LONG TERM LOAD FORECAST – THE SOURCE FOR NETWORK PLANNING

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INTRODUCTION

The liberalization of the energy market has increased the need to optimize network operation costs and minimize losses. Investments into the network have reduced and therefore it is important to develop the existing network in an efficient manner. Long term load forecast is the source for effective network planning, because only with sound knowledge about the development of customer behavior can the network planner create future scenarios in accordance with the given rules of regulators. As load forecast is based on a known model of the existing network, it is important to have the correct representation of loads at both medium and low voltage levels.

In this paper a three step approach is described to plan the necessary investments for ensuring the effective operation of the network. Step 1 describes how all loads are modeled to get a base for load forecast. Step 2 is definition of load increases/decreases in networks which are split into structural groups/classes and Step 3 is the simulation and evaluation of these network developments. Throughout all steps the planning engineer is supported by simulation software.

CORRECT LOAD MODELLING

Depending on the evaluation tasks, the voltage level and the network data available, different approaches to modeling the loads within the network are made.
If a consumer is considered from the network point of view, then as well as the different aggregations of its consumption (cluster) the power in form of the maximum demand is also of interest.
In HV and MV networks the metered data is normally sufficient to model each load in detail. Clusters are not generally considered, as each single load is already a comprehensive aggregation, depending on the number of loads in the connected feeders.

Diversity factors

Looking at distribution networks, the metered, or otherwise gathered, data has to be checked by plausibility algorithms. In many cases the original data are not in the form that calculation software can easily deal with. Therefore the following procedure has become widely accepted:

1. Assumption of P/power factor or I/power factor for all loads.
2. Definition of metering points in the network:
   a. Transformer maximum demand
   b. Measured currents in the feeder
3. Input of measured load data e.g. energy
4. Calculation of the diversity factor for all loads downstream of the meter.
5. Calculation of the second diversity factor between all feeders

To achieve this, first of all the loads in each separate feeder will be allocated according to the ratio of the measured currents. Each load in a feeder will get the same diversity factor g_g according to:

$$g_g(x) = \frac{P\max(feeder)}{\sum Pi\max(consumer)}$$

The confidence limits (statistical certainty) in this case are extremely dependent from the size of the sample. The spread increases for small numbers of consumers.[1]
Next step is the adaptation of the total feeder load to the maximum demand measured at the transformer. This requires a two step allocation, as all the measurements are not time coincident and need a correction.
Further plausibility checks compare the spread of diversity factors over all feeders with similar consumer structures. Despite adjustments, one error that regularly occurs with this modeling is the excessive increase of loads at the feeder end .This is caused by the losses, which have a high impact on this type of network.

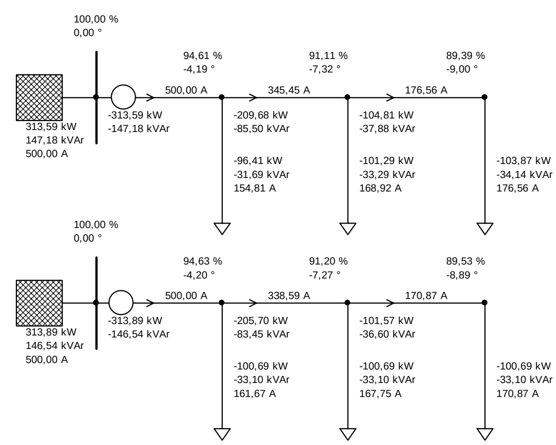

Figure 1: 2 different feeders where the load have been trimmed to a meter reading based on loads or currents

Load profiles

A second approach is a modeling method which could be described as ”Bottom up“. With the knowledge of the type of the consumer (mainly at the low voltage level) specific load profiles will be selected and assigned to the load, together with the measured consumption data (kWh). In Germany the VDEW offers diverse consumer collections (clusters) for the different seasons in year and days of the week. With this a load flow can be simulated for a specific time in the year.

