FULLY AUTOMATED CALCULATIONS IN BOTH MV AND LV NETWORKS

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ABSTRACT

Alliander, a Dutch DSO, has succeeded to automate the process of network model generation and calculating of the MV and LV network. As a result both near-real time insights as well as an uniform validation model for safety, quality and capacity analysis are general available and operationally used within the company. The generated network models are available for all departments in the company. As a result, a drastic time reduction for generating actual network models is achieved.

INTRODUCTION

Within Alliander, network analysis was partly automated, but many manual activities were still required. MV network models were semi-automatically generated from the GIS-system and needed manual adjustments, for example: data concerning load, generation and the maximum loading of substation feeders. Also errors in network topology (due to poor quality of GIS data) had to be corrected manually. The outcome of the various calculations was manually combined into a performance list. This resulted in a time consuming process (>2000 hours for the MV network). Due to the manual activities, the risk of failures and issues regarding non-uniformity was high.
Analysis of LV network quality was only performed on occasional basis due to the time consuming activities to set up a correct network model. Due to the impact of the increase of photo voltaic, heat pumps and electric vehicles also similar calculations like in the MV network are necessary.
A small pilot showed the possibility of automating the generation and calculation of LV network models [1].

ADDRESSING THE PROBLEM

A multi discipline project team consisting of Alliander Asset Management (responsible for network analysis), Alliander IT (with knowledge of the GIS and other data systems) and Phase to Phase (vendor of the calculation software) was formed to develop a fully automated process for the network analysis and validation.
The complete process is shown in Figure 1.

The automated process can be divided in five steps:

1. After selecting the relevant substations or Ring Main Units (RMU) , the networks are traced in the GIS-system (NRG-BAR) and relevant measurement data is collected from EMS-SCADA. The network and measurement data are stored in tables in the SAP HANA system.
2. From these tables the Network Builder builds the network model files.
3. Following, the Checking Engine corrects data errors and missing data, resulting in final network model files. These files are stored on the so called “Content Server”, a file system which is accessible within the whole company. Data errors are reported to the “Data desk”, the department responsible for correct data.
4. The Calculation Engine performs the necessary technical calculations and sends reports to both the “Content Server” as well as SAP/HANA.
5. Finally the results of the calculations are analysed to report the quality of the network.

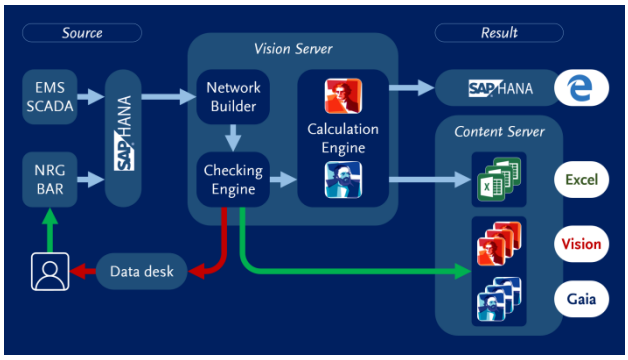

Figure 1: Flow scheme of automatic network generation and calculation

MEDIUM VOLTAGE ANALYSIS

The main reason for MV analysis is to decide whether or not the networks comply to requirements both from the regulator as well as the company itself.
The voltages in the network must be within specific bounds. No overload is tolerated on network components like cables and transformers. Short circuits may not result in dynamic or thermal overload. In case of disturbances the network must be restored with a limited number of switching actions.

Method

The method used can be distinguished in three steps: Build, Check and Calculate.

Build

Data of the MV-network fed by an HV/MV substation are combined in specific tables in SAP/HANA. For these data various sources of information are used. From these tables a basic network calculation model is build. The model contains both a schematic representation similar to the network schemes used in the Control Centre (Figure 2) as well as geographical visualisation (Figure 3).

Check

In the checking procedure errors are corrected and missing data is added. Examples are:

- Missing or too extreme loads are assumed to be a percentage of the feeding transformer capacity.
- Missing technical data of components is corrected with the help of default lists.
- Missing protection settings are corrected based on the Alliander protection philosophy.
- The total simultaneous feeder loads are adjusted based on the available substation measurements.

