EFC-400 - Magnetic and Electric Field Calculation

Telecommunication, Power Lines and Stations

User's Manual

Berlin - 2020

narda
Safety Test Solutions

EFC-400 - Magnetic and Electric Field Calculation

Telecommunication, Power Lines and Stations - According to EN 50413, IEC 62226-1, IEC 62232, ICNIRP, EU Regulations

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1. Introduction

1.1 Usage of the Manual

Welcome to the EFC-400 user's manual!

This manual will give you an extensive insight into the basics of field calculation and the operation of your **EFC-400** software.

Before proceeding with the installation please read the **Getting Started** chapter.

A general overview of the menus and the program is illustrated in the **Program Description** chapter.

This user's manual contains a thematically ordered description of the program functions. It can be used for learning the program systematically or as a reference book.

Special emphasis was put on the **Case Studies** chapter. Examples for the calculation of a power transmission line and of telecommunication base stations are given therein.

In the **Appendix** all data formats used by **EFC-400** are presented in order to allow processing and exchange with other programs and to refine the environment of the program (e.g. libraries) according to your needs.

1.2 General Range of Application

The program **EFC-400** was originally developed for the computation of low frequency magnetic and electric fields of conductors. Computing is carried out using the law of Biot-Savart and the charge method, allowing any arbitrary arrangement of conductors in three-dimensional space. Due to the three-dimensional ansatz, it is possible to solve every quasi-stationary problem in the low-frequency range.

In the next step of development audible noise and RF-level calculation for high voltage equipment have been implemented.

The latest implementation is the computation of high frequency field strengths and power density according to VDE 0848, with the possible calculation of beam characteristics from vertical and horizontal aperture angles or importing fractional beam diagrams.

The following examples give an insight into the range of application for the computation of the electric and magnetic field strength.

- power transmission lines
- overhead wires of tramway and main-line service
- route of suburban train and subway
- onboard power supplies of ships, aircraft's etc..
- earth cables, also with helical twist
- transformer and terminal stations
- power stations

- mobile phone bases stations
- mobile phones
- broadcast and TV transmitter
- radar equipment
- amateur radio
- LW- and MW-Transmitter
- line-of-sight radio links

Corresponding examples are available on the installation CD and are described in detail in the **Case Studies** chapter.

After completion of the first stage of development the calculation speed was increased so that EFC-400 computes large areas with a workstation-like performance. All time-critical routines were programmed directly in assembler-language. Theoretically the maximum number of calculation points can be 32000 x 32000 = 1000 millions. Practically the hard disk capacity determines the upper limit.

The resulting data are presented by **EFC-400** in a function-related and elegant form.

- ❑ XYZ-representation
- ❑ 2D-representation
- ❑ Isolines-representation
- ❑ Statistics
- ❑ 3D virtual reality

The following interfaces are available for export:

- ❑ ASCII table (3D-Array) -> MS-EXCEL™
- ❑ DXF polylines (Isolines) -> AutoCAD™
- ❑ ASCII table (4D-Color Array) -> Stanford Graphics™
- ❑ ASCII table (3D-Vectors) -> Stanford Graphics™
- ❑ BMP, JPG, WMF, AVI and GIF-format

EFC-400 is available in the following versions, including all functions or tuned for special applications:

Product	**EFC-400**	**EFC-400 Station**	**EFC-400 & Sound**	**EFC-400 Telecom.**	**EFC-400 Enterprise**
calculation method	E, B	B	E, B, dB(A)	E, H, S	E, H, B, S
frequency range	0 - 30 kHz	50 - 60 Hz	0 - 30 kHz	1 kHz - 300 GHz	0 - 300 GHz
calculation area (*1	unlimited	150x150 m	unlimited	unlimited	unlimited
limit value assessment % (*2	•	•	•	•	•
measuring data processing	•	•	•	•	•
phase optimization	•		•		•

(*1 max. 32000 x 32000 calculation points
(*2 for dB(A) not possible

Please note that only a small section of the field of application can be presented here. **EFC-400** offers a general approach of solution which is extendible by program extensions. Moreover, **EFC-400** has open interfaces so that new fields of application can be developed, which have not been considered till now.

1.3 Units and Symbols

Units and definition ranges of the physical quantities used by **EFC-400** are listed below:

Quantity	Units	Resolution
X, Y, Z coord.	[m]	0.0001
R radius	[mm]	0.001
Psi angle	[°] or [gr]	0.001
P power	[W]	0.001
I current	[A]	0.001
U voltage	[kV]	0.001
Phi phase	[deg]	0.001
S power density	[nW/m²] - [kW/m²]	0.001
E el. field strength	[nV/m] - [TV/m]	0.001
H mag. field strength	[pA/m] - [kA/m]	0.001
B mag. induction	[fT] - [kT]	0.001

EFC-400 works with Cartesian coordinates, Z is the altitude.

All angle are defined 'mathematically' with positive direction of rotation.

2. Theoretical Basics

2.1 Magnetic Induction

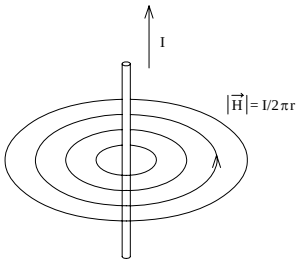


Fig. Magnetic field of a conductor

Every conductor carrying an electrical current is surrounded by a magnetic field. The field can be illustrated by lines of force, which form concentric circles around the conductor. The direction of the lines of force is given by the right-hand rule, in which the thumb points into the technical current direction. (Note: **EFC-400** uses the physical current direction, which is complementary to the technical.)

The magnetic induction of a configuration of conductors is calculated with the Biot-Savart equation as a superposition of the subfields of individual conductor segments. Every infinitesimal segment contributes to the complete field:

$$d\vec{B}(t) = \frac{\mu_0}{4\pi} \frac{d\vec{l} \times \vec{r}}{r^3} I(t)$$

dB and I are generally time-dependent and are transformed into complex quantities to simplify the computation.
If we assume that the segment i of the length l is in the origin of the coordinate system parallel to the X-axis, its contribution to the field at the point *P(x, y, z)* is then:

$$\left|\vec{B}_i(t)\right| = \frac{\mu_0}{4\pi r} I_i(t) \left[\frac{L_i - x_p}{\sqrt{(L_i - x_p)^2 + r^2}} + \frac{x_p}{\sqrt{x_p^{\,2} + r^2}} \right]$$

with the vector components:

$$B_{xi}(t) = 0$$

$$B_{yi}(t) = -\frac{z_p}{\sqrt{y_p^2 + z_p^2}} \left|\vec{B}_i(t)\right|$$

$$B_{zi}(t) = \frac{y_p}{\sqrt{y_p^2 + z_p^2}} \left|\vec{B}_i(t)\right|$$

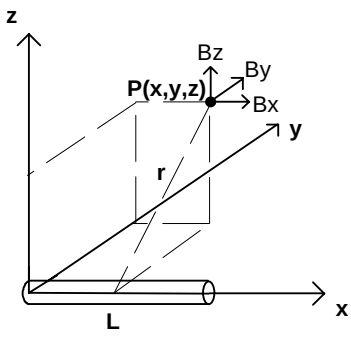


Fig. Subrope in the coordinate origin

Every conductor is split by this method into segments, whose number can be selected by the user. If the conductors have a sag (e.g. power transmission line) the program simulates this with a parabolic arrangement of the segments. A sufficient precision is normally obtained by selection of 10-20 segments. For the purpose of verification the number of segments can be increased. If there is only one segment (straight conductor), the program simulates the automatic altitude customization of a conductor segment (with the length of the span width) on the relevant sag for the point *P(x, y, z)*. The field component in line direction then disappears by definition. The precision is larger than for cases of only 2,3,4... segments. Additionally, the computation time is shorter. The precision of the method is only limited by the floating point arithmetic. The difference between reality and model depends on the subdivision of the conductors in a finite number of segments.

