section Bofferdange – Bertrange with a voltage of 380kV.



Grid reinforcement - Step 3 Schematic

A prerequisite for the installation of the 380kV extension between Bofferdange and Bertrange is the decommissioning of the existing 220kV double line Heisdorf – Bertrange.

It should be noted that the grid configuration shown hereafter is only meant to be an intermediate step.



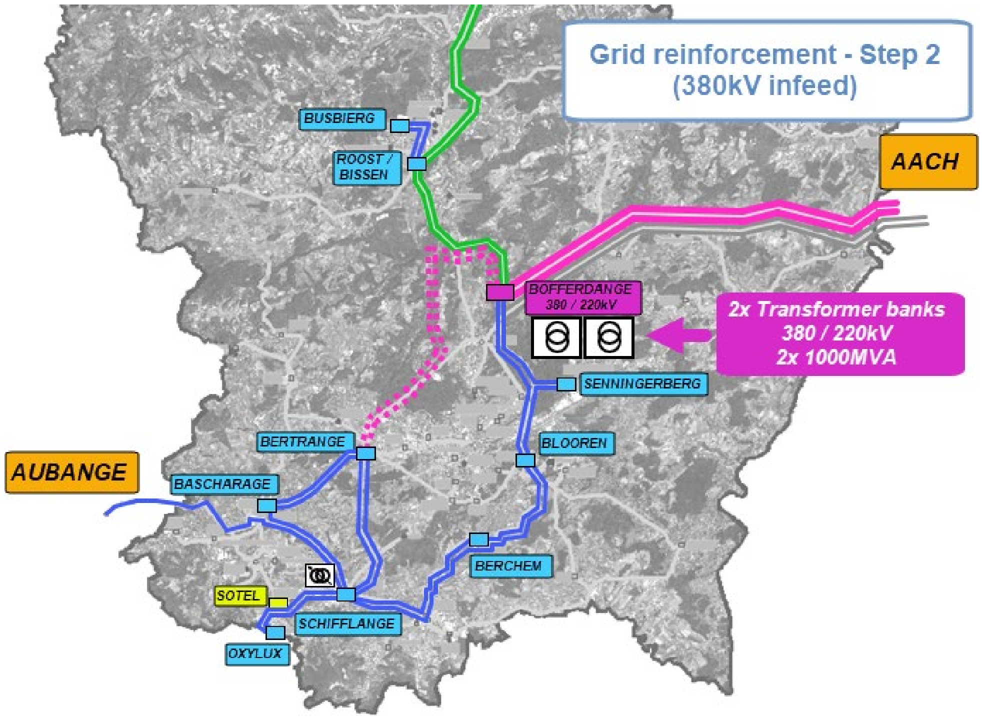
Planned transformer capacities
380kV / 220kV

Concerning the future voltage transformation from the 380kV level to the 220kV level, the objective is to have at least the same total transforming capacity as the total transmission capacity of the grid, even in a major failure case.

