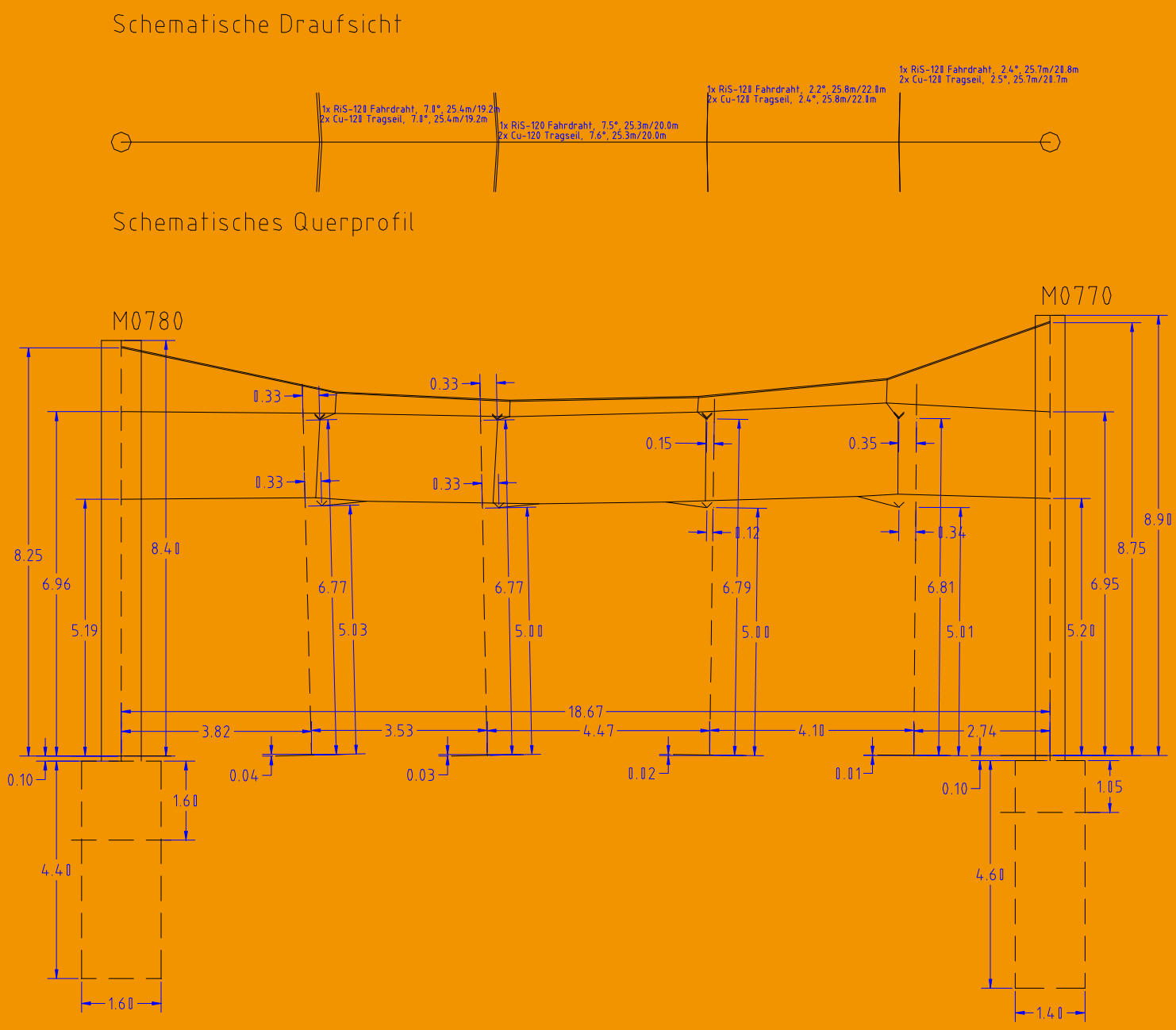
GA Energieanlagen Süd

GA-wire
Design of Overhead Contact Systems



Introduction

The design of overhead contact systems for the short-distance traffic requires a great number of factors to be taken into account, such as:

- topography
- compulsive spots of structures (e.g. under crossings and tunnels)
- track geometry and cant of rails in curves
- geometry of vehicle
- speed of vehicles
- timetables
- additional loads caused by change of temperature, wind, ice, traffic lights and lighting systems
- contact-line materials
- Position of feeding points
- possible position of suspension
- points and resulting alternatives of the cable supports' structures
- local soil conditions

Taking due account of the above-mentioned factors, the design phase may be launched in the following steps:

- definition of supports
- definition of suspension points
- definition of cable support structures
- static calculation of cable support
- structures and cantilevers
- dimensioning of cable support
- structures and cantilevers
- dimensioning of poles and wall anchors
- dimensioning of pole foundations
- site plans
- technical drawings
- material lists

More than other elements, cable support structures are often specially difficult to calculations: one the one hand, optional parameters such as pitch of bearer cables, position of fastenings and resulting cable forces are to be considered.

