Digital low Voltage grid – Using new Technologies to Optimise Planning and Operational Processes

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Abstract

Using new technologies and data made available through cheaper communication technology, as well as a completed Smart Meter rollout will offer a lot of opportunities.

Salzburg Netz has developed a GIS-based system for analysing low voltage grids using real time data provided by measurements in secondary substations, digital switching records and Smart Meter data.

Having a real time switching state in every low voltage grid enables ranking the quality of every low voltage grid down to each branch. Without measuring them individually, it optimises the planning process for low and medium voltage grids, and helps to integrate technologies like charging stations, heat pumps, or PV-systems.

1 Introduction

The subject of this paper is a development based on the experience collected through multiple research projects like *ZUQDE* and *DG Demonet* for medium voltage grids, as well as *DG Demonet Smart Low Voltage Grids* and *Integration of Loads and Electric Storage Systems into advanced Flexibility Schemes for LV Networks (Leafs)* for low voltage grids. The full reports of these projects can be viewed via www.energieforschung.at.

Its aim is to showcase a solution for the better integration of technologies, like charging stations, heat pumps and PV-systems. Measurement data provided through different sources like a Smart Meter installed in different households in low voltage grids, a measurement setup in secondary substations, providing active and reactive power, as well as voltage measurement data and a real time switching state in medium and low voltage grids to allow filtering the collected data and exclude irrelevant measurement data collected outside normal switching state scenarios, is used to better supplement traditional grid calculations.

2 Initial Situation

This chapter focuses on the current situation of grid loads and methods of grid calculation, as well as the estimated numbers of charging stations, heat pumps and PV-systems that have to be integrated according to current forecasts.

The current distribution grid of Salzburg Netz has a total line length of about 17,000 km with 27 primary and nearly 5,000 secondary substations.

Voltage Level	Overhead Line (km)	Cable (km)
110 kV	561	43
10 kV and 30 kV	1,690	2,695
400 V	474	11,775

Table 1: System Lengths

The maximum grid load excluding generation is about 860 MW with about 4.2 TWh of yearly total energy consumption.

As of January 2021, 3,600 electric vehicles are in use in Salzburg. This leaves about 310,000 cars, 64,000 motorcycles, 40,000 trucks and approximately 40,000 tractors. Public transport as well as transit traffic on one of the major North-South motorways connecting Germany, Italy and South-Eastern-Europe is also a major factor, which will result in a higher demand for charging stations in the future. Excluding public transport and transit traffic, the daily demand will increase by approximately 4.5 GWh/day.

Additionally, about 50,000 oil based heating systems using oil will have to be replaced by sustainable systems within the next decade. Current surveys, done by Salzburg Netz, show that up to 60% of those consider heat pumps as an alternative.

Decentralised generation should be taken into account, in addition to the already existing systems with approximately 800 MW of hydropower, 110 MW of PV and about 150 MW of biomass and conventional power plants.

Current estimates done by laser scan and not factoring in statics or other factors, show that rooftop potential exceeding 900kWh/m² per year in Salzburg is up to 3.2 GW with additional potential for open space PV-systems if they are legally allowed in the future.

In case all of these trends prove to be true, the grid capacity will have to be nearly doubled and prioritising grid reinforcement becomes more important.

3 Grid Calculation

To identify the necessity of grid reinforcement in low and medium voltage grids, Salzburg Netz uses either a GIS-based system (LV), or a conventional network calculation tool (MV) for load flow calculations.