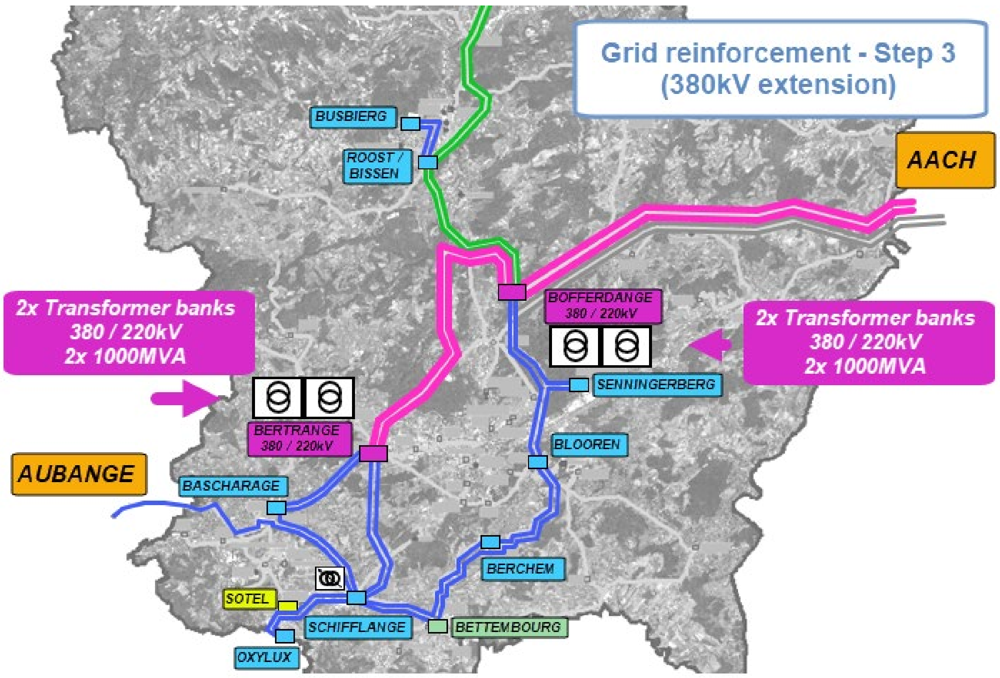
For the realization of that objective, two possible versions are currently under detailed analysis.

Installation variant 1:

In a first variant, it is planned to install 2 transformer banks with 1000MVA of transmission capacity each, at the new station Bofferdange, during the grid reinforcement **step 2**.

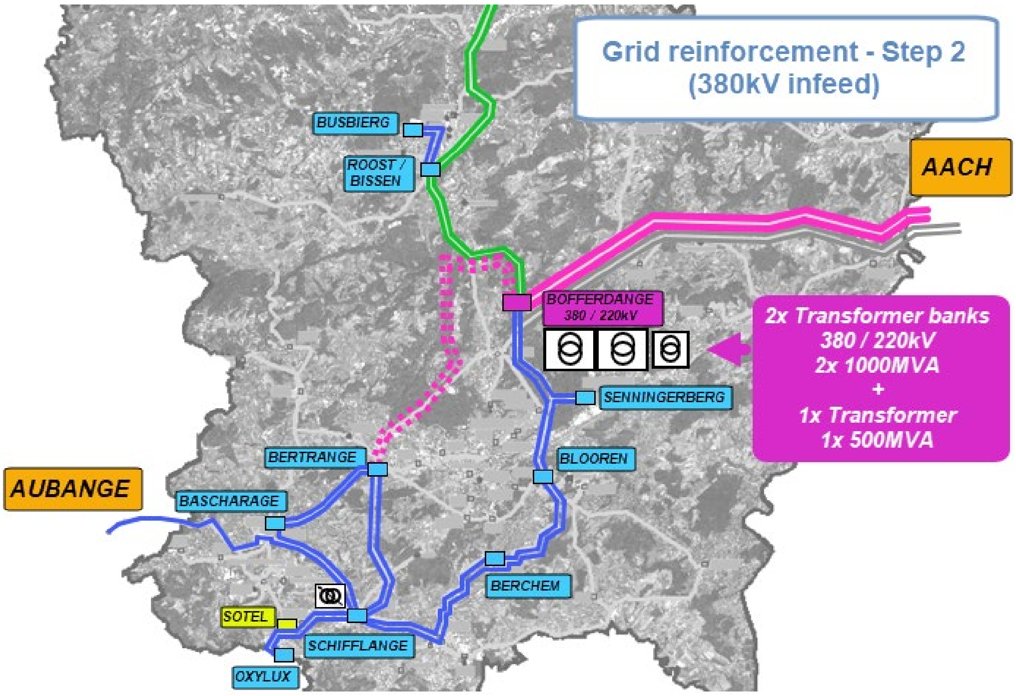


Afterwards, during the grid reinforcement **step 3**, it is planned to install 2 additional transformer banks with 1000MVA of capacity each at the station of Bertrange.