For the computation of the field strength the coordinates of the point under consideration are transformed into the local coordinate system of the respective segment. This happens by a displacement and a following rotation. The calculation provides the contribution of the segment to the complete field vector, which has to be transformed back to the world coordinate system.
Vectorial addition of the field contributions yields the field vector:

$$\vec{B}(t) = \begin{pmatrix} B_x(t) \\ B_y(t) \\ B_z(t) \end{pmatrix}$$

In the case of a sinusoidal current with a constant frequency

$$I(t) = \hat{I}\sin(\omega t)$$

the RMS-value is defined as

$$I = \hat{I} / \sqrt{2}$$

The field vector rotates on a fixed ellipse, whose main half axis represents the peak value.

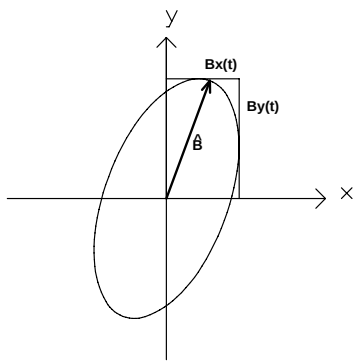


Fig. Rotation ellipse of the B vector

In case there is a mixture of different frequencies the field contributions of the individual segments are temporally expanded, added up and integrated over the time.

EFC-400 calculates the absolute value, the single components and the peak value:

$$|B|,\ B_x,\ B_y,\ B_z,\ \hat{B}$$

An interpolation mode is available, accelerating the computation of large areas. In this mode a predefined number of points within one calculation interval is computed by fitting a polynomial of 3rd order. The corresponding error is displayed in the status window. To keep the error as small as possible and to accelerate the computation of large areas in larger distance from field sources, the **DYNAMIC INTERPOLATION** mode was developed. In this mode the program will ensure that, even in critical areas (e.g. under conductors), the error will remain below 0.1% by adjustment of the required number of calculation points.

The functions described above are explained in detail in the **Calculation** chapter.

2.2 Electric Field

The electric field strength can be represented by the negative gradient of the scalar potential *Φ (x, y, z)*:

$$\vec{E}(\vec{r}) = -\vec{\nabla}\Phi(\vec{r})$$

with

$$\vec{\nabla} = \begin{pmatrix} \partial/\partial x \\ \partial/\partial y \\ \partial/\partial z \end{pmatrix}$$

This potential or potential difference describes the work which is necessary to move a test charge from a reference point with potential *Φ (x, y, z) = 0* to the point with the potential *Φ*. In praxis the reference point is set to infinity. The potential at a distance A to a source charge is then given by:

$$\Phi_A(\vec{r}) = \frac{W}{q} = \int_{\infty}^{A} \vec{E}(\vec{r})\, d\vec{s}$$

This integral can be solved as follows for a line-type charge segment which lies in the origin parallel to the X-axis:

$$\Phi_i(x_p, y_p, z_p, t) = \frac{Q_i}{4\pi\varepsilon_0} \ln \frac{(x_p) + \sqrt{x_p^2 + y_p^2 + z_p^2}}{(x_p - L_i) + \sqrt{(x_p - L_i)^2 + y_p^2 + z_p^2}}$$

The negative gradient yields the field contribution of a subrope to the electric field at the point *P(x, y, z)*.

The complete computation process is similar to that of the magnetic field. An exception, however, is the determination of the line charges Q_i. These are not predefined unlike the subrope currents but must be calculated with the help of the surface voltages of the conductors.
To do this, a line charge is assigned to the center of every conductor segment. The quantity of this charge is determined by solving the above equation for the surface potential *U*. In case of *n* conductor segments this yields a system of equations with *n* unknown variables:

$$U_i = PK_{ij}\, Q_j$$

PK_{ij} is described as the matrix of the potential coefficients. Inverting PK_{ij} yields the distribution of the line charges. **EFC-400** is able to solve this set of linear equations for an matrix with 16000 x 16000 elements (Methods: LU-decomposition or conjugate gradient). A predefined conductor geometry can be approximated by 16000 segments. Note that the computation can take several days (proportional to n^2-n^3) and the required hard disk space can exceed 1 GB.

1000-2000 segments are completely sufficient in praxis. For computing only a few span fields, inverting the matrix of potential coefficients does not have a large contribution to the total processing time.
A higher segmentation is only necessary for crossing conductors. In this case, the segment length should be in the same order of magnitude as the distances between the conductors. Otherwise considerable calculation errors may occur. The mode **AUTO SEGMENTS** determines the necessary number of segments automatically, so the calculation error is minimized.

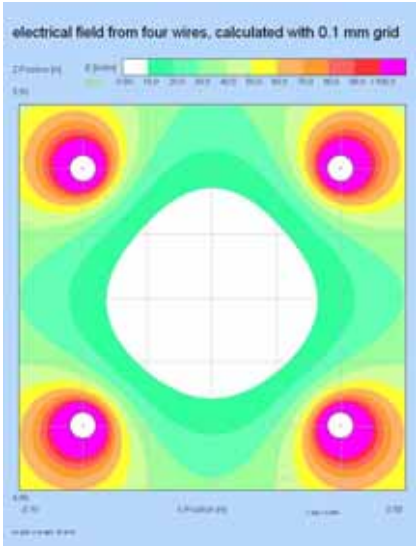
For computation of power transmission lines in large areas only the diagonal and the neighbor elements of the matrix are different from zero. Such a matrix is described as *Sparse matrix*. For the efficient solution of these matrices there exists a **SPARSE MATRIX** algorithm in **EFC-400**. If a charge distribution for several span fields is considered, the interaction between the first and the last span field can be neglected. The user can accelerate computation by setting a radius outside which any interaction is neglected.

The computation time for electric fields is 2-3 longer than for magnetic fields. This is due to the matrix inversion and to the application of the mirror-charge procedure. Unlike for magnetic fields the influence of the ground is not negligible because it is an almost perfect conductor compared to the high impedance of air. The electric lines of force stay practically vertically on the ground. This is taken into account by reflecting the complete configuration of conductors at the ground and computing these with inverted sign. Therefore the computation effort is larger than for magnetic fields.