For these corrections, the knowledge from experts in the company is used.

When data problems occur, they are reported and will be corrected in the data systems, which results in a continuous improvement.

The checking results into final network model files (one for every substation), with a companywide uniform representation. These files are stored on a location where they are widely accessible for other people and departments in the organisation.

Calculate

Calculations are performed by the network analysis tool Vision, which is developed by the Phase to Phase company and widespread used by the various DSO's in the Netherlands.

First, two load-flow calculations are performed to obtain the extreme steady state situations in the network. The first calculation is performed with high load and low generation and the second one with low load and high generation. From these calculations the extreme voltages in the network are available as well as the maximum voltage deviation on a specific node in the network. Also the maximum loading of components is available.

Next, short-circuit calculations (both 3-phase and single phase) are performed. The short circuit currents are compared with the maximum permissible thermal current for cables and transformers and with the maximum dynamic rating of the bus-bars.

Finally, an outage analysis is performed. For every cable in the network it is examined whether the network can be restored when this cable is out of service (e.g. due to a fault or maintenance). The restoration must be performed within a limited number of switching actions and may not result in exceeding voltage limits or overloading of components.

For every substation an Excel-report is generated which is stored on the same location as the network model. This report is also available for the other persons and departments within the company.

The results of all substations are summarized in an Excel file to get an overview of the MV network. In this summary, the substations are ordered based upon requirements both for quality as for network capacity. This summary is used for network improvement investments proposals.

Results

The first results of the automatic analysis of all 200 medium voltage networks are available since the end of 2016.

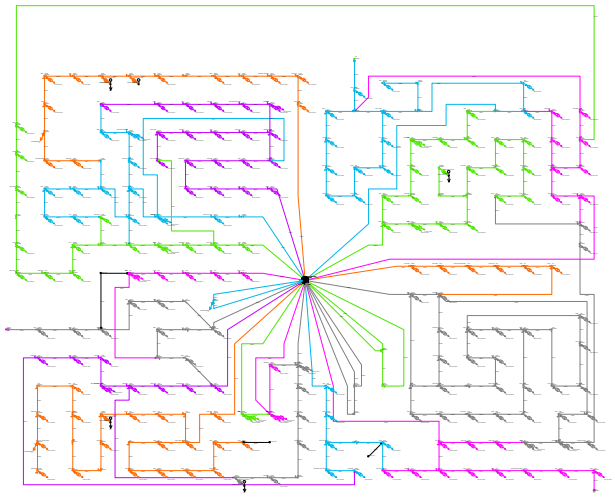

Figure 2: Schematic view of the MV network Vliegenbos.

Figure 2 gives an example of the schematic representation of an MV network fed by a substation. This schematic representation is similar to the scheme used in the Control Centre.

Figure 3: Geographic view of the MV network Vliegenbos.

Figure 3 shows the geographical representation of the same network.

At this moment still some manual activities remain required. Those activities mainly deal with comparing the network schemes with the schemes used in the control Centre and by updating and rearranging the HV/MV substation components. However, this system reduces the manual work to approximately 300 hours instead of 2300 hours. As a result, there is more time to analyse the results of the calculations and their impact on investment decisions.

Advantages for the company

All network files are actual, uniformly build and can be updated on request. The uniform way of representing the network model makes it easy to be used by other applications and departments within the company, like network extensions and studies on future scenarios.
At this moment these network files are used for the project Fault Location in MV networks [2].

LOW VOLTAGE ANALYSIS

The main reason for LV analysis is to decide whether or not the networks comply with requirements both from the regulator as well as from the company itself.
Like in MV-networks, the voltages in the network must be within specific bounds. No overload is tolerated on network components like cables and transformers. Short circuits may not result in thermal overload.
Other issues to be dealt with in LV networks are voltage variations due to inrush currents and safety requirements. Inrush currents may not result in annoying voltage variations (flicker). This results in requirements for the network impedance.
Safety considering workers in the field, results in a maximum time a short circuit may last. In a considerable part of the LV network earthing is provided by the DSO. This earthing can be provided both to customers (TN-earthing) as well as to the earthing of objects used for public lighting. In these parts of the network the safety of persons touching an earthed object is important. This results in a limited value and duration of touch- and fault voltages during single phase to earth faults.