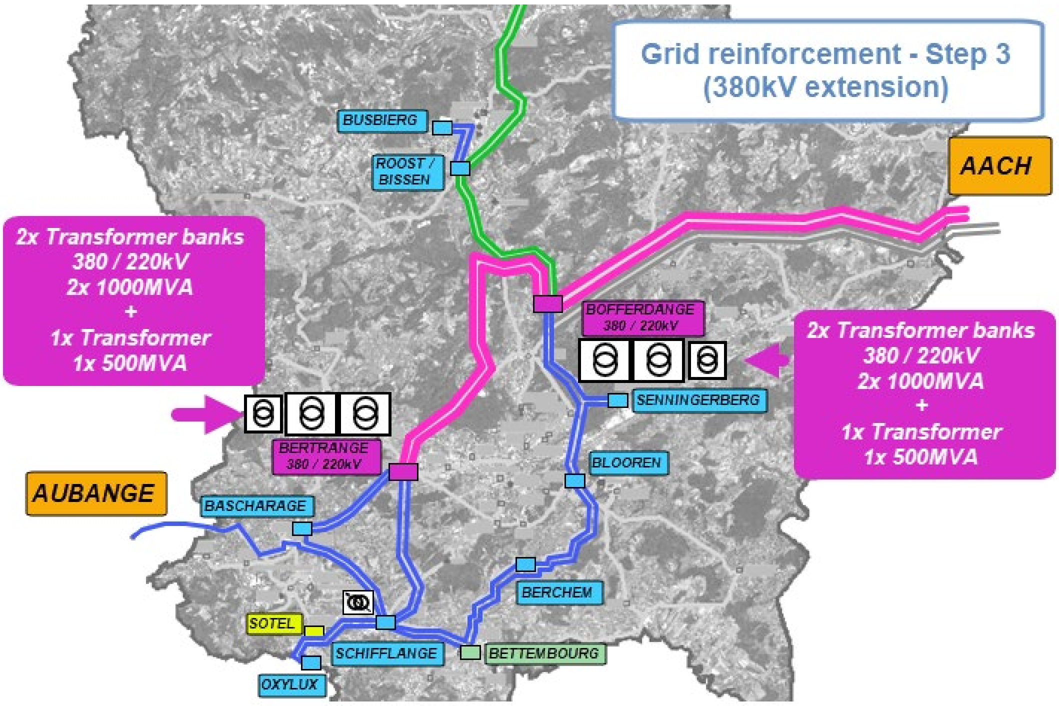


Installation variant 2:

A second implementation possibility would be to install 2 transformer banks with 1000MVA of capacity each and 1 additional transformer with a capacity of 500MVA at the new station Bofferdange, during the grid reinforcement **step 2**.



Later on, during the next grid reinforcement, **step 3**, 2 additional transformer banks with 1000MVA of transmission capacity each and 1 additional transformer with a capacity of 500MVA would be installed at the station of Bertrange.



The most important advantage of the variant 2 is that the minimal total transforming capacity will still be 1500MW per station, even in case of a transformer failure.

Planned transformer capacities
220kV / 65kV (110kV)

The maximum load of the transformers of the stations Bertrange, Schifflange and Blooren is already quite high nowadays. And in the future, taking over the growing load of those transformers by neighbouring stations, during a failure case, will become increasingly difficult.

In order to improve the current and future security of supply and in order to cope with the future energy demands, the installation of additional 220kV / 65kV (110kV) stations is necessary:

- A new station at **Senningerberg** will improve the electrical energy supply and the security of supply of the district **Kirchberg** of the capital city, the area around the **national airport**, and region **East** of the country.
- A new station at **Bascharage** will improve the electrical energy supply and the security of supply of the regions **West and South-West** of the country.
- A new station at **Bettembourg** will improve the electrical energy supply and the security of supply of the regions **South-East** of the country.

On the high voltage distribution grid, it is planned to make a successive transition, per region, from the 65kV voltage level to the 110kV voltage level in the future. As a consequence, the superordinated transformers, that means the existing 220kV / 65kV transformers, must be successively replaced by 220kV / 110kV models of higher power. In order to facilitate that voltage transition, it is planned to use multi-tap transformers which can be used with 110kV and 65kV.