2.3 Audible Noise and RF-Level

EFC-400 & Sound is the solution for free air plants of the energy industry, which emit sound and RF interference levels caused by corona discharges due to the electric field strength. The essential features are:

- **Electric field strength at Transmission Lines and Terminal Stations**
- **Surface field strength at Wires**
- **Acoustic Noise Level after different Methods**
- **RF Interference Level**
- **Phase optimization for Transmission Lines**
- **Measurement Data Import and Interpolation**



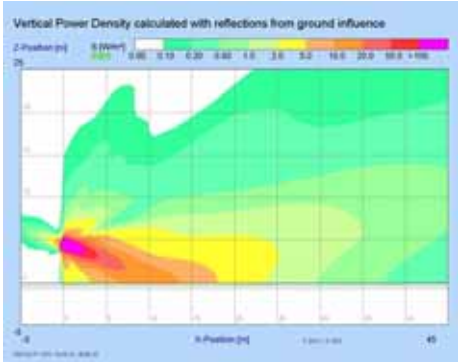
Illus.: surface field strengths of 4 wires

'EFC-400 & Sound' in addition to the calculation of the electric ground field strength determines the surface field strengths in 100 points on the surface of every conductor or conductor segment. These exact surface field strengths serve as input data for the noise and RF level calculation, while conventional procedures assess the surface field strengths only by means of 'hand formulas'.
The 6 employed methods for the level calculation correspond to different sources, all based on empirical examinations, can be selected by the user. With the chosen formula the sound level is determined due to the part-conductor method by the fact that the noise potential is calculated by scalar addition of the spatial distributions of all single segments. The method can treat arbitrary conductor configurations under consideration of the sag. The procedure does justice to the orientation, the separation and the surface field strength of every single segment.
The results are represented as Iso-lines just like the electric field strength. The sound level can be read out at every position below an overhead transmission line or within a terminal station.
The procedure is implemented for alternating current and direct current.

2.4 HF Power Density and Field strengths

'EFC-400 Telecommunication' is the standard-compliant solution for transmitter and telecommunication plants in the high frequency domain. The essential features are:

- **E/H-field and power density**
- **Radiation pattern due to the antenna characteristics**
- **Directional beam diagram import**
- **Losses through buildings**
- **Plot as % of limit values**
- **Set-up of HF-field land registers**
- **Measurement data import and interpolation**



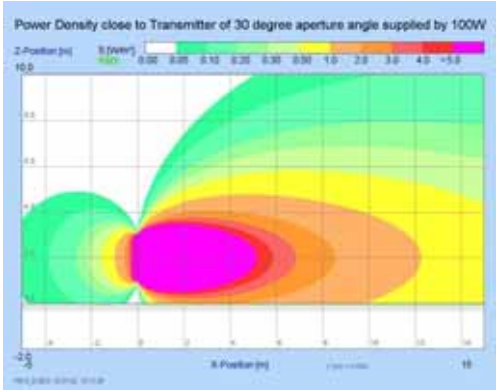
Illus.: calculation with directional beam diagram and reflection on ground

'EFC-400 Telecommunication' calculates field strengths and power density according to DIN VDE 0848, while the radiation pattern is taken into account by the angle quota of normalized spherical harmonics.
The form of the spherical functions gets determined numerically by the technical data such as the aperture angles etc. or can be imported as measured radiation pattern. Horizontal and vertical directional beam diagrams are independently from each other and are converted with an interpolation of third order into continues spatial functions.

'EFC-400 Telecommunication' normalizes the angle quota by integration over the spherical surfaces in dependence of the radial quota function, also providing directional beam diagrams. Power flux through any surface therefore is constant over the topography from near to far distance, supposed conductive ground condition is valid.
The antenna gain is determined on 0.1% precision by the integration and can however be overwritten by the user if the deviation of the aperture angles is larger as the error of the gain given by the manufacturer.

The calculation takes into account the complete information through which the far-field region of a transmitter is defined. Methods for the numeric solution of the wave equation are over-meant for far-field region calculations and lead to faults by discretization of complex structures as well as high data input effort and long computing times.

EFC-400 Telecommunication bases on one of the most fundamental physical laws - the conservation of energy - and approximates the local area around a transmitter by control of the far-field region. Conservation of energy is valid also in the local area in which the spatial distribution in opposite to a point source is improved by segmentation.

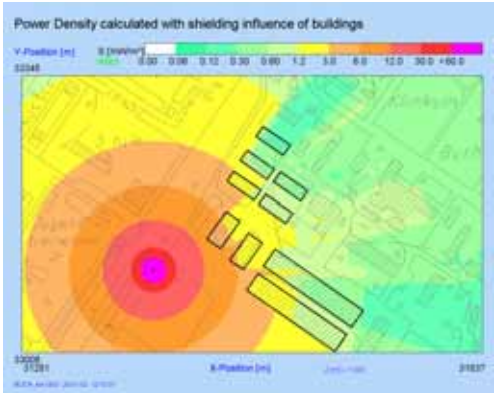


Illus.: near-field region under segmentation

The method is suitable for the near-field region because the normalized spherical harmonics do not just start in the centre of a transmitter.
Each transmitter consists out of a model of a predefined number of radiator parts with finite radius, through what the appearance of a uniqueness is avoided. The part radiators show respectively single phase relationships and get superposed to the complete field which radiates from the whole transmitter structure.
Other authors have compared this method with calculations of the 'Momentenmethode' and found acceptable agreement for the local area.

During calculation of large areas the consideration of all material constants and every sturgeon objects merely results in an increase of errors. 'EFC-400 Telecommunication' therefore includes only the reflection on ground which can be indicated in per cent, and the building influence which gets calculated out of an individual attenuation factor.

The correct determination of the field under inclusion of sturgeon influences is reserved to measurement procedures whose results can be fed in under interpolation.



Illus.: shielding influence of buildings in the municipal area

Because conservation of energy is presupposed, the method is superior to other procedures of field calculation with regard to precision and speed. The method is developed particularly for the ascertainment of the exposure in the ambient environment range i. e. for towns and administrative districts - a range in which every trial of a phases and frequency adjusted solution of the wave equation for all available sources fails. According to the appearance of frequency mixtures 'EFC-400 Telecommunication' calculates the worst case. Various frequency quotas are judged to predefined reference value curves and added up onto the percent exploitation of the sum limit value.

To perform a field calculation only the knowledge of the emitter location and the manufacturer data sheet are required. Due to the efficient data input faults can appear hardly. Because the locations are determined on the topographical map, the set-up of a HF-field land register is directly possible jet including up to 100.000 transmitters in simultaneous calculation.

EFC-400 Telecommunication is usable for judgment of the conformity of mobile telecommunication base stations according to DIN VDE 0848 part 383 and provides a far-field region model and a synthetic model suitable to cover the inquiry of the conformity limits in the ranges far-field region as well as emitting near-field region and as valuation criteria integrates the ICNIRP recommendations (1998) and the European advice recommendation 1999/519/EEC.

3. Getting Started

3.1 Hardware Requirements

To guarantee a smooth operation of the program following minimum configuration is required:

Processor:	Intel multi-core 3 GHz
RAM:	4 GB
Free hard disk space:	50 GB

Note that the performance can be significantly enhanced by using a larger amount of main memory.
EFC-400 is able to use the entire main memory so that increasing the main memory reduces computation time. (No time-consuming hard disk accesses!)
The maximum efficiency of **EFC-400** can only be achieved if the available space on hard disk is sufficient for the number of calculation points. **EFC-400** determines the maximum number of calculation points from the free hard disk space (1 million points /4 MB).
If the main memory does not suffice for the computation, **EFC-400** will use virtual memory. Windows manages the virtual memory as a swap file on hard disk, so a large virtual memory negatively affects the computation speed.
If the virtual memory does not suffice either, **EFC-400** swaps independently to disk.