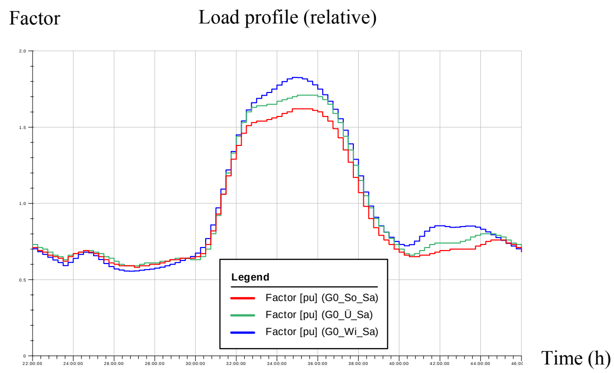

Figure 2: variation of load profile with time at different times of the year for a chosen cluster

As most of the profiles are base on energy the generic approach also needs a conversion into power. Investigations in Vienna [2] showed, that most appropriate model is the following function:

$$P = a1 \cdot (1 - e^{-\frac{Ep}{b1}}) \quad \text{and} \quad Q = a1 \cdot (1 - e^{-\frac{Eq}{b1}})$$

b1 is normally 8760 (representing the hours per year) and a1 is a typical parameter for the consumer cluster (e.g. 10).
A verification of this value could be done when entering Ep with 1500 kWh for a typical house in an LV network. The result is known to be 1,5 kW for this typical consumer.

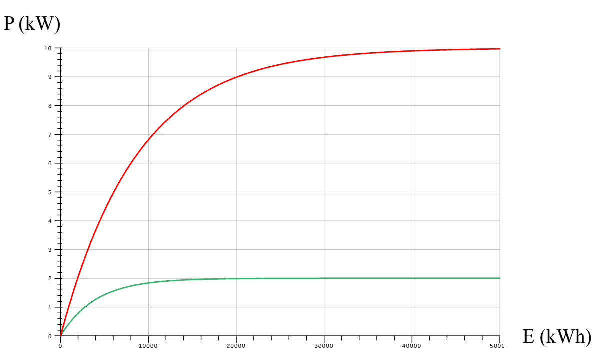

Figure 3: Power as a function of energy for 2 different consumer types

Load profiles as an instrument for customer aggregation (cluster) in principle can simulate only the structural dependent component of the consumption i.e. only the parts that are based on consumption structure and external influence factors. For aggregations of N << ∞ these profiles will be superimposed by individual consumption components, which vary stochastically and cannot be modeled by profiles.
Nevertheless it is possible to generate a diversity factor g(x) for the different clusters, which is no longer dependent of the feeder but of the number of consumers of the same type in the feeder downstream.[3]

$$g(x) = a2 + (1 - a2) \cdot e^{-\frac{x-1}{b2}}$$

a2 is the probability range for the standardized normal distribution (e.g. 85% range) and b2 is dependent on the cluster

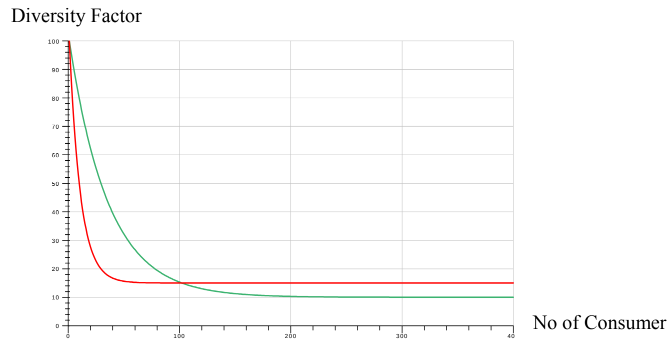

Figure 4: diversity factor as a function of number of elements in the cluster

This load modeling forces the simulation to add injections on each node upstream the feeder to compensate the variable diversity factors.
Another challenge is to determine how to simulate correctly feeders where there are different types of clusters with extremely different numbers of elements. In this case the cluster a low number of consumers will be dominant and have a high spread which distorts the model. A manual weighting should be applied in this case.