That modification and adjustment of all the stations and connections of the 65kV grid for a transition to the higher voltage 110kV serves the purpose of increasing the grid capacities in general. More specifically, the transition ensures that the future grid will have sufficient capacities to accept a high generation from renewable energy sources.

The necessary transforming capacities of the stations have been determined by a detailed analysis of the subordinated 65kV (110kV) grid. Although that analysis is not documented in the framework of this document, those capacities are summarized in the spreadsheet hereafter.

In detail, it is planned to replace the existing 220kV / 65kV transformers as shown in the following table:

Station	***Existing Transformers (3-Winding) 220 / 65kV***	***Planned Transformers* (2-Winding with compl. tap) 220 / 110 / 65 kV***
Flebour	125-200MVA 125-200MVA	200/300MVA 200/300MVA
Roost (Bissen)	200MVA 200MVA	200/300MVA 200/300MVA
Heisdorf (Bofferdange)	100MVA 100MVA 125-200MVA	200/300MVA 200/300MVA
Bertrange	125-200MVA 125-200MVA	200/300MVA 200/300MVA
Blooren	200MVA 200MVA	200/300MVA 200/300MVA
Schifflange	200MVA 100MVA 100MVA	200/300MVA 200/300MVA
Bascharage (in project)	/	200/300MVA 200/300MVA
Senningerberg (in project)	/	200/300MVA 200/300MVA
Bettembourg (in project)	/	200/300MVA 200/300MVA

* The planned replacement transformers have a nominal power of 300MVA at a rated voltage of 110kV and a complementary tap for 65kV (200MVA)

Planned reactive power compensation

The increasing and variable electricity infeed from renewable energy sources, as well as the growing amount of cables are causing voltage problems on the Creos grids. The system stability and the quality of supply might suffer from it.

In detail, the growing amount of cables in the grids is generating an excessive reactive power, so that the voltage on the 220kV grid is getting close to the upper admissible limit. The upstream operator Amprion has repeatedly requested a lowering of the voltage on the 220kV high voltage grid, but currently Creos has no possibility to actively control the voltage on that voltage level.

As reactive power management and voltage control are amongst the obligations of all TSOs, it is necessary to install a reactive power compensation to control the reactive power flow at the borders of the grid / country and to reduce the voltage level on the 220kV grid.

For this purpose, a consultant has performed a detailed study during the year 2020 to find the optimal solution in terms of reactive compensation regarding the type and placement of compensation measures within the Creos grid. Resulting from this study, a parallel shunt compensation with variable adjustment has been chosen as the most appropriated technique.

It is planned to install the compensation equipment on various locations on the Creos grid from the year 2022 on, according to the following spreadsheet:

Initial installation locations	***2022 - 2024 [MVAr]***
Schifflange	*100 - 150*
Bissen / Roost	*100 - 150*

Additional installation locations	***2030 + [MVAr]***
Bertrange 380 kV	*100*
Flebour	*100 - 150*

* Those figures should be considered as the preliminary results of the compensation study. Changes might be necessary during the specific implementation of the project.

The projected compensation also aims to fulfil the following requirements in the end phase of the deployment:

- Full compensation of the 380kV lines at the station of Bertrange
- Prevention of cross-border reactive power flows with Germany by installing compensations at the stations Bissen and Flebour
- Reactive power flows to all neighbouring countries should tend to 0 MVAr
- Full use of the total compensation capacities from 2030 on

Conclusions and recommendations

Concerning step 1 of the grid development

There is a risk that the existing 220kV infrastructure may reach its limit between 2025 and 2030, depending on the actual growth of the power demand and of the generation. A major grid reinforcement is needed.

The construction of a 380kV infeed (see step 2) with its corresponding 380/220kV transforming station will only be possible on condition that a part of the existing 220kV infrastructure will be dismantled afterwards. In consequence, to ensure the electrical supply in a major failure case of the 380kV infeed, the reinforcement of a part of the 220kV structure with high-temperature conductors (T_{Lmax}=150°C) will be necessary.