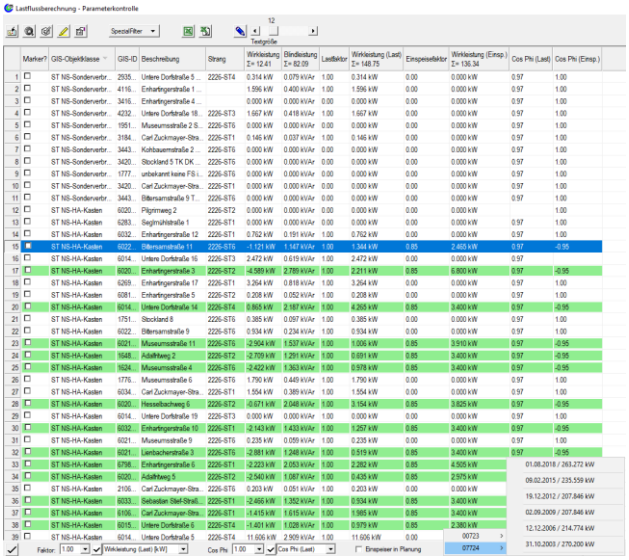

Figure 1: Parameter Control for Load Flow Calculation LV-grid

Figure 1 shows the parameter control of a general low voltage grid calculation including an active and reactive load per grid connection point, as well as an active and reactive feed in power when necessary (e.g. PV-system).
The loads are calculated based on the yearly consumption of the grid connection point. The feed in power is calculated using the installed active power.
The bottom right corner shows the available measurement data from the MV/LV-transformer that can be used to rebalance and resize the loads as can be seen in figure 2.

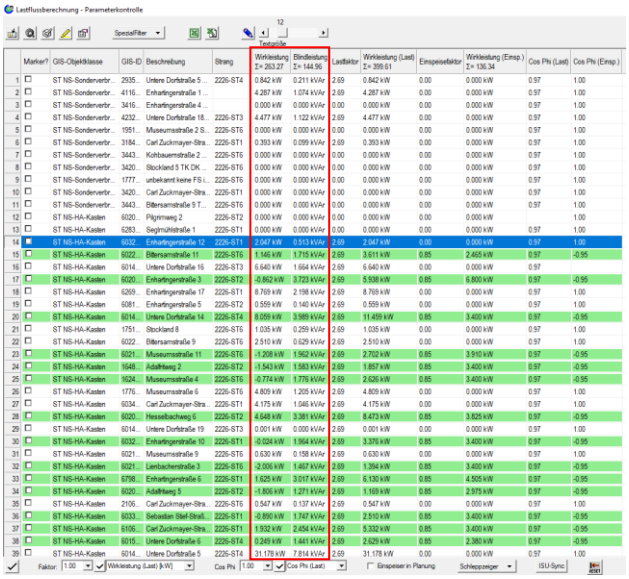

Figure 2: Resized Parameter Control for Load Flow Calculation Using Transformer Measurement Data

Using the load based on the yearly consumption as an initial factor, the total load of the LV-grid is estimated. Compared to the measured maximum load of the transformer, this results in a scaling factor that is then applied to the individual loads of each connection point. The load in the top row, for example, has increased from 0.314 kW to 0.842 kW after resizing.

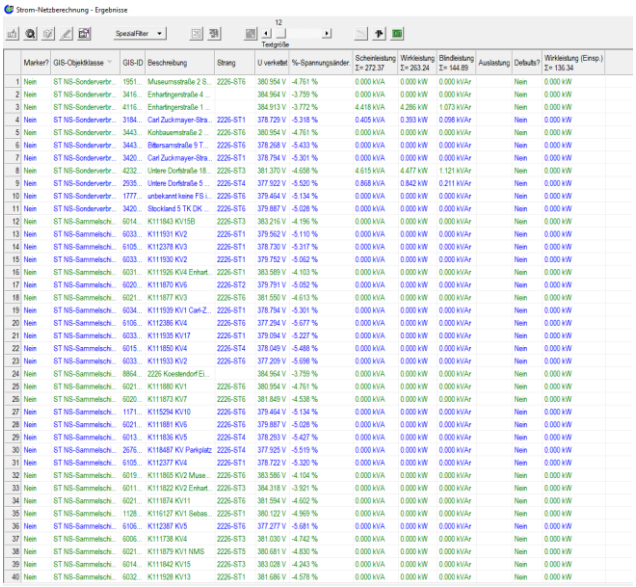

Figure 3: Calculation Result View

The load flow calculation results shown in figure 3 include a calculated voltage level per busbar as well as a percentage of the maximum possible load per cable and transformer. After voltage levels become available through Smart Meters, a voltage level per feeder and scenario will be made available here. Further the plausibility of the results is checked and the option of an automatic recalculation with a redistribution of the loads is offered.