LOAD FORECAST DATA

After having an approved current network model, load forecast data has to be evaluated.
One important requirement for the simulation software is its ability to model time dependency. This allows network elements to handle time stamps such as commissioning or decommissioning date so that changes in network structure can be modelled. Network changes across the calculation time can then be stored within one single model (case) and the date and time at which the simulation is carried out determines the actual network configuration.
In medium and low voltage networks because of the large number of elements it is not possible to describe the behaviour of each load individually. Therefore the next important step is to divide the network in different structural classes.

Structural network classes

Low voltage networks have to be structured according to classes like density of population, proportion of cables, regional orientation, social-economic structures etc. These are the typical clusters for network costs and load behavior in the future. To achieve optimum results, distribution tasks and areas should be comparable. Then the planner can draw conclusions from the structure to the demand and costs of the network. A synthetic reference network could be built. [4]

These clusters need not have a geographical correlation. We generally call them load groups. Each individual member of this group will develop according to the defined forecast; even it is in totally different local areas.

Time	f [p.u.]	P [kW]	Q [kVAr]
01.01.2000	1,000	200,000	100,000
01.01.2001	1,000	205,000	102,000
01.01.2002	1,000	212,000	105,000
01.01.2003	1,000	220,000	109,000
01.01.2004	1,000	235,000	115,000
01.01.2005	1,000	248,000	120,000

Figure 5: Historical absolute development of a load cluster.

Geographic network classes

A different kind of cluster are the geographical areas, mainly in MV networks, which are bordered by e.g. rivers, railway tracks of even large streets and therefore even the trench to the next area can be costly. For these groups we define load polygons. For each of these polygons we have to define an individual load forecast. This is split into two different descriptions. The general forecast which results from the historical behavior in the area and secondly knowledge about specific future development, e.g. new housing areas or industry developments. These two types could be superimposed.

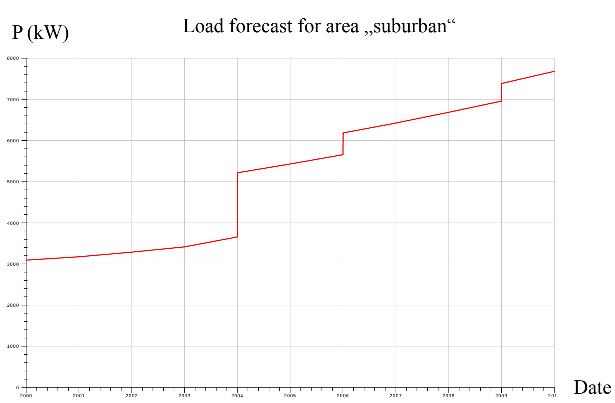

Figure 6: expected load behavior of an area after superposition of history and future data.

Individual development of elements

In any case there will be a group of loads left which do not fit either into load groups or into load polygons. In this case it is necessary to define a specific load forecast from historic metered data, enhanced by the knowledge of the future behavior (e.g. decommissioning).

To come to a conclusion, at which time new generation is necessary a fourth forecast has to be entered, the secured power (generation) in the whole network.

All types of definition are available in the used planning software PSS™SINCAL.

LOAD DEVELOPMENT

The next step is the definition of the planning horizon which regularly is 10 to 15 years. The software then steps though this period taking into consideration, the continuous yearly load development of all clusters, the additional loads at specific date and of course the changing topology of the network over time. Historical load development is interpolated into the future. All necessary data for the planner's evaluation are available in reports, spreadsheets and on the network diagram.

First evaluation is the stepping forward in time, using a mouse click, observing the loading of the equipment, by color change, as a result from load flow analysis. There the user can see easily when a replacement or improvement will be necessary according to voltage drops, losses or loading of branches. The visible network diagram will change according to the topology changes defined in time stamps of elements. E.g. equipment with commissioning date 2010 will not be taken into consideration in 2008 and will not be displayed in a view of this time.