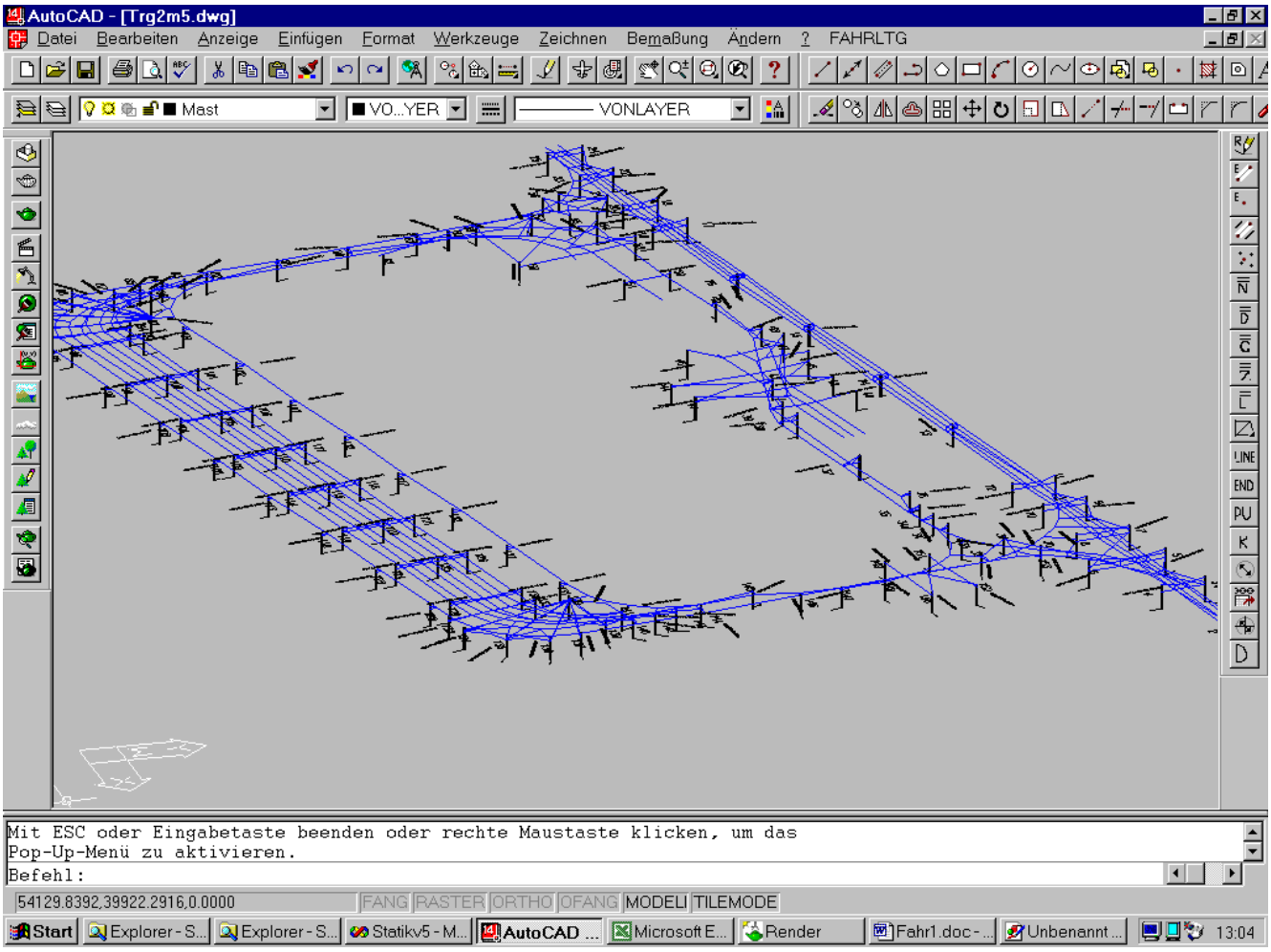
On the other hand, the law of static dictates certain requirements regarding location of panel points and suspensions which may differ from the planned position. Unwelcome changes of the contact wire heights at certain suspension points, for instance, may result from such circumstances.

More than just determination of cable forces, the static calculation of cable support structures requires also determination of position and height of fastening and panel points, in due consideration of various additional loads, and is aims at safeguarding the planned position of the suspension points in relation to the track geometry.

Pic.1 Visualization of an overhead contact system in a typical environment

In the course of any project, changes occur: the course of the contact wire, for instance, or the position of the poles may have to be varied, wall fixtures may have to be displaced. Such changes of the design may effect the entire project immensely. Alterations as mentioned above, can be coped with efficiently and safely by means of suitable EDP. GA-wire is a program package which allows input and administration of data on a comfortable graphic surface, as well as the required calculation and analysis, for projects of any size. All features are efficient, economic and technically perfected.

The highly comfortable software also allows practice-orientated documentation of the system plants. Front-wall views, for instance, and particularities of the overhead contact systems can be filed as pictures.



Pic.2 3-D view of an operating plant

Program Development and Technical Data

Hardware Requirements:
RAM:min. 2 GB,
hard disk: min. 10 GB free memory, digitalisation tray (recommended)

Program Languages:
Microsoft Visual C++, VB, VBA

Operating Systems:
Windows-XP/Windows-7

Standard Software:
AutoCAD 2009/2010/2011,
MicroStation V8/XM/V8i
MS-Excel-2003/2007

The functions of GA-wire are invoked by AutoCAD/MicroStation standard PULL-DOWN menus.