3.2 Installation

The following chapter describes the installation of the **EFC-400** software. You can find the latest information about installation in the **INSTALL.TXT** file and in the attached installation guide.

Before starting installation, you should check your hardware configuration for the minimum requirements described in the **Hardware Requirements** chapter.

To install **EFC-400**, please perform the following steps.

1. Create a backup-copy of the original program media.

2. Check the hardware requirements.
   (See chapter **Hardware Requirements**)

3. Start Windows™ and insert the EFC-400 installation CD into drive. In case the installation program does not execute automatically, start installation with 'Execute CD-Drive:\start.exe'. Change to the page 'Install Products', click on the 'EFC-400' button and follow the given instructions.

4. The setup program copies all files from drive to the destination directory and creates the directories used by EFC-400 including the new group 'EFC-400' on your desktop and in your start menu.

   Note: During installation process the setup program copies files to the EFC-400 directory and creates the directory structure therein. No further modifications on the system will be made.

5. Before starting EFC-400 the first time, you have to execute the program 'Register', if it has not been launched automatically, to personalize your program version via serial number and user name. If a Hardlock is enclosed to the package, attach it to the parallel / USB interface and install the additional drivers.

   Note: In case of problems during the registration process, remove all TSR-programs from your system (such as 'SHARE') and restart 'Register'. If your program version is protected by a Softkey, you have to call your distributor for providing your personal authorization code. The Softkey depends on hardware and changes every time when executing 'Register'. There is no registration required for software updates.

   Note: Icons for the Hardlock drivers are automatically installed with EFC-400. Execute 'Install HL-Driver' of the EFC-400 program group and follow the statements given in the Hardlock documentation (see appendix of EFC-400 manual).

6. Remove media from the drive.

7. After successful registration EFC-400 can be started by double-clicking.

   Note: The connection of files with the extension 'GEO' to EFC-400 is created during the first start of the program. By double-clicking on a '*.GEO'-file, EFC-400 will execute automatically.

8. A program group and the **EFC-400** icon will be created during installation. Now you can alter the arrangement of the program group according to your requirements.

9. If you want to use the Database Interface, because of XML Format no further installation is needed. XML is also used to enter measurement or ground data manual or to load these as database.

10. Before installing **EFC-400** on a network server, please read the instruction **EFC-400 network installation** and the **README** file.

You have finished the installation successfully. All files are in the directories you specified. The file types used by **EFC-400** are listed and described in the appendix.

3.3 Software Protection

The software protection can be realized by a **Softkey** or by a **Hardlock**. You can find out about this in the installation guide and in the README files. In each case you have to execute the **register** - program before you can start **EFC-400**.

Registration:

When you start **EFC-400** the first time a dialog appears:

Program not registered, 'register' first!

The registration is managed by the program REGISTER.EXE.

For registration the serial number, the user name, and perhaps the Softkey are needed. If the entered data are correct, you can start **EFC-400**. You will find the username and the serial number in the about-box. Updates and program upgrades do not require any renewed registration.

The Run-Only command line version is not provided with a software protection so that extensive tasks can be distributed to as many machines as necessary.

It is not possible to start a second instance of **EFC-400** with a single-user license in a network. The start of the second instance is interrupted and the error message **Network Access Denied!** is displayed. On one PC you can execute several instances of **EFC-400** in anyway.

4. Program Description

4.1 Main Window

The figure below shows the main window of **EFC-400**, containing the Pull-Down menus and the toolbar. The title bar shows the name of the program and the version number.

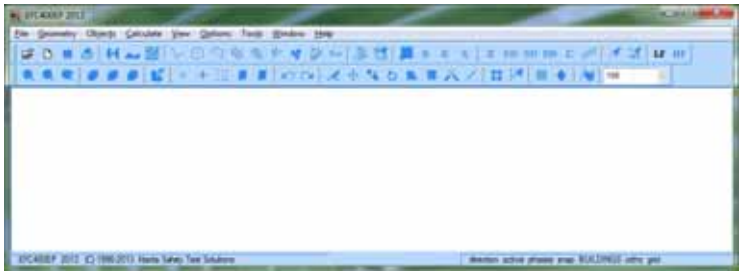


Fig. main window

The menus contain functions for calculation, representation, data export, and printing. The command **Exit** in the **File** menu quits the program.
As long as no geometry is opened, most menu entries are disabled. The enabled functions are marked black.

EFC-400 functions are controlled by mouse and keyboard sequences. Some keys will be used frequently. These special keys are **ESC**, **PgUp**, **PgDn** and the **cursor keys**.

These special keys have the following functions:

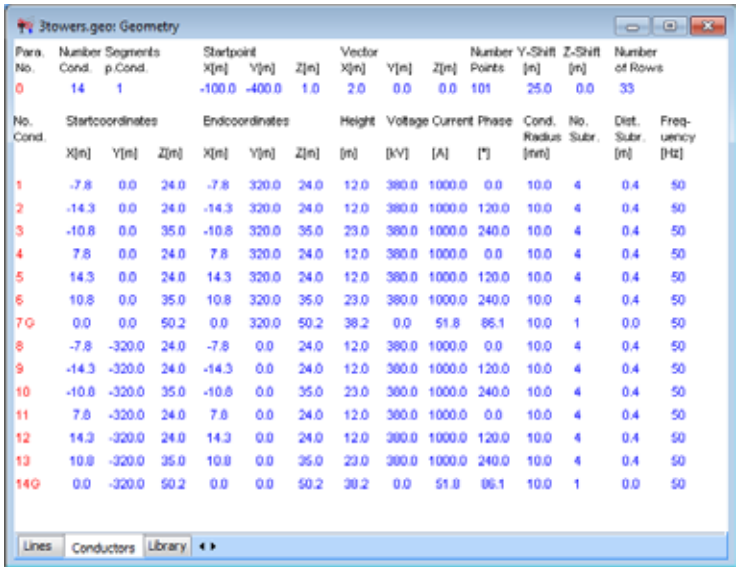
ESC	-	quits the current action
PgUp, PgDn	-	page turnings (geometry, tower)
CURSOR	-	row selection

Changing between LF and HF

Changing between LF- and HF-mode is done with the corresponding toolbar buttons. The special versions for LF and HF do not have this buttons and are per default in the right mode.

4.2 Geometry Window

The **Geometry Window** is divided into two areas. The upper one shows the calculation parameters. In the lower area the objects are listed. Depending on the LF or HF mode these are conductors or transmitters.