Method:

The used method is similar to the method for MV-analysis (Build, Check and Calculate). However there are differences.

Build
Data of the LV-network fed by a MV/LV ring main unit (RMU) are combined in specific tables in SAP/HANA. For these data various sources of information are used. From these tables a basic network calculation model is build. The model contains schematics according to the network geography (Figure 4). Also full geographical visualisation is available (Figure 5).

Check
In the checking procedure errors in the data are corrected and missing data is added. For these corrections knowledge from people in the organisation is used.
Examples are:

- Missing data for fuses in the RMU is corrected, based upon cable cross-section diameters and the earthing of the customers connected (TN or TT).
- Missing technical data of components is corrected with the help of default lists.

Data problems are reported and will be corrected in the data sources, which results in a continuous improvement.
The checking results in a final network model file for each RMU. These files are stored on a location where they are accessible for other people and departments in the organisation. They can be used for modelling and studying network extensions and future scenarios, but also for analysing voltage and other Power Quality problems.

Calculate
Calculations are performed by the network analysis tool Gaia, which is developed by the Phase to Phase company and widespread used by the various DSO's in the Netherlands.
Like in the MV analysis, first two load-flow calculations are performed to obtain the extreme steady state situations in the network. The first calculation is performed with high load and low generation and the second one with low load and high generation. From these calculations the extreme voltages in the network are available as well as the maximum voltage rise or drop between the connections and the LV bus-bar of the feeding Ring Main Unit. Also the maximum loading of components is available.
Next, voltage variations due to inrush are calculated. From these calculations also the network impedance is obtained. This impedance is an indication for flicker aspects.
Also, short-circuit calculations (both 3-phase and single phase) are performed. The short circuit currents and their duration are compared with the maximum permissible thermal current for cables and transformers.
The duration of the short circuit is also used for classification of network safety.
Finally, the safety regarding touch voltages is analysed. Single phase to earth faults are performed on connections where earthing is provided by the grid operator. The calculated values are compared with the Dutch requirements for safety that either the fault voltage is below 66 V or the duration of the fault is less than 5 seconds.
All results are stored in the SAP HANA environment, where further analysis is performed.

Table 1 Classification criteria for the LV network

	Criteria		
	Good	**Poor**	**Bad**
Voltage (general)	$215 \leq V \leq 245$	$210 < V < 215$ or $245 < V < 250$	$V < 210$ or $V > 253$
Voltage drop due to load	$\Delta V \leq 5.5\%$	$5.5\% < \Delta V \leq 6.5\%$	$\Delta V > 6.5\%$
Voltage rise due to generation	$\Delta V \leq 5.5\%$	$5.5\ \% < \Delta V \leq 6.5\%$	$\Delta V > 6.5\%$
Network impedance	$Z \leq 283$ mΩ	283 mΩ $< Z \leq 523$ mΩ	$Z > 523$ mΩ
Safety for customers	$U_{fault} \leq 66$ V or $t_{fault} \leq 5$ s		$U_{fault} > 66$ V and $t_{fault} > 5$s
Short circuit duration	$t_{fault} \leq 5$ s		$t_{fault} > 5$s
Short circuit firmness	OK		Not OK
Loading of cables	$L \leq 70$ %	70 % $< L \leq 100$%	$L > 100$%
Loading of transformers	$L \leq 100$ %	100 % $< L \leq 120$ %	$L > 120$ %

Analysis

Based on the calculated results, the Ring Main Units are ranked (Good, Poor or Bad). First the results of the various calculations are compared with the classification criteria of the various aspects like safety, Power Quality and requirements regarding network capacity (see table 1). Based on these results the over-all ranking is performed by applying weighting factors on the various criteria. All these weighting factors and criteria are thoroughly discussed with network planners and decision makers.

The ranking of the Ring Main Units is the base of the ranking by zip-code. These rankings are made visible on a map. Actually this map will be the start-point for further analysis.