GA-wire is ideally matched to fit the specific requirements of the overhead contact systems. It is based on a new iteration method for calculation which is independent of the support structures' configuration. AutoCAD and MicroStation offers a reliable program interface which is based on program language C and its graphic three-dimensional modelling function meets all existing requirements. Further standard software is included to support calculations and presentations.

In the development phase, the program components were checked with due care, and tested in cooperation with our technical design and assembly dept. Taking into account the recommendations from our clients as well as our assembly dept., we carry on improving the program.

GA-wire stands out for its suitability for design of entire overhead contact systems as well as performance of single and comprehensive loads and intersection calculations.
The program's flexibility enables static calculations of any given support structure's configuration with no need to adapt the program. Thus, dimensioning of simple contact lines, catenary's type systems and intersections, fixed or tensioned, cantilevers and lighting cable supports is an easy and safe work.

GA-wire offers further elements to support assembly of overhead contact systems:

- Calculation of pole alignment (to counter-balance incline of pole)
- Calculation of lengths of catenary's-type systems suspensions
- Static calculation for cantilever constructions with due regard to pole deflexion
- Recalculation of working depths in case of changes to execution on site
- As-built drawings

The calculation data are constantly checked by the design engineer as well as independent examiners. Allowed tolerance in the cable support structures' geometry is $\pm$ 1 cm.

Track Geometry

The correct input of the track geometry is most essential for track-bound trams, since design of contact wire run and selection of suspension points depend thereon. GA-wire represents the track geometry as a track axle and shaped as an CAD polyline, while the cant of rails appears as a point with related Z coordinate. The track geometry may be entered either by another CAD program such as CADR-1 or INTERGRAF, in the form of a DXF-formatted polyline in an ASCII file, together with the point coordinates, or directly i.e. in CAD by means of the digitalisation tray.

After track axle and cant of rails have been included, the geometry of the vehicle can now be taken into account. A database which is integral part of the program, contains the most important measures of different vehicle types. Also hand-done input via dialog window is possible. On this basis, the program calculates the "contact-wire axle" – a curve which is actually run, from the centre of the current collector - and the deflection curves for the vertices.

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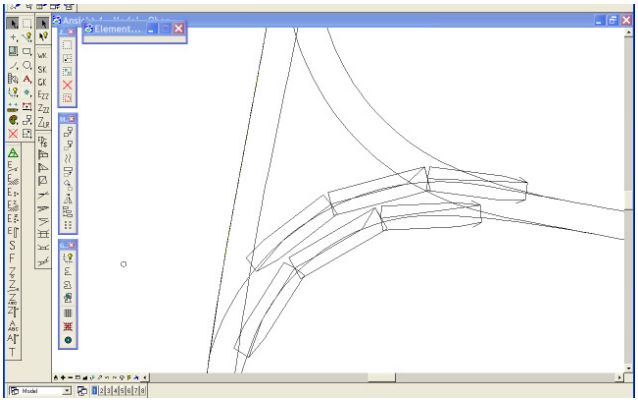
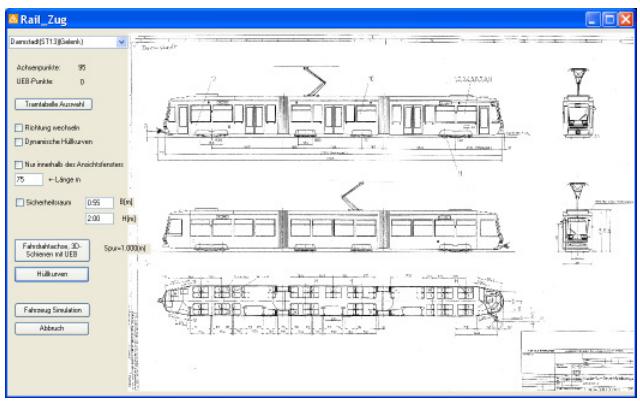
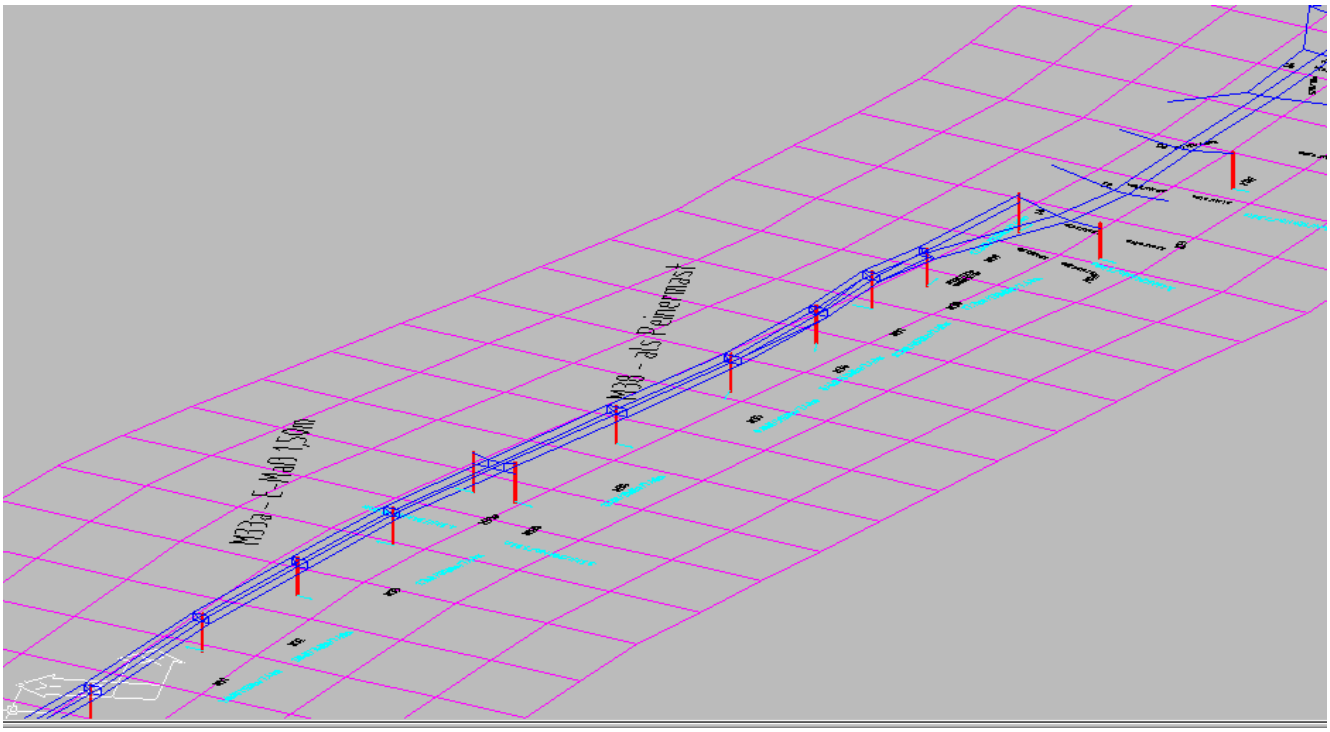
With the contact-wire axle as a basis, the run of the contact wire can be fixed by hand, using CAD standard functions. Moreover, GA-wire enables automatic determination of the zigzag line. Thanks to this automatic function, the contact wire run can be optimised on routes with few compulsive spots. Also, the contact wire run may be evaluated by means of animation of the vehicle's movement along the track axle. This includes simulation of track incline, movements of vehicle and contact wire over the collector. This animation is useful for visual control of the data fed into the program. Simultaneously, the current collector's abrasion is shown in a beam chart. Those parts of the route with no contact between contact wire and current collector are marked in colour. This facilitates the user's orientation and if necessary, quick correction of possible errors.





