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Steps towards a CO2 neutral HV Substation

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SUMMARY

HV Products, civil works, busbars etc. to realise a Substation are responsible for a certain CO2 footprint. In this paper I describe the calculation and root causes for the CO2 foot print with an example of a 220 kV GIS and a 110 kV GIS Substation. In a second step means and measures are described of how to reduce the direct and indirect CO2 emissions and how to potentially compensate the residual CO2 foot print. The Major CO2 footprint of a HV substation is caused by the Joule losses during 40 years of operation. The replacement of the SF6, the compensation of the CO2 footprint in the Supply chain of the manufacturer are strongly reducing the CO2 footprint by more then 70%. The so called “left over” is the CO2 emission due to the electric losses.

200 words

KEYWORDS

Eco declaration, CO2 footprint, HV equipment, SF6 free switchgear, CO2 compensation

1 Introduction

HV Substations have a CO2 footprint due to the different HV Products, civil works and electric losses. In this paper I describe the different sources of the direct and indirect CO2 emissions in the eyes of a Grid operator. The focus is therefore the CO2 footprint in the use phase and the right choice of technology. Environmental parameters are becoming key in the selection of the product.

SF6 free solutions are available but this technology represent a minor fraction of the CO2 footprint of a Substation. Different ways must be found to become finally CO2 free.

2 The Axpo Grid

Axpo Grid is providing energy to about 3.5 Mio People in Switzerland by its 110/50 kV subtransmission network. The transformation of its grid from 50 kV to 110 kV was started by 1984 and will be completed by 2027. The goal is to reduce the electric losses and provide enough energy for the future needs. The Axpo Grid has 2200 km of HV lines, 250 km HV cables and about 40 Substations.

The strategy of Axpo Grid is to use, whenever available, SF6 free HV and MV products. Selecting power Transformers by considering environmental key parameters and request sustainability programms from the suppliers.

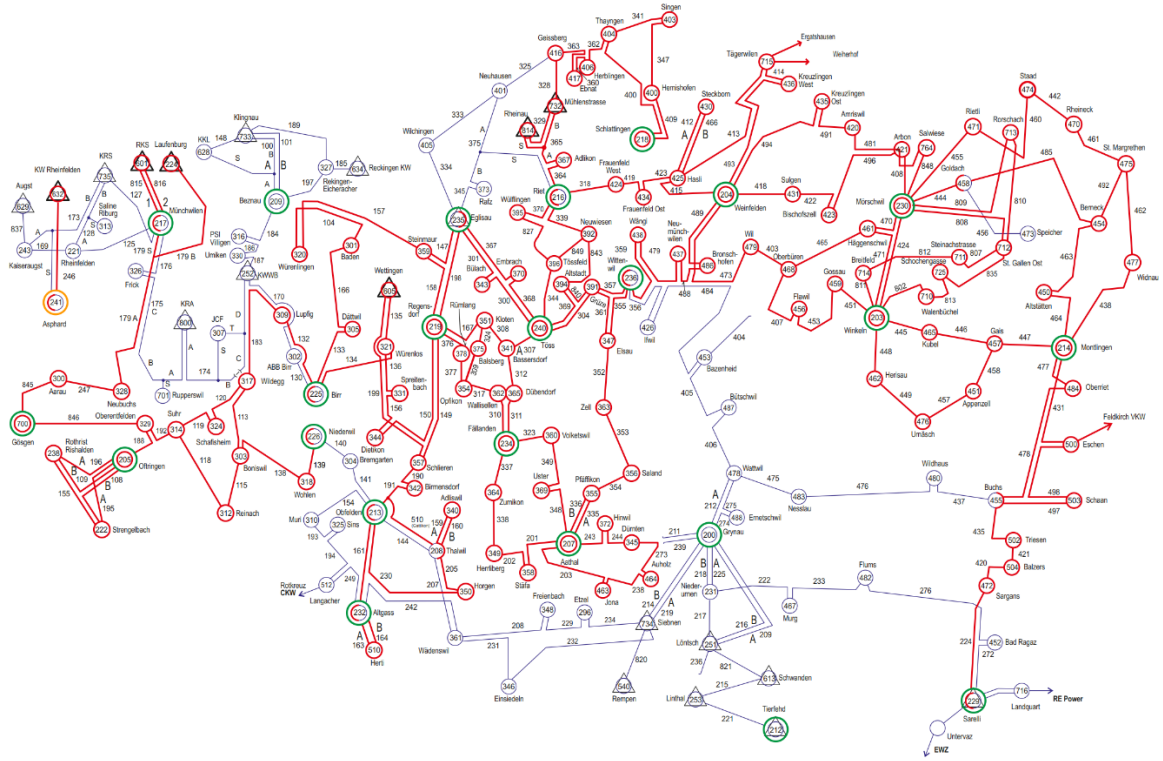

Figure 1:The Axpo Grid

2.1 The direct and indirect CO2 emissions in Tons of CO2

Direct an indirect CO2 emissions of the Axpo Grid are accounting to about 16’000 tons of CO2 annually.