The problem in general is that current transformer stations only use a drag point ampere meter to measure this maximum load, which leaves a lot of uncertainty regarding the time period, circumstances and time of the measured load peak, because the data is only collected every one to three years.

Additionally, PV-systems reducing the yearly energy consumption distort the allocation of loads, making it harder to correctly calculate the grid, especially because there is no further measurement data, like voltage levels in some of the connection points of households, to compare the results to.

For medium voltage grids a similar problem exists. Figure 4 illustrates the load profile of a 30-kV-feeder.

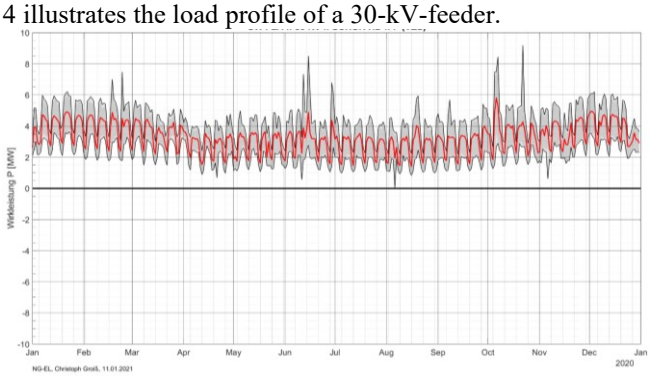

Figure 4: Parameter Control for Load

Depending on the scenario (feed in scenario or maximum load), a suitable load value for the feeder is chosen. The load distribution on the feeder is then resized using the chosen value and the maximum loads of each transformer station, collected by the drag point ampere meters, as a distribution factor over the length of the feeder.

Again, the same problem as with low voltage grids exists: the lack of decentral voltage measurement data makes evaluating the results nearly impossible.

4 Using Measurement Data to Evaluate Grid Calculation Results

DG Demonet Smart Low Voltage Grid used Smart Meters, installed in a low voltage grid with 40 PV-systems and 35 charging stations, to collect measurement data on the difference between planning process and reality.

The red square in the middle of figure 5 shows the difference between the current planning process and the additional voltage band available if voltage measurements are factored in.

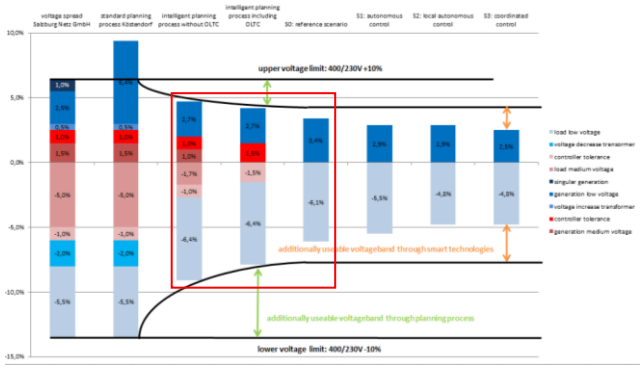

Figure 5: Measurement Results Smart Low Voltage Grid

Measurement data collected over multiple years allows a revaluation of calculation results and increases both the capacity for new loads, as well as new generation systems.

5 Real Time Switching State in Low Voltage Grids

While having a real time switching state in medium voltage grids is the standard in current SCADA-Systems, data in low voltage grids is normally only collected offline e.g. on paper.

Figure 6 shows a typical secondary substation including the medium and low voltage feeders connected to it, as well as elements like the transformer and the fuses of each individual feeder.