Pic.3 : Optimisation of the contact-wire run with regard to current collector's abrasion

Topography

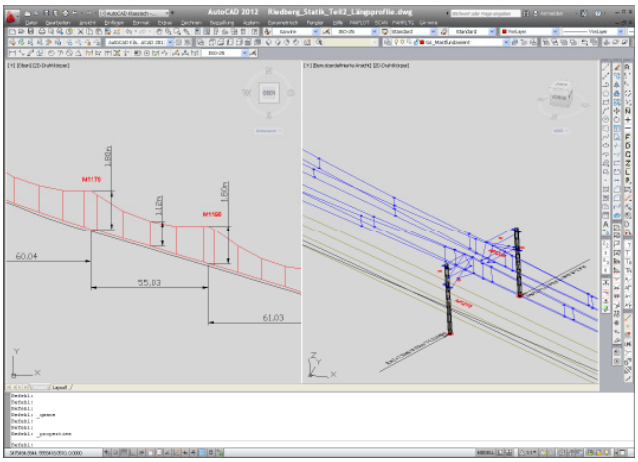


Pic.4 : 3-D-view of ground geometry

The designer often encounters great differences in altitude of the ground, e.g. tunnels, bridges, etc. in rural areas.

GA-wire features allow 3-D-modelling as well as the static calculation, of contact lines under aforementioned circumstances. The 3-D-modelling is supported by AutoCAD standard features.

Inclusion and use of 3-D-models of ground and support structures add considerably to the accuracy of support structures' static and quality of design work, in general.