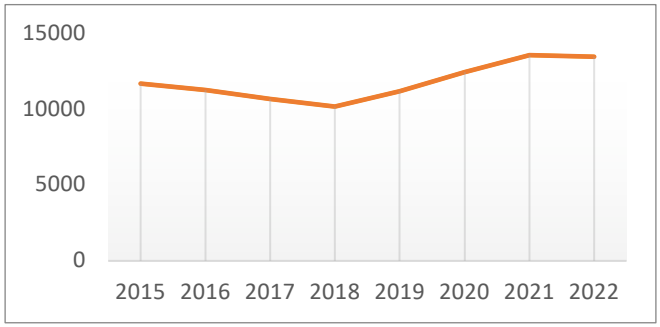

Figure 2: indirect CO2 emissions due to transmission losses

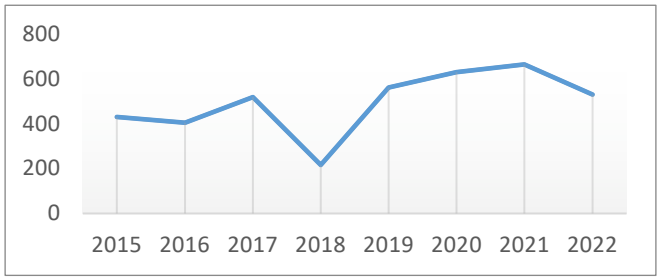

Figure 3: Direct CO2 emissions due to SF6 losses

The Transmission losses of the Axpo Grid are about 130 GWh in the Year 2021 and the losses of SF6 are about 23.5 kg. The annual leakage rate is below 0.2% and the transmission losses about 0.7%.

For the calculation on the indirect emissions, I considered the Swiss user mix on electricity [1] with 128.9 g of CO2 per kWh and the GWP on SF6 to 23500[2]

3 Example Eco balance of a 220 kV GIS Substation and 110 kV GIS SF6 free substation

3.1 220 kV AIS [6]:

A comparative Life cycle assessment had been carried out in the year of 2012. At that time the focus was on the full Eco declaration and comparison of different HV Technologies. During the years the focus are drawing towards the CO2 footprint. Now it must be focused on the transformation to become SF6 free and CO2 neutral.

As shown in figure 4, the losses of SF6 are accountable for 52% of the CO2 footprint by lower load currents (80% of the time 25% of the nominal current). The balance changes drastically by applying different load current scenarios. This have an impact in the technology choice.

By replacing SF6 and the fact, that manufactures are compensation in the supply chain there CO2 emissions [7] only the electricity consumption is by then accountable to the CO2 footprint for the grid operator. The major drawback is certainly that not all manufactures have today a clear strategy on reducing their CO2 emissions in the Supply chain. Some do have a clear strategy [7]. In any case it will take more than 10 years, sometimes even 30 years to become CO2 neutral.

The electricity consumption are losses for the grid and this losses needs to be purchased on the electricity market. This investment is considered operational cost (OPEX) for the DSO / TSO in Switzerland. If the electricity product to compensate for the losses is CO2 free, than the final goal to become CO2 neutral could be achieved.

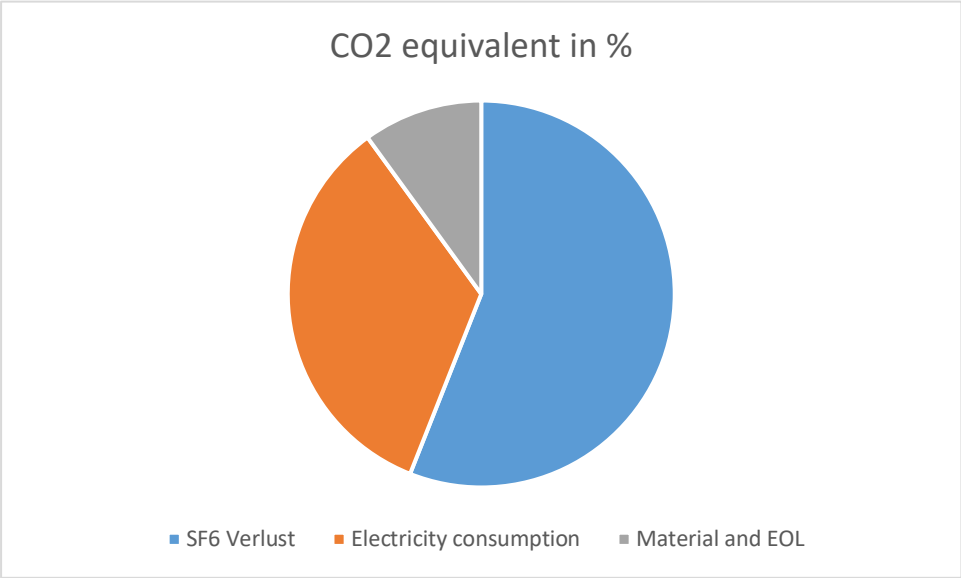

Figure 4: CO2 equivalent of the 220 kV HV GIS substation

The electricity consumption per HV Product shows, that the Power transfomer is accountable for > 90% of the electricity consumption during the lifetime.