3towers.geo: Geometry

Para. No.	Number Cond.	Segments p.Cond.	Startpoint X[m]	Y[m]	Z[m]	Vector X[m]	Y[m]	Z[m]	Number Points	Y-Shift [m]	Z-Shift [m]	Number of Rows
0	14	1	-100.0	-400.0	1.0	2.0	0.0	0.0	101	25.0	0.0	33

No. Cond.	Startcoordinates X[m]	Y[m]	Z[m]	Endcoordinates X[m]	Y[m]	Z[m]	Height [m]	Voltage [kV]	Current [A]	Phase [°]	Cond. Radius [mm]	No. Subr.	Dist. Subr. [m]	Freq-uency [Hz]
1	-7.8	0.0	24.0	-7.8	320.0	24.0	12.0	380.0	1000.0	0.0	10.0	4	0.4	50
2	-14.3	0.0	24.0	-14.3	320.0	24.0	12.0	380.0	1000.0	120.0	10.0	4	0.4	50
3	-10.8	0.0	35.0	-10.8	320.0	35.0	23.0	380.0	1000.0	240.0	10.0	4	0.4	50
4	7.8	0.0	24.0	7.8	320.0	24.0	12.0	380.0	1000.0	0.0	10.0	4	0.4	50
5	14.3	0.0	24.0	14.3	320.0	24.0	12.0	380.0	1000.0	120.0	10.0	4	0.4	50
6	10.8	0.0	35.0	10.8	320.0	35.0	23.0	380.0	1000.0	240.0	10.0	4	0.4	50
7G	0.0	0.0	50.2	0.0	320.0	50.2	38.2	0.0	51.8	86.1	10.0	1	0.0	50
8	-7.8	-320.0	24.0	-7.8	0.0	24.0	12.0	380.0	1000.0	0.0	10.0	4	0.4	50
9	-14.3	-320.0	24.0	-14.3	0.0	24.0	12.0	380.0	1000.0	120.0	10.0	4	0.4	50
10	-10.8	-320.0	35.0	-10.8	0.0	35.0	23.0	380.0	1000.0	240.0	10.0	4	0.4	50
11	7.8	-320.0	24.0	7.8	0.0	24.0	12.0	380.0	1000.0	0.0	10.0	4	0.4	50
12	14.3	-320.0	24.0	14.3	0.0	24.0	12.0	380.0	1000.0	120.0	10.0	4	0.4	50
13	10.8	-320.0	35.0	10.8	0.0	35.0	23.0	380.0	1000.0	240.0	10.0	4	0.4	50
14G	0.0	-320.0	50.2	0.0	0.0	50.2	38.2	0.0	51.8	86.1	10.0	1	0.0	50

Lines | Conductors | Library

Fig. Geometry Window in LF mode

The Geometry Window is the starting-point for working on geometry datasets. You can select and edit objects. With the register at the bottom of the window you can open the library to add new objects. In the LF-mode you also can change to an higher logical level where transmission-, cable- or railway-lines can be changed as one.

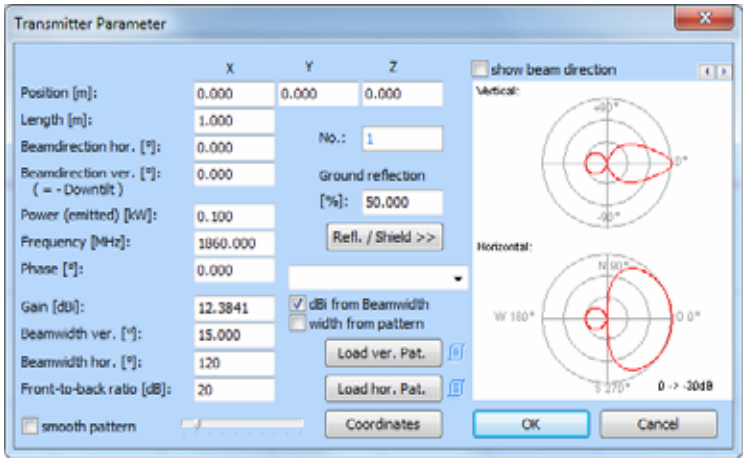
As soon as the geometry dataset is modified according to your needs, the calculation parameters can be set by selecting **Calculation Parameter** from the **Calculate** menu and the calculation process can be started from the **Calculate** menu.

Note: The calculation process will only start if the geometry data has changed. Otherwise, calculation can be forced by executing the **Reset Data** function in the **Calculate** menu.

Changing qualities of objects

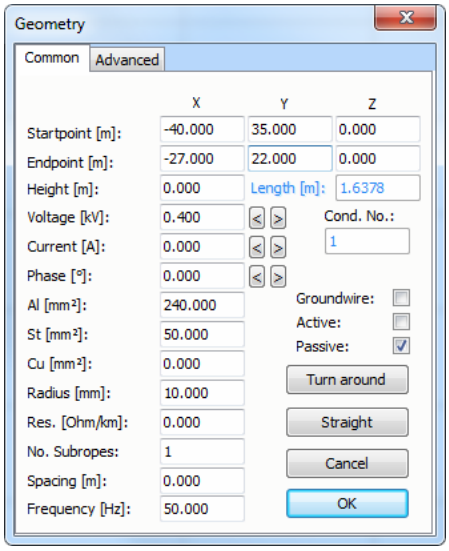
Change the qualities of the objects by the fact that you click with the right mouse button on a list entry in the geometry window.

The Transmitter dialogue appears in the HF mode.



Illus.: Transmitter parameter dialogue

In the NF mode the conductor dialogue is opened where you can define rectangular cross sections and fix the material constants under the register 'advanced'.



Illus.: Conductor dialogue

4.3 Construction Window

The **Construction Window** shows a graphic of your geometry.

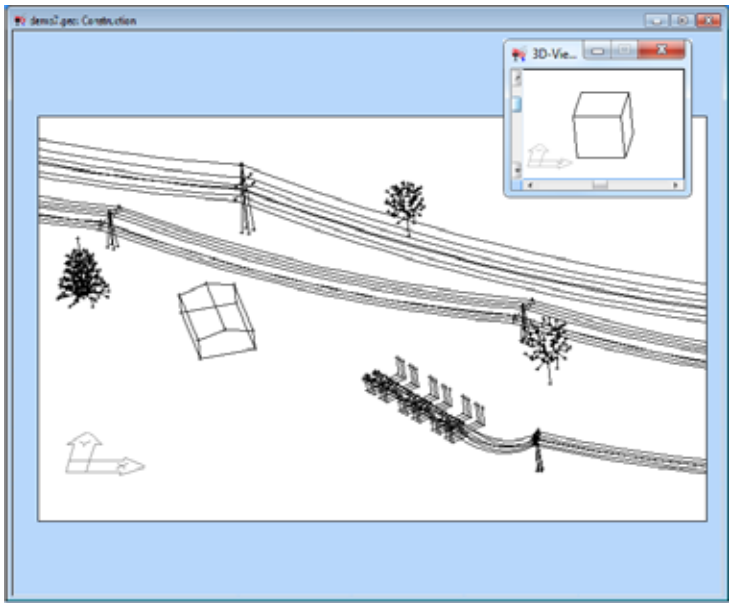
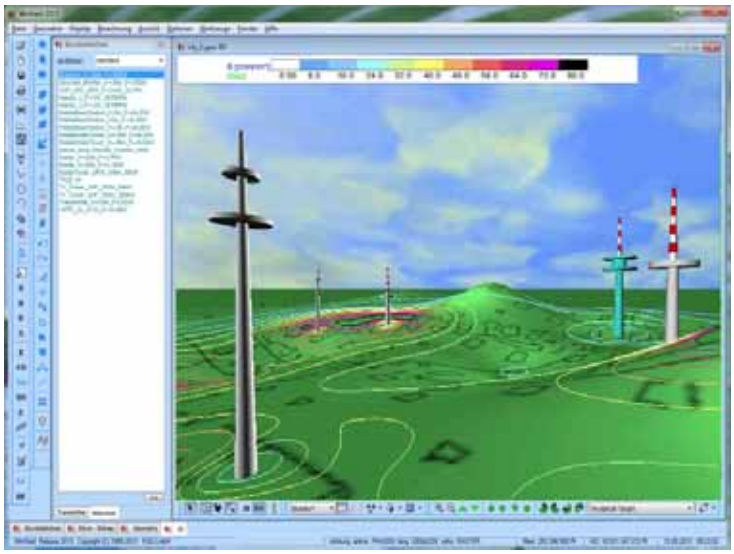