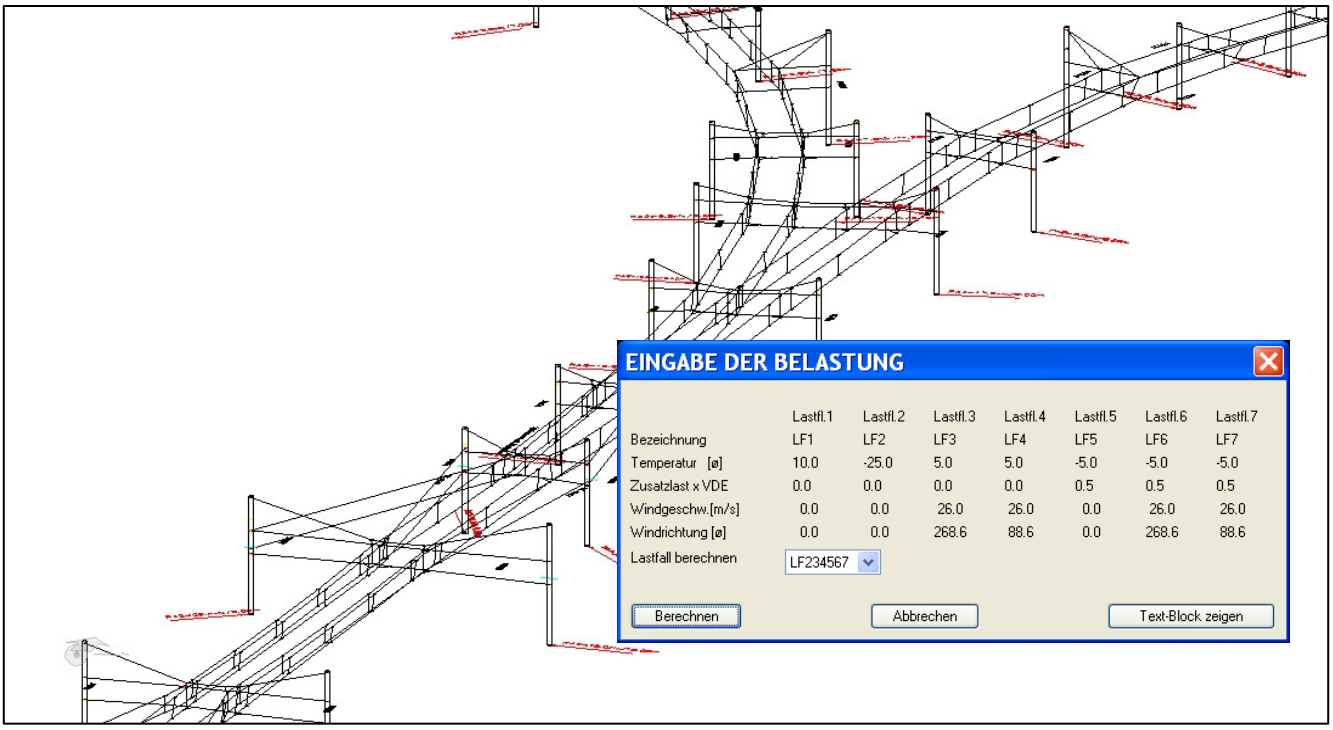
Pic.5 : Longitudinal profiles of catenary with droppers

Static Calculation of Support Structures

Static calculation of support structures is the most essential module of the program package. The input of support structures is based on AutoCAD's standard features, "LINE" and "DOT". At first, all cables, wires and rods are drawn as AutoCAD lines, thereafter their specific attributes are assigned accordingly. The physical data are imported quickly and easily from an integral database. The calculation scheme for the support structure is defined by the user. Height and position of the fastening and panel points may be either preset as default value or released for automatic calculation, in any given combination; the same applies for the wire pitch. The tractive force of the cables and the contact wire may be either specified or calculated, depending on the type of contact line: fixed or tensioned, with or without cable spring. Additionally, the armature weights may be defined for each panel and suspension point, with no limit whatsoever regarding complexity of the support structure. To facilitate input of the data and definition of the support structure, GA-wire offers a number of pre-programmed constructions:

- cantilevers over 1 track/2 tracks for catenary's-type and simple- contact line with bearer cable;
- cross-support structures over 2 tracks/3 tracks, with/without cross-span adjuster, etc.

With the static module, a new dynamic strategy is applied which differs greatly from common procedures: It is independent of the support structure's configuration. In fact, each support structure is assumed to be a network of lines and dots, with their appropriate definitions. The program analyses each iteration step made in the course of calculation. Direction and size of the following iteration step are decided on the basis of this analysis.



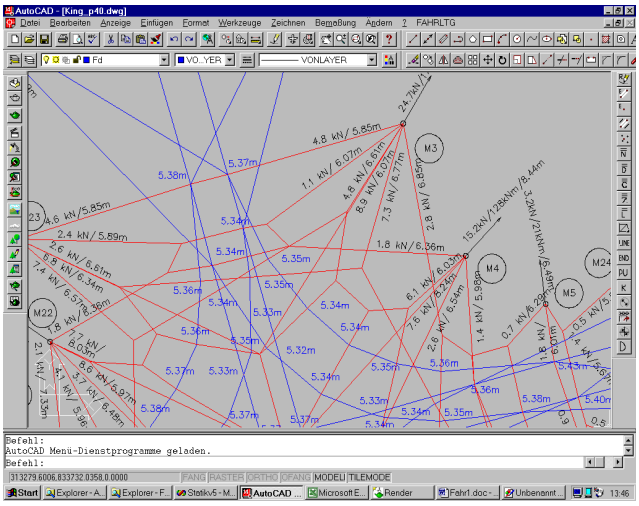
Pic.6 : Simulation of an overhead-contact system with optional additional loads