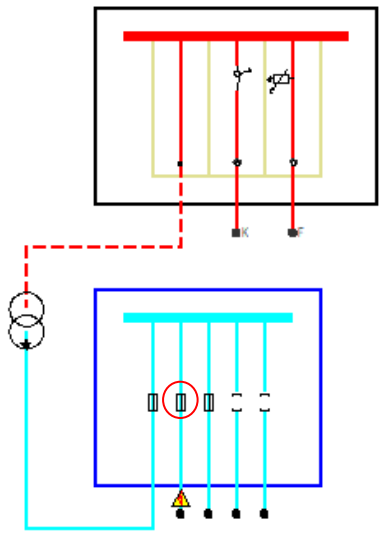

Figure 6: Secondary Substation

The red circle indicates the element which can be seen in figure 7 in more detail.

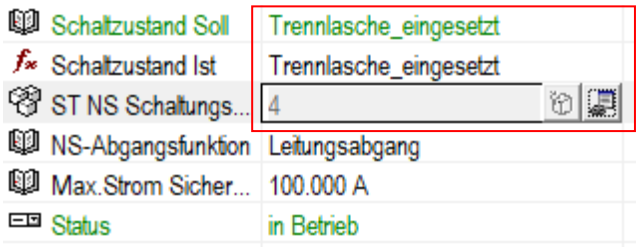

Figure 7: Low Voltage Feeder With 100A Fuse

Figure 7 shows the GIS-view of a low voltage feeder including the normal switching state in the top row, the current switching state in the second row, as well as the number of different switching states in the database for this element.

Figure 8 shows the different timestamps of this measurement data.

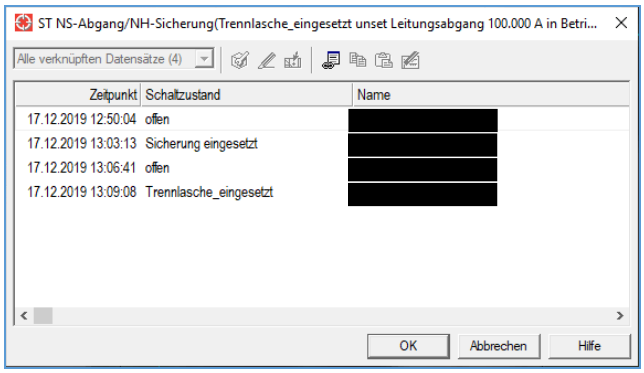

Figure 8: Different Switching States in the Database

This data can be used to automatically restore historic switching states to, for example, evaluate fault scenarios relevant for insurance cases. The major use; however, is to find time periods for every low voltage grid where the switching state diverged from the normal state and use these time periods to automatically filter the collected measurement data.

Using this data for every feeder in every low voltage grid, with working Smart Meters, a maximum and minimum voltage level per year, as well as a voltage profile can be created using the "PQ-Report"-function of the Smart Meter.

6 Digital Switching Records

Figure 9 shows a feature of the mobile GIS-version used by Salzburg Netz.

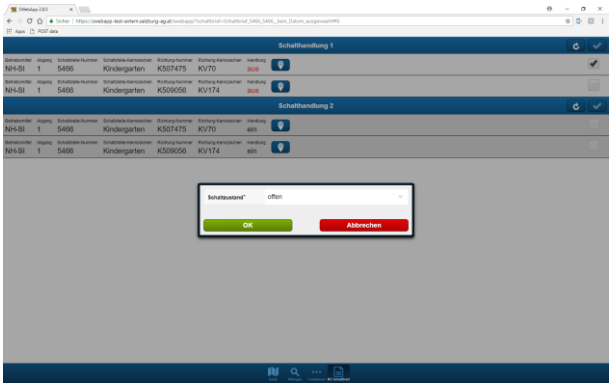

Figure 9: Digital Switching Records Using a Mobile GIS-APP

This app allows the documentation of every action taken in the low voltage grid either through a pre-planned switching procedure (via GIS), or in case of a situation where pre-planning is not an option (e.g. faults) through an ad hoc version.

The planning process for a switching state change up done via GIS can be seen in figure 10.