Fig. Construction Window in LF mode

You can modify objects by mouse as known from CAD, while viewing the geometry from any 3D-viewpoint. Therefore elect the command **3D-Viewpoint** from the main menu or the local menu.
All construction functions, particularly **Select-, Move-, Copy By Mouse** e.g. are fully functionable. While moving in the 3D space you can read the relative coordinates as usual. The moved objects always lie in the plane of the actual calculation area.
For the construction of complex plants you can view those from every viewpoint and also work on them. The cube and the coordinate symbol always clarify the viewpoint.

4.4 Virtual Reality Window

The Virtual Reality Window has the same priority as the construction window and can moreover show the calculation data. You can mark objects just the same and use the same functions like in the construction window.



Illus.: Virtual Reality Window in HF mode

Note: Please, be sure however that you cannot mark objects within control cubicles or buildings directly. Pressure the function key F7 to remove buildings and control cubicles as in the construction window to get grip on the internal structure.

The pink hemisphere in the Virtual Reality Window is the view target of the camera. With the mouse control the view is changed as follows: drag with the left button moves the view target in the plane (at simultaneously pushed down Ctrl button in the height), moving with the middle button changes the distance to the view target (zoom in/out), pull or move with the right button shifts or tips over around the view target.
A view below the ground is only possible if the representation of the sky is switched off. Objects can be selected, moved, copied and inserted by mouse as in the construction window.

The turn in steps of 90 degrees at insert by mouse is carried out as in the construction window with the <, > cursor buttons. The choice of absolute coordinates in 3D isn't possible since these aren't defined. You can open a menu by click with the right mouse button on the free range of the local toolbar to e.g. configure the representation of the background map.

Note: 3D objects are of *.3Ds format (3D-Studio Max). EFC-400 produces the objects automatically. Trees, houses, cars etc., are delivered in the directory 'Lib3ds' and are by means of the 'assigns 3Ds' button connected with blocks.

Note: If you liked to look at height profile graphic instead of the Virtual Reality window, you can switch the Virtual Reality interface off under 'advanced settings | system'.

4.5 Line Editor

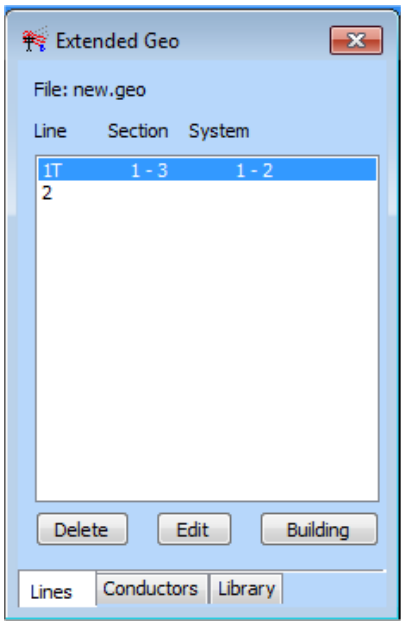


Fig. Line Editor

The **Line Editor** was developed especially for the comfortable construction and modification of power transmission lines, earth cables and railway lines. The Line Editor is opened by the register Lines. The **Line Editor** is only available in LF mode.

Note: To change between Line and Conductor Editor (... Extended and Standard Geometry Format) alternatively you can click on the EXT toolbar button.

In the **Line Editor** conductors are combined to tower systems, which are connected to towers. Towers can be grouped to transmission lines. The advantage of this design is the easy handling of transmission lines, like rotation or movement. The electrical current of the whole transmission line can be set by input of only a single value. If an individual tower is moved the conductors are handled as if they were elastic.

At the top of the **Line Editor** the name of the current file is displayed. In the middle part, the existing objects are listed by numbers. Every existing line is displayed with its corresponding sections and systems. Transmission lines are marked with **T**, cable lines with **C** and railway lines with **R**. The main difference concerns the symmetric three-phase current of transmission and cable lines in contrast to asymmetric currents of railways. Here the currents can be different on rails and cat wires.

By a double-click on a selected list entry with 'T' the **Tower Manager** is activated. Thus the corresponding towers and systems can be edited. Entries with 'C' or 'R' call the **Cable** or **Railway Manager**.

Tower Manager

The **Tower Manager** is used for managing a selected power transmission line. Here you can add or replace towers and modify existing elements. *Real* towers are constructed only if the tower height is positive. Otherwise, *virtual* towers are created, which may represent earth cable lines or railway lines. Virtual towers only represent the start or end point of a section without being existent physically.

Fig. Tower Manager

Towers are grouped, and equipped with connected systems of conductors. Corresponding electric and geometric settings can be carried out after clicking on the buttons **System Config** and **Conductor Config**.

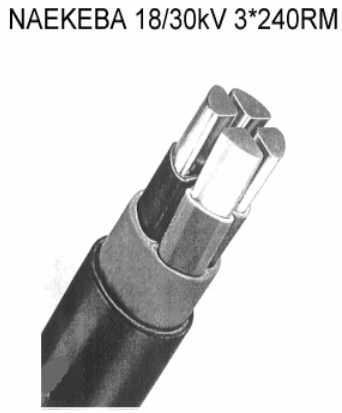


Fig. Cable

Cable Manager

The **Cable Manager** is used for managing a selected cable. You can add or replace cables and modify existing elements. The window is similar to the **Tower Manager** with the exception, that some identifiers are different and some edit boxes are disabled.

Railway Manager

The **Railway Manager** is used for managing a selected railway line. The same description is valid as for the **Tower Manager** and the **Cable Manager**.