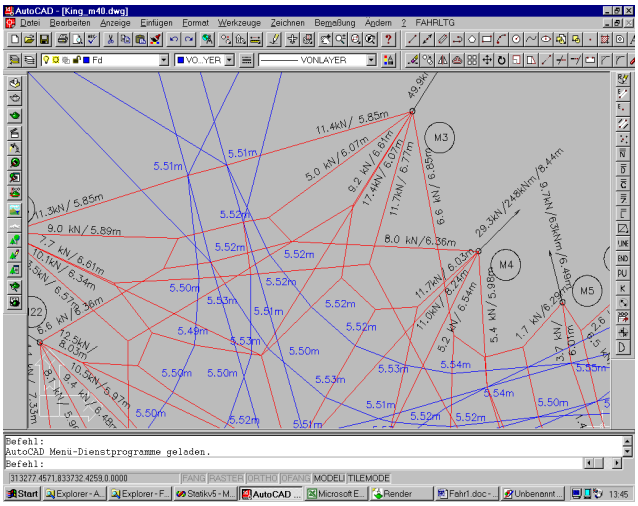
The next step is performance of all compulsive parameters in the calculation scheme (constant forces, irremovable points, unchangeable coordinates, etc.) by means of progressive and dynamic changes to the optional parameters (forces, coordinates of panel points, height of mast fixings, etc.).

Upon conclusion of structural calculations (forces, height of fixings, coordinates of panel points), additional loads are included into a further calculation. Additional loads (temperature, ice, wind, traffic lights and lighting systems) may be defined by the user himself.

Calculation under the program covers changed forces and even new position and height of contact wire, in consideration of these additional loads.

The results of the static calculation such as cable forces, height of fastening points and resultant tension at top of pole, are added as titles to the drawing. The titles are linked to their appropriate cables, wires and poles by means of internal CAD references; thereby, automatic updating of them is ensured upon each change to the project.





Pic.7 : Wire forces and height of contact line at -40°C

Calculation of Pole and Foundation

The software component calculating pole and foundation, is based on:

1. calculation of resultant tension at top of pole and drawing-up of an ASCII file by CAD
2. importation of the data into and dimensioning of poles and foundations, in Excel.

Consequently, the resultant tension is produced automatically by AutoCAD on the basis of cable forces, directions and heights. Automatically, all cables acting to the pole, are included into the program's calculation. The pole height may either be preset by the user or chosen automatically by the program.

Many factors have to be taken into account for calculating poles and foundations. The data are gathered in an Excel table and then processed in a Visual BASIC program. Then, wide-flanged I-shaped poles consisting of normal and reinforced standard profiles with or without side plates, are dimensioned.

Here, the user may preset safety factor, permitted pole deflexion or wind load on the pole, by himself.

Basic data for this calculation:
resultant tension of pole top, free pole length, orientation of the wide-flanged I-shaped pole in relation to the net force.

The calculation work is actuated by a click on additional Excel icons.

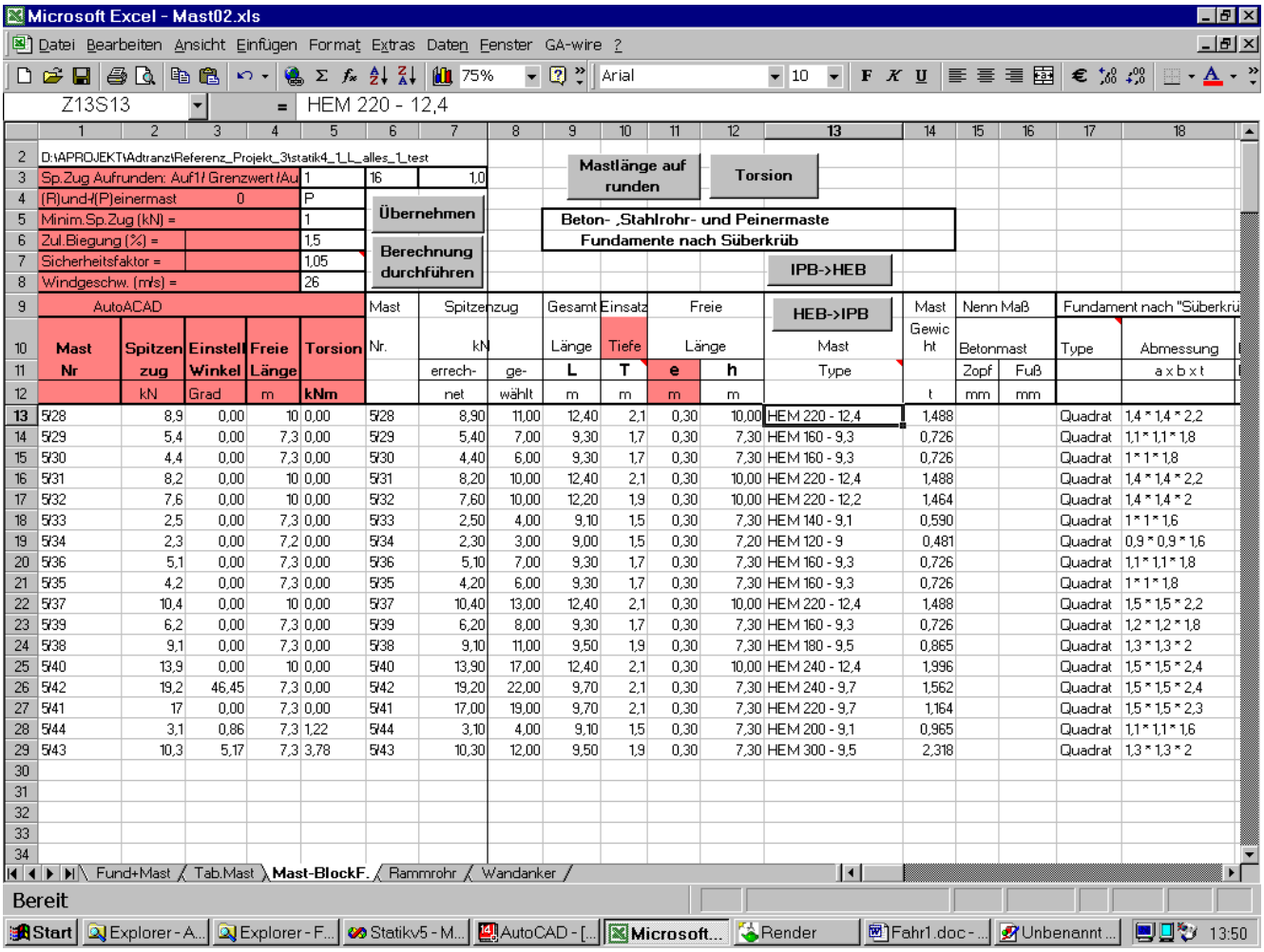
Calculation of poles and dimensioning of concrete block foundations are done simultaneously, by the program. The foundation depth is either chosen automatically or defined by the user.
In the latter case, all other dimensions are adapted and checked in accordance with specific critical values in order to identify possible mistakes such as an undersized foundation depth by the user.