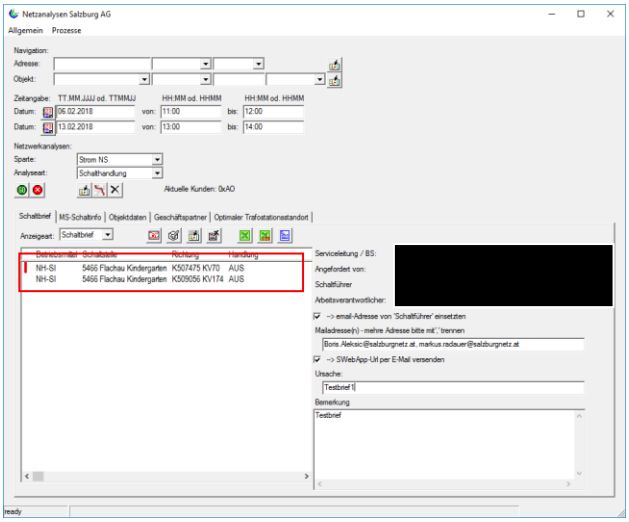

Figure 10: Planning Tool for Temporary Switching State Changes

In the marked area the chosen cable distributor/transformer station and the targeted switching element can be seen.

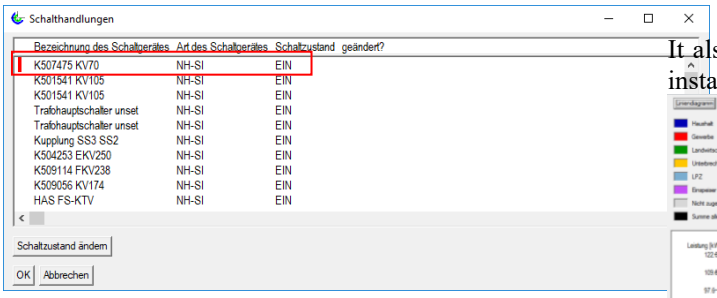

Figure 11: Input Window for the Required Feeder

Figure 11 illustrates the selection of the switching element in the cable distributor/secondary substation.

After this process the customers affected by the change are automatically detected and a serial letter is produced that is then used to inform them about the duration of the change and how they will be affected by it.

7 Asset Analyser

The GIS based asset analyser is currently being expanded to fit the new requirements. In the past its main use was to automatically analyse single low voltage grids and the synthetic load profiles in use.

Figure 12 shows an automatically collected summary of a low voltage grid including the total energy consumption per synthetic load profile.

The marked area in the bottom right corner shows the minimum and maximum load for the chosen day as well as for the chosen year and will include options to view the same for voltage measurement data, in the substation and at the end of each feeder in more detail as soon as the data becomes available via Smart Meter.

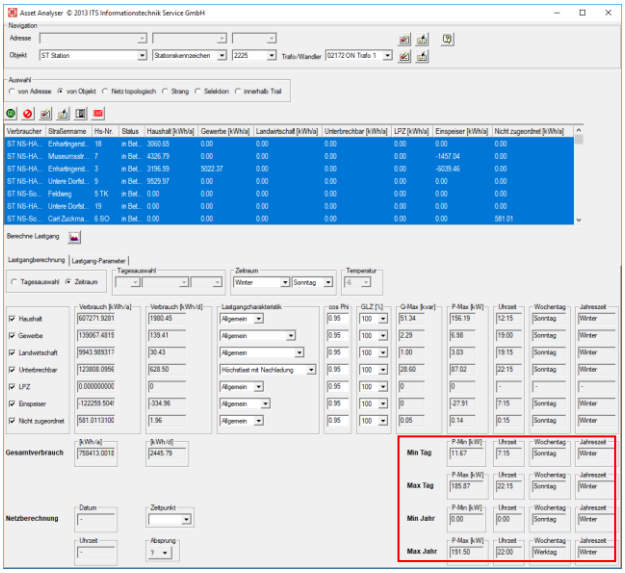

Figure 12: Asset Analyser for Analysing low Voltage Grids

It also enables a synthetic load profile of all the customer installations connected to the grid, as seen in figure 13.