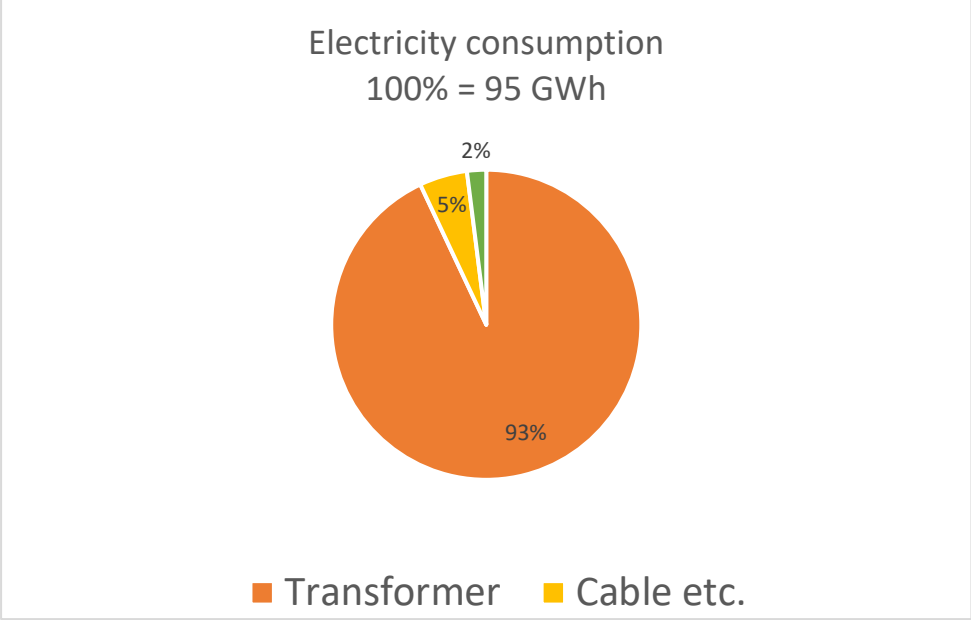

Figure 5: Electricity consumption of 220 kV GIS Substation during 30 years

For the selection of the power transformers, Axpo is considering high cost on no load and cupper losses to give the incentive to manufacture an efficient transfomers. Price per kW on no load losses are 15'000 CHF and cupper losses 6000 CHF.

The example shows

3.2 110 kV GIS SF6 free Substation [3]

Axpo Grid is principally installing Solutions for HV and MV without SF6. In the year 2017 the first g3 GIS substation had been built. The experience during the last 6 years is very positive. The LCA

study, which had been done in 2017 clearly identified the CO2 footprint reduction of 70% compared to a SF6 solution. Not considered in this study had been the power transformers.

The GIS has an internal resistance of 94 uOhm, which results into a Joule losses of about 80 GWh during 40 years or about 10 tons (128.9 g CO2/kWh Swiss mix) of indirect CO2 emissions. The total CO2 footprint of the GIS Solutions during its life cycle is 60 tons of CO2. The financial compensation of 60 tons, by a price of 90 EUR/tons is quasi negligible and can easily become CO2 neutral.

Example: https://www.atmosfair.de/de/

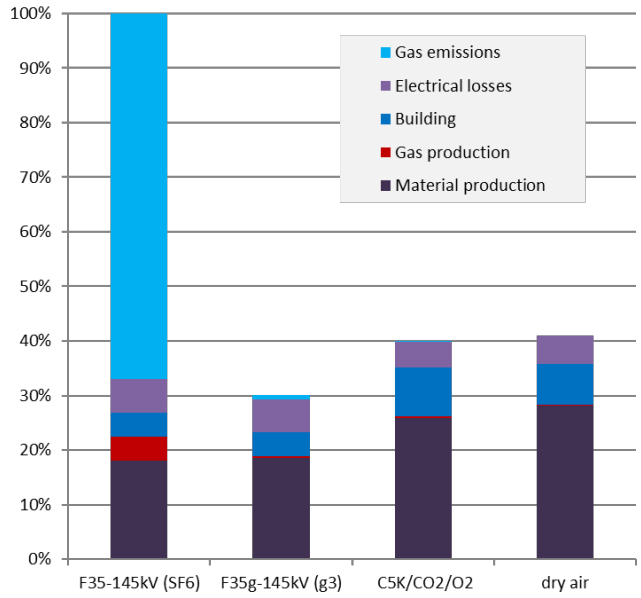

Figure 6: LCA for a 110 kV Substation Etzel at Axpo Grid.

4 Conclusions

The examples of the eco analysis on the 220 kV and 110 kV Substations show an easy way to become CO2 neutral as a grid operator. The CO2 footprint will drastically be reduced by SF6 free solutions, CO2 compensation in the supply chain of the manufactures and by the procurement of the Joule Losses with CO2 free electricity. Unfortunately the neutralisation of the CO2 at the manufacturers will take 10 years or more. The compensation of the leakage emissions of non SF6 free solutions during life time can be done by by investing into CO2 certificates. In Switzerland this compensation can not be considered as part of the grid cost. Even if this cost are not very high, it needs to be clarified by regulatory administration.

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