The calculation method applied here, is the so-called "Süberkrüb" method. The soil characteristics have to be determined for each site, individually.

Calculation of Pole and Foundation

Since drive pipe foundations are of growing importance, GA-wire has included a module for dimensioning drive pipes. On the basis of the soil characteristics and intended pipe bending, the designed pipe's utilization and permitted minimum thickness are calculated by the module.

Thereby, the user is able to optimise the drive pipe. For successful performance of this task, reliable soil characteristics from an expert survey are a must.



Mast Nr	Spitzenzug kN	Einstell Winkel Grad	Freie Länge m	Torsion kNm	Mast Nr.	Spitzenzug errechnet kN	Spitzenzug gewählt kN	Gesamt Länge L m	Einsatz Tiefe T m	Freie Länge e m	Freie Länge h m	Mast Type	Mast Gewicht t	Nenn Maß Betonmast Zopf mm	Nenn Maß Betonmast Fuß mm	Fundament nach "Süberkrü Type	Fundament nach "Süberkrü Abmessung a x b x t
5\28	8,9	0,00	10	0,00	5\28	8,90	11,00	12,40	2,1	0,30	10,00	HEM 220 - 12,4	1,488			Quadrat	1,4 * 1,4 * 2,2
5\29	5,4	0,00	7,3	0,00	5\29	5,40	7,00	9,30	1,7	0,30	7,30	HEM 160 - 9,3	0,726			Quadrat	1,1 * 1,1 * 1,8
5\30	4,4	0,00	7,3	0,00	5\30	4,40	6,00	9,30	1,7	0,30	7,30	HEM 160 - 9,3	0,726			Quadrat	1 * 1 * 1,8
5\31	8,2	0,00	10	0,00	5\31	8,20	10,00	12,40	2,1	0,30	10,00	HEM 220 - 12,4	1,488			Quadrat	1,4 * 1,4 * 2,2
5\32	7,6	0,00	10	0,00	5\32	7,60	10,00	12,20	1,9	0,30	10,00	HEM 220 - 12,2	1,464			Quadrat	1,4 * 1,4 * 2
5\33	2,5	0,00	7,3	0,00	5\33	2,50	4,00	9,10	1,5	0,30	7,30	HEM 140 - 9,1	0,590			Quadrat	1 * 1 * 1,6
5\34	2,3	0,00	7,2	0,00	5\34	2,30	3,00	9,00	1,5	0,30	7,20	HEM 120 - 9	0,481			Quadrat	0,9 * 0,9 * 1,6
5\36	5,1	0,00	7,3	0,00	5\36	5,10	7,00	9,30	1,7	0,30	7,30	HEM 160 - 9,3	0,726			Quadrat	1,1 * 1,1 * 1,8
5\35	4,2	0,00	7,3	0,00	5\35	4,20	6,00	9,30	1,7	0,30	7,30	HEM 160 - 9,3	0,726			Quadrat	1 * 1 * 1,8
5\37	10,4	0,00	10	0,00	5\37	10,40	13,00	12,40	2,1	0,30	10,00	HEM 220 - 12,4	1,488			Quadrat	1,5 * 1,5 * 2,2
5\39	6,2	0,00	7,3	0,00	5\39	6,20	8,00	9,30	1,7	0,30	7,30	HEM 160 - 9,3	0,726			Quadrat	1,2 * 1,2 * 1,8
5\38	9,1	0,00	7,3	0,00	5\38	9,10	11,00	9,50	1,9	0,30	7,30	HEM 180 - 9,5	0,865			Quadrat	1,3 * 1,3 * 2
5\40	13,9	0,00	10	0,00	5\40	13,90	17,00	12,40	2,1	0,30	10,00	HEM 240 - 12,4	1,996			Quadrat	1,5 * 1,5 * 2,4
5\42	19,2	46,45	7,3	0,00	5\42	19,20	22,00	9,70	2,1	0,30	7,30	HEM 240 - 9,7	1,562			Quadrat	1,5 * 1,5 * 2,4
5\41	17	0,00	7,3	0,00	5\41	17,00	19,00	9,70	2,1	0,30	7,30	HEM 220 - 9,7	1,164			Quadrat	1,5 * 1,5 * 2,3
5\44	3,1	0,86	7,3	1,22	5\44	3,10	4,00	9,10	1,5	0,30	7,30	HEM 200 - 9,1	0,965			Quadrat	1,1 * 1,1 * 1,6
5\43	10,3	5,17	7,3	3,78	5\43	10,30	12,00	9,50	1,9	0,30	7,30	HEM 300 - 9,5	2,318			Quadrat	1,3 * 1,3 * 2