System Configuration

The electric parameters of a line can be set in the **System Configuration Window**. This window is accessible through the **System Config** button from the **Tower, Cable or Railway Manager.**

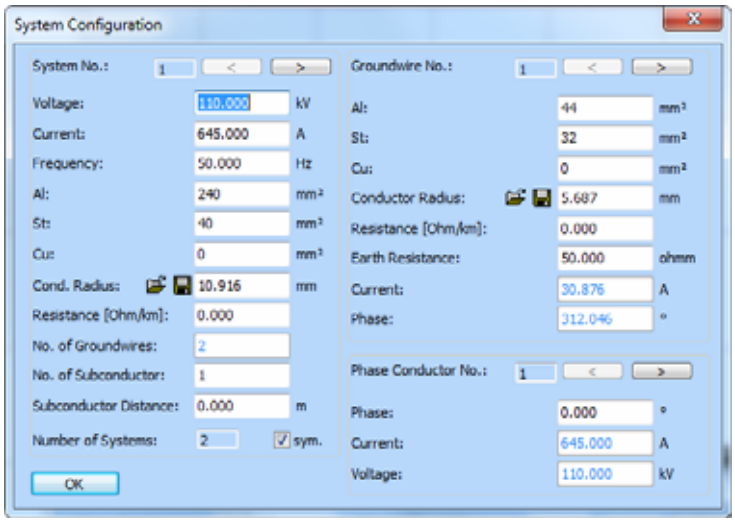


Fig. System Configuration

The parameters on the left side refer to the respective system of the selected transmission line. With the arrow buttons **<** and **>** the system which is currently being worked on can be specified.
The parameters for ground wires can be found at the top right window area, beneath the parameters belonging to the phase conductors.
The arrow buttons are used to change between the individual ground wires and phase conductors.

Conductor Configuration

The **Conductor Configuration Window** is used to edit the points of suspension of the actual tower selected in the **Tower Manager**.

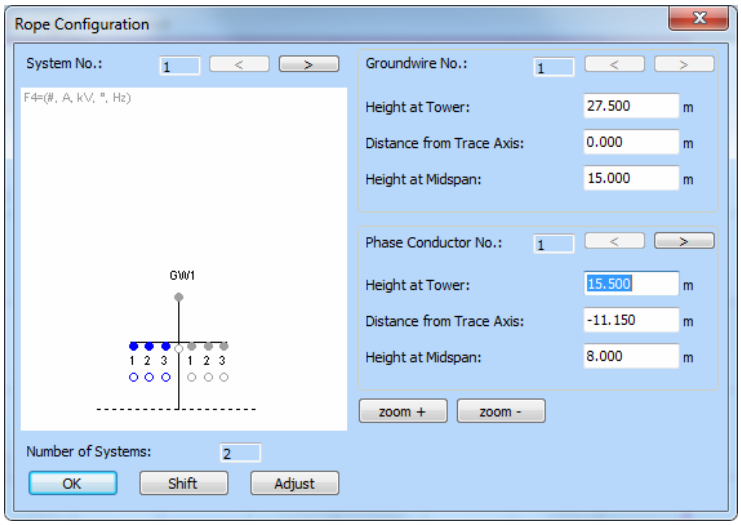


Fig. Conductor Configuration

At the right side of the screen the points of suspension of every single conductor can be entered. You can use the arrow buttons to change between the individual conductors or ground wires.

At the left side of the screen a schematic graph of the tower which is currently being worked on is shown. Any change of the conductor coordinates causes the sketch to be immediately redrawn. In order to select a particular system, the arrow buttons can be used. The current system is marked blue.

To define the conductor positions, two additional tools are available.

With the **Shift** command you can adjust the ground clearance of an individual conductor, system or all the systems of the current tower.

If you do not know the ground clearance in the middle between the two current towers (the actual and the following) but at any other position, the **Adjust** function enables the calculation of the required value. To do this, enter the ground clearance at a distance (x-position) from the first tower.

Note: The actual span field is the area between the current tower and its successor.

4.6 Library Manager

With the **Library Manager** you can handle existing libraries or create new ones. With the register you can change between towers, cables or general objects which are blocks. Depending on LF or HF mode blocks are switch gear components or transmitter.

Fig. Library Manager with view of towers in LF mode

At the top of the window you can find the name of the loaded library. On the left side all the objects of the library are listed. On the right side you can modify the parameters. The object bitmap is also shown.

4.7 Options Dialog

The available options are divided into 6 groups. In the special versions for LF or HF the groups can be restricted.

With the menu entries **Load Config** and **Save Config** several configurations can be loaded and saved. Additionally, the entry **Automatic Configuration** offers the facility to save and load configuration data together with geometry data. In this way it is possible to keep the correct configuration for each project.

The functions are:

Standard :
general program settings
(e.g.: representation, title, ...)

Extended :
calculation settings
(e.g.: interpolation points, sparse matrix inversion, ...)

Technical :
calculation settings
(e.g.: frequency, time-dependent field, ...)

Power TL :
calculation settings for power transmission lines
(e.g.: segments per tower, ...)

Cataster :
calculation settings for coordinates and ground
(e.g.: emission frame, view ground profile, ...)

Audible Noise :
calculation settings for audible noise
(e.g.: method, weather condition ...)

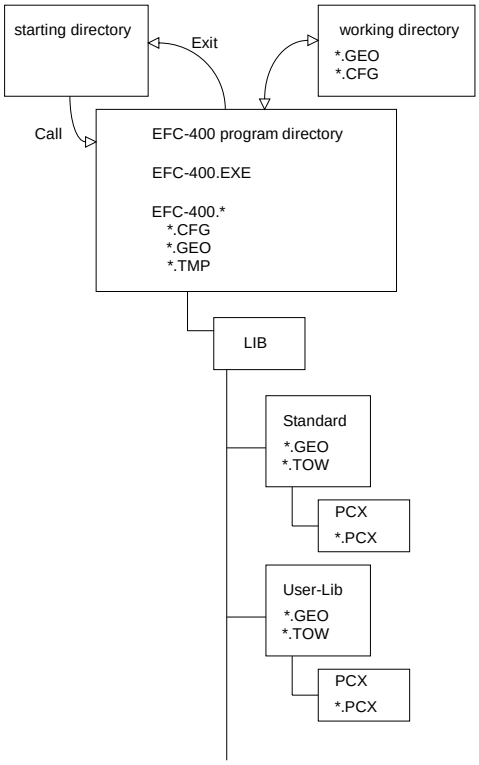
4.8 Directory Structure

EFC-400 has user-friendly functions for file and directory administration.

This includes:

Libraries are saved in the subdirectories LIB, BlockLib and TransLib of the **EFC-400**-program directory. When a library is built, a new subdirectory with a new library name is created to guarantee clarity.

EFC-400 continues to work in the directory used in the previous **EFC-400** session. This is realized by saving the last working directory and changing the directory when starting the program.



It is possible to start **EFC-400** in one of the following ways:

1) **EFC-400** is started by double-click on the application icon in the explorer.
2) **EFC-400** is started from the command line**.**
3) A file with the extension GEO is executed in explorer.

Case 1+2): The working directory corresponds to the previous working directory.
Case 3): The working directory corresponds to the directory of the GEO-file.

```
EFC-400 program directory
        +---Example
        ¦       +---Bahn
        ¦       +---Berlin
        ¦       +---U-Bahn
        +---LIB
        ¦       +---Bahn
        ¦       ¦   +---PCX
        ¦       +---Kabel
        ¦       ¦   +---PCX
        ¦       +---Special
        ¦       ¦   +---PCX
        ¦       +---Standard
        ¦           +---PCX
        +---Protocol
        +---Report
        +---Temp
        +---Tutorial
```

CFG-files are saved in the subdirectory CONFIG. If a **Config-Path** was specified**,** files are saved there.

EFC-400 uses 6 paths adjustable by the user:

Work -Path
Temp -Path
Config -Path
Library -Path
Report -Path
Protocol -Path

These are explained in the following.