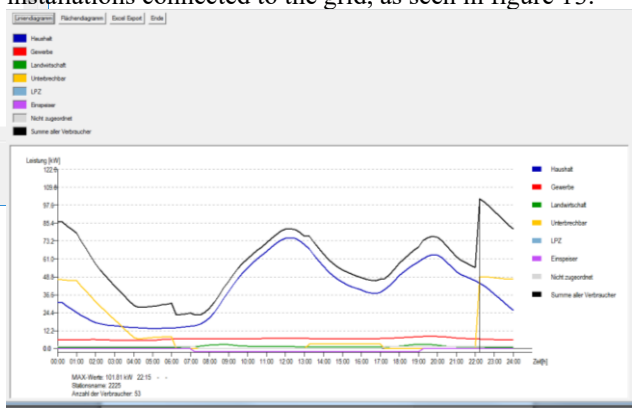

Figure 13: Summary of Load Profiles Using Asset Analyser

Figure 14 shows an option to view data like temperatures; where necessary transformer load profiles and voltage profiles of the low voltage busbar can be controlled.

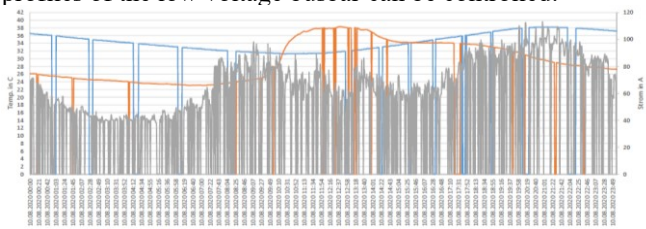

Figure 14: Preview Transformer load, Outside Temperature and Temperature Transformer box

This data can be filtered using the real time switching states to fit the required scenario/switching state. The resulting data can further be analysed to receive a ranking of the "worst" feeders in the low voltage gird.

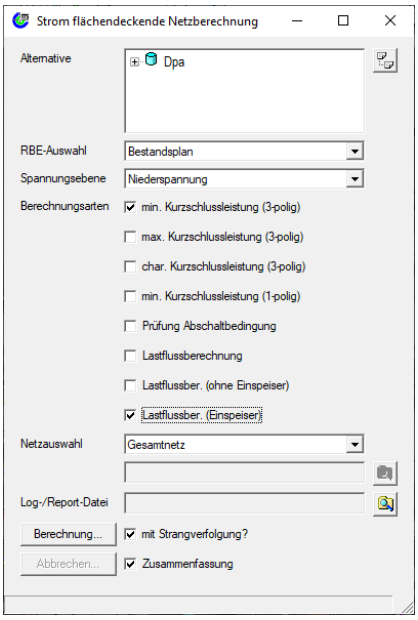

Figure 15: Low Voltage Grid Analyser

Figure 15 shows a specialised application based on the normal low voltage grid calculation tool, enabling a calculation and report of every low voltage grid resulting in a complete overview of the lowest voltage level on every low voltage feeder and every secondary substation. This allows the inclusion of load profiles in transformer stations and Smart Meter data in the future; and, therefore, offers a perfect starting point and data base to optimise the calculation of medium voltage grids.

8 Conclusion

Switching records collected through using an application integrated into the mobile GIS-version used by Salzburg Netz provide a lot of advantages. Using the already established process of planning and documenting temporary switching states of the low voltage grid, (semi-automatically) informing customers affected by the changed state of the grid, as well as logging all the necessary data e.g. acting persons, outside parties involved, without any unnecessary additional paperwork.

Through having this real time switching state in every low voltage grid, data collected through smart metering can be validated. This, for example, allows to automatically exclude time periods when the switching state was not in its normal, optimised form, enabling a ranking of the quality of every low voltage grid down to branch level.

The result is a ranking of low voltage branches having critical parameters, like a high total load, voltage measurements nearing the limits of the allowed voltage band, or even finding a wrongfully set transformer ratio, enabling asset managers as well as low and medium voltage grid planners to optimise the integration of new technologies like charging stations, heat pumps, or PV-systems, by knowing the exact state and potential for integration of every grid.

9 References

All the pictures used are property of Salzburg Netz GmbH. The research projects mentioned received funding by the Austrian Research Promotion Agency (FFG) and the Klima- und Energiefond (KLIEN).