The rankings represent a base for investment proposals, regarding further network improvements.

Also an obligatory report for the regulator regarding safety is automatically created.

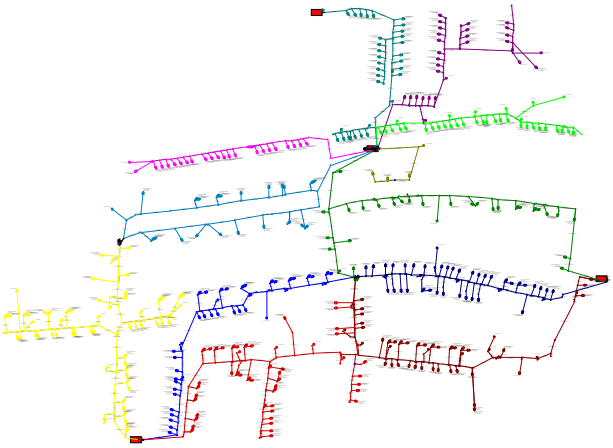

Figure 4: Schematic overview of the LV network fed by RMU Bachstraat

Results

The first test results of the automatic analysis of 100 Ring Main Units were available at the end of 2016. The first results look very promising. The project will result into 34000 LV network files available in April 2017.

Figure 4 gives an example of the schematic representation of a the LV network fed by the RMU Bachstraat, where Figure 5 shows the geographical representation of the same network.

Figure 5: Detailed geographic overview of a part of the LV network fed by RMU Bachstraat.

Figure 6 gives an example of the classification overview of the LV network.

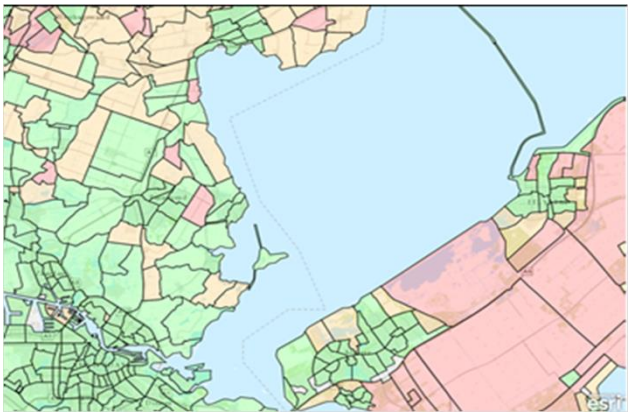

Figure 6: Example of a classification overview of the Alliander LV network (colours not based on actual figures)

FUTURE WORKS

So far, a solid platform for retrieving the as-is MV/LV network data has been created. This platform will be serviced and maintained by Alliander Asset Management. It is expected that future developments will result into additional functionality, according to users requests, like combining MV networks, additional protection calculations (selectivity) and a better automated representation of the HV/MV substation model.
With frequent refreshments of the automated network files and continuous improvements on the data, the software and the model(s), it is expected that this platform solution remains for many years and will be the starting point for predictive calculations as well.

CONCLUSIONS

An automatic system for building and analysing the MV network is successfully realized in 2016, resulting into a uniform accepted model and representation of the MV Network. Up to date network models are available for and being used by other departments and applications in the company.

Small adjustments due to modelling of feeding HV/MV transformers remain necessary. However, this system reduces the manual work to approximately 300 hours instead of 2300 hours. As a result, there is more time to analyse the results of the calculations and their impact on investment decisions.
The data errors will continuously be reported towards and corrected by the responsible data-owners.
A project to automatically generate and analyse network files for the LV networks has been started halfway 2016. The first results are very promising. It is expected that all 34000 LV networks will be modelled and analysed in April 2017.
The automatic creation results in uniformly build network models, which can be generally used within Alliander by network planners and decision makers.
Finally, the project has delivered two products (network files and reports) which can easily be updated. Therefore, it is expected that these products represent the Alliander MV and LV Networks and therefore remain in service for many years from now. Next to this, model improvements and additional functionality are expected to be included in line with requirements received from various users and/or the regulator.

REFERENCES

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