Therefore, to prepare for the future energy demands and to secure the energy supply, it is advisable to conduct the following reinforcements in **step 1:**

- Replacement of the existing conductors of the 220kV lines coming from Bauler between the country border and Heisdorf / Bofferdange with high temperatures conductors (HTLS / ACCC conductors)

As an interim step, it is planned to conduct the replacement with high temperatures conductors on the lines coming from Bauler between the country border and Roost / Bissen.

The upstream grid operator Amprion has to be involved in this reinforcement process and has to commit itself to an overall higher import limit. The transmission capacities of the concerned grid sections between Niederstedem, Bauler and Luxembourg must meet the necessary requirements.

Concerning step 2 of the grid development

For the purpose of ensuring the electrical energy supply in the mid and long term, it is planned to conduct the following reinforcements in **step 2:**

- Complete the replacement of the existing conductors of the 220kV lines between Roost / Bissen and Heisdorf / Bofferdange with high temperatures conductors (HTLS / ACCC conductors)
- Construction of a new 380 / 220kV transformer station in Bofferdange
- Construction a new 380kV high voltage double line between the projected station of Aach (near Trier) in Germany, the new 380/220kV station in Bofferdange and the 220kV station in Bertrange. The line section Bofferdange – Bertrange will be operated with a voltage of 220kV until the completion of the grid reinforcement step 3.
    - ➔ A prerequisite for the construction of this new 380kV double line is the dismantlement of the existing 220kV double lines Trier/Quint - Heisdorf and Heisdorf - Bertrange, after the completion of the 380kV double line.

The upstream grid operator Amprion has to be involved in this reinforcement process and has to commit itself to an overall higher import limit and to the necessary increase of the transmission capacities.

Concerning step 3 of the grid development

As the power demand will very likely continue to increase between 2030 and 2040, foremost in the central part and the south of Luxembourg, the next expansion should follow in **step 3:**

- Construction of new 380 / 220kV transformer station in Bertrange (modification / expansion or reconstruction of the existing 220kV station Bertrange)
- Operation of the new high voltage double line between the station of Bofferdange and the modified / upgraded station of Bertrange with a voltage of 380kV

At the end of the forecast period between 2035 and 2040, the reinforced 220kV grid connection Bauler - Flebour may reach its limit during a major failure of the 380kV infeed, depending on the actual growth of the power demand and of the generation.

Concerning the load of the industrial grid "SOTEL"

SOTEL has been considering switching a certain part of its load from its current supply, ensured by a grid connection with Belgium and France, to the Creos grid. The switch of the additional load of 280MW from the industries connected to the SOTEL grid to the planned grid infrastructure of Creos would be possible after the completion of second step of the grid development. Eventually, as that total load consists of a group of industries, a partial switch could also be possible.

This additional load is of importance in any major grid extension project as it would allow the SOTEL load to be switched away from the BE and FR markets to the more attractive DE-LU market and would contribute to the financing of a new infrastructure through the additional consumption and related grid fees.

In any case, it is recommended to conduct the necessary studies in order to assess the possible grid perturbations due to the electric arc furnaces from the steel industry, which are constituting the biggest share of the load connected to the SOTEL grid.

It should be mentioned that different reasons prohibit a connection between the Creos grid and the currently existing direct line between the SOTEL system and France. It is clearly not planned or intended to make a connection between the Creos grid and the electricity grid in France.

Concerning electrical energy transits

Moderate electrical energy transits up to 300MW between Germany and Belgium should be possible in most of the here studied grid expansion cases under normal operational conditions. Of course, there may be some restrictions during major failure cases.

Concerning the costs and benefits of the investments

The planned grid development steps will surely need substantial capital investments and additional operational costs. However, the additional costs are expected to be borne by higher demand volumes, which in turn will positively affect the prospective grid fees.

In any case, the planned grid developments are necessary and should be seen as investment into the future of Luxembourg's electrical energy supply. The target, and main benefit, is to achieve adequate grid capacities to securely supply Luxembourg's electricity customers.

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