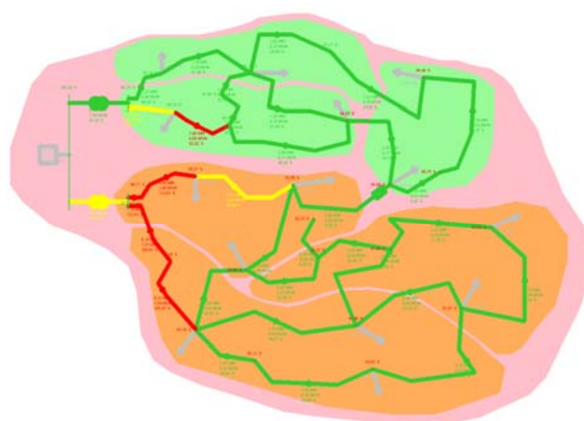

Figure 7: Load flow results at a specific date in future colored by loading and voltages showing different load polygons.

To get a deeper impression about the changes in the different network parts, the user can analyze the load increase curves in diagram form for all areas and each branch which has been defined by the user for investigation. [5]

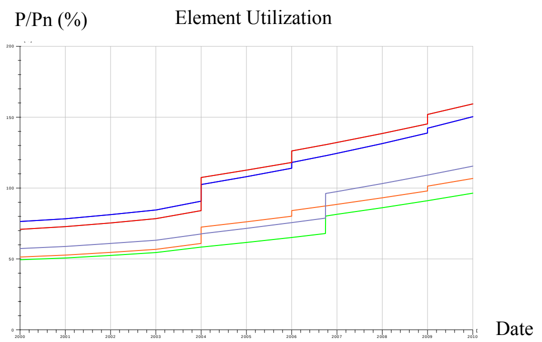

Figure 8: Loading of diverse network elements across the years.

If the study is done during a master plan in highly developing areas an overall diagram with the total generation capacity and the demand in the network shows, if or when a "collapse" of the network will happen, if no investments are made into the network.

An effective evaluation is the coloring of the different load areas according to load density as it is shown in the figure 10.

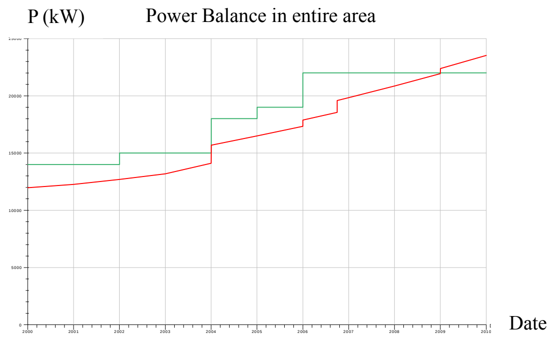

Figure 9: generation and load consumption in total network

By stepping between the different scenarios (times) with a single mouse click, the planning engineer can simulate, what will happen in the different areas and where load centers are moving to in future. This gives the best base for a long term network planning. For a detailed master plan other aspects have to be taken into consideration, too, like losses, short circuit power, reactive power balance, reliability of supply, cost efficiency and others. [6]

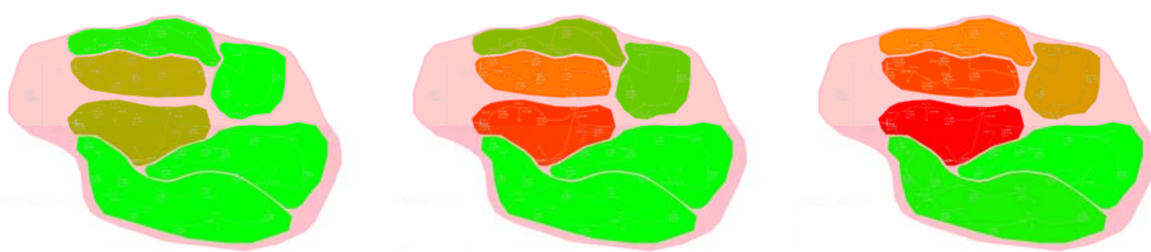

Figure 10: Load density in different load polygons during a period of 10 years load development

CONCLUSION

Based on a proven load model for the existing network and with knowledge of historical load behavior it is possible to perform a long term load forecast with help of a software tool. The described process gives a detailed and reliable picture of the future network and is therefore the source for a strategic network planning. Combining this with the cost calculation of the network will offer a base for investment planning.

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