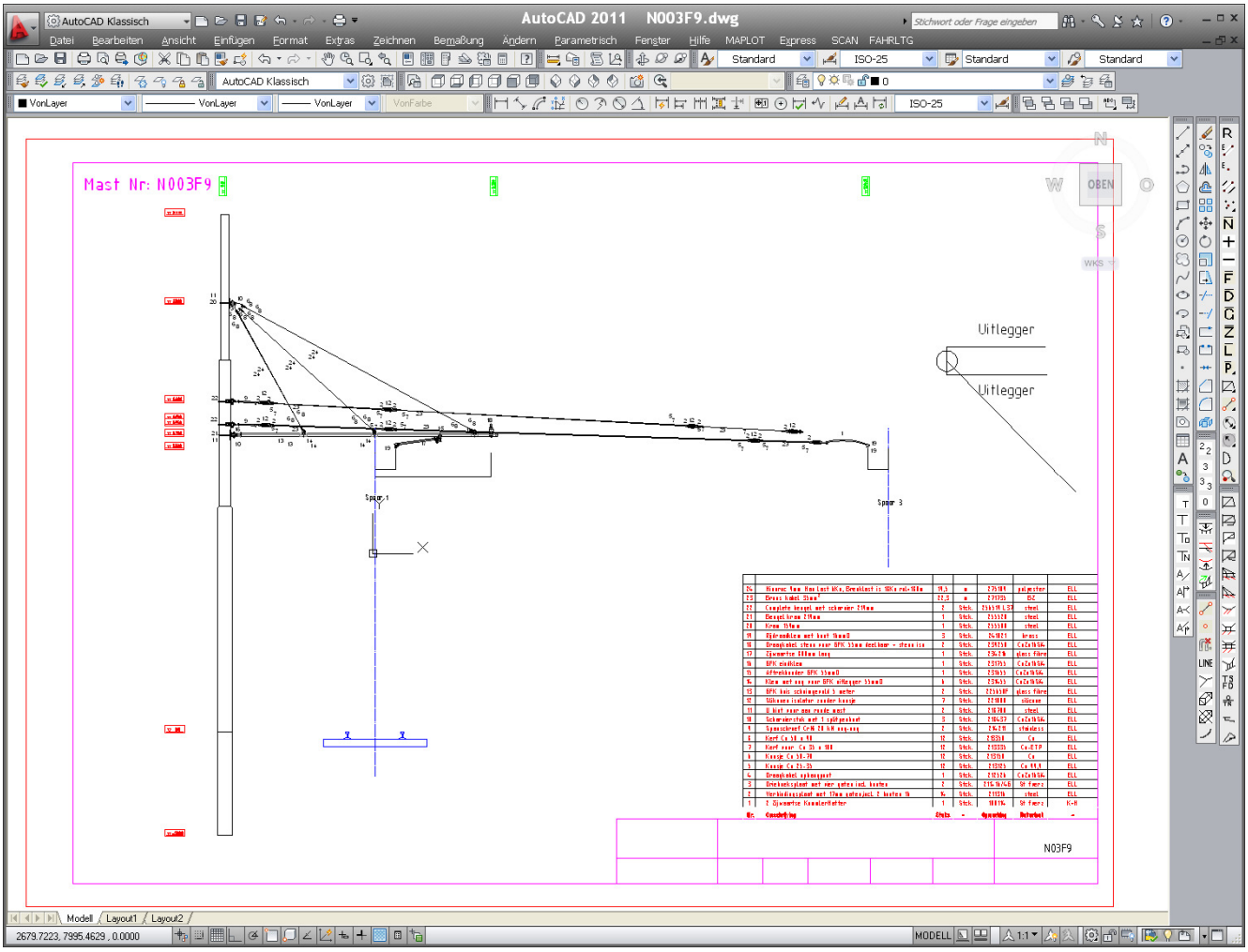
Pic.8 : Calculation of pole and foundation.

Drawing-up of Construction Drawings and Parts Lists

The construction drawings component is based on a graphic database covering all contact line materials. This database is invoked by means of an CAD search and administrative software.

Thanks to this software, drawings of parts and support structures may be found and loaded rapidly. This system also enable automatic material specifications made from the construction drawing. The program supports both the central database by means of "standard drawings", and customer-specified constructions.

Owing to an interface between CAD and Excel, the specification may be produced and administrated in an automatic Excel function.



Pic.9 : Systems drawing with parts list

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