Work-Path:

Main configurations used by EFC-400 are stored here.

EFC-400.CFG
EFC-400.DXF
EFC-400.LIB
EFC-400.BKL

These files contain information about the computation options, color settings, libraries etc. Usually the **Work-Path** is the directory EFC-400. It should be changed only for network operations.

Temp-Path:

Temporary files used by **EFC-400** are stored here.

B.TMP
E.TMP
BP.TMP
EP.TMP

These files - plus the swap file which is created by **EFC-400** when the main memory is exhausted - are used for saving the computation data. It is advisable to put the Temp-Path on a drive with a lot of free space.

On a network, every user should define his own **Temp- Path.**

Note: Overwriting of the CALC******.**TMP swap files of different users or processes cannot occur. But the temporary computation data can be deleted if there is a common TEMP-directory.

Config-Path:

Configuration files used by **EFC-400** are stored here.

*.CFG

These files contain information about the computation options, color settings etc. Usually the **Config-Path** is the directory EFC-400\CONFIG. It should be changed only for network operations. In a network the users can define their own **Config-Paths.** Otherwise they ought to be aware that they are working with a common pool of configurations.

Library-Path:

In a network all users will normally work with the same library (towers and blocks). Thereby new elements are available for all users. If necessary, users can create their own **Library-Paths.** This can be important, for example, if different user groups are working on various projects.

Note: Every Library-Tower is defined in its own TOW-file. The corresponding bitmap is stored in subdirectory PCX (or BMP). During the creation of a geometry file containing towers, the reference to the tower bitmap is stored in the GEO-file. The references consist of a relative path, e.g. Standard/PCX/EE110.PCX. This facilitates moving a library to another drive or into a new path. If the user changes the path settings of the library, the towers of the earlier geometry files are presented together with the bitmaps of the same name stored in the new directory. If these are not available, no display will be carried out - if the file contains another figure than the original, this will be displayed! (This concerns of course only the tower bitmap. The real tower remains unchanged.)

Report Path:

Report files used by ReportSmith™ are stored here. With these files reports of **EFC-400** geometries can be created.

Protocol-Path:

This directory contains files for creating protocols and is used by ReportSmith™.

Additionally **EFC-400** displays the program directory. This directory cannot be changed in **EFC-400**.

5. Data Input

The geometry elements of **EFC-400** are **transmitter conductor, ground wires, towers, cables, transmission lines, buildings, cases, metal plates** and **blocks**. The following chapter describes the combination of these elements to a geometry data record.

5.1 Project-Info

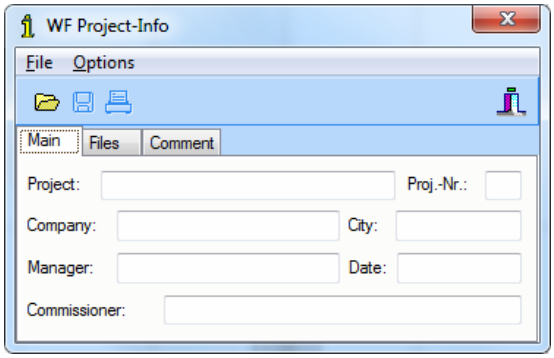


Fig. Project Info

A project information file can be created for every **EFC-400** geometry data record. This contains general information such as

Project	-	project title
Proj.-No.	-	project no.
Company	-	company
Manager	-	project manager/editor
City	-	city
Date	-	date of construction
Commissioner	-	customer

and offers the possibility to add a commentary. Additionally, the information window displays the names of those files belonging to the project which are used by **WF-Protocol** for creating protocols.

Geo Data	-	geometry data record
Data Plot	-	bitmap of a view window
Towers	-	bitmap of a schematic tower or transmitter sketch
Statistics	-	statistical information

Double-click on the entry field for file names will automatically open a file dialog.

There are tree ways to call **Project-Info**.

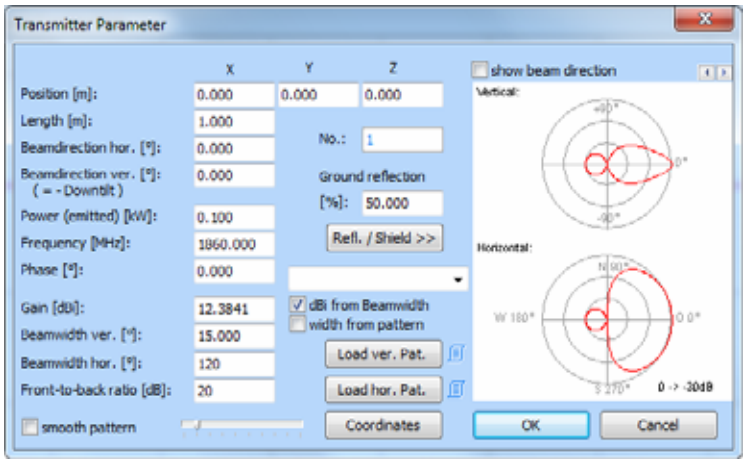
1) EFC-400: **File | Project | Info**
2) EFC-400: **File | Project | New:** new geometry/project
3) explorer: direct execution of WF-Info

When you open a geometry, **EFC-400** opens the corresponding Info-file automatically. Otherwise you must manually load a Geo file or a database.

Note: The project information belonging to a geometry database are stored in a file with the corresponding file name and the extension IFO.

5.2 Transmitter

In this section the geometry data record and the input process for transmitter are described. You can understand transmitter as single emitter or as emitter parts of a complex antenna system.



Illus. Transmitter parameter dialogue

A Transmitter is described through geometric (above) and electric (middle) parameter as well as the radiation characteristic (below).
The ongoing no. serves as identification and cannot be changed. The reflection at ground has to be attached for most application cases as 0% because the absorption predominates.

Position parameter:

The position and the length define the location and the measurements of the Transmitters. The beam direction defines the orientation. The Transmitter is inclined with the vertical beam direction and is represented in the construction window correspondingly.

Electrical parameter:

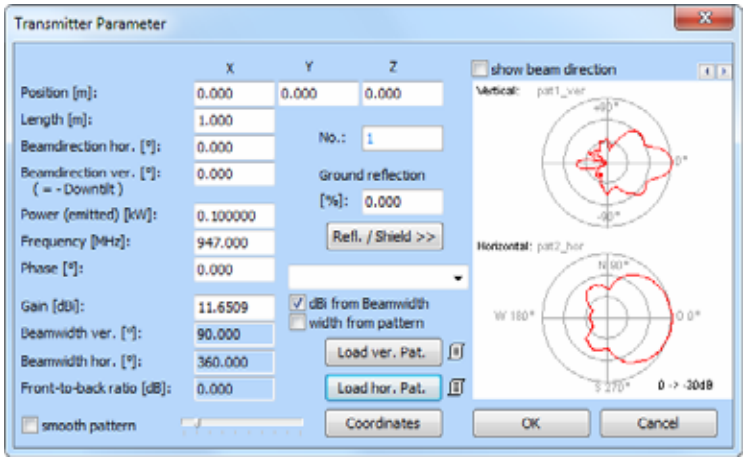
Frequency and transmitted power are adjustable according to the conditions. The phase relationship should be 0°, if you not want to build up a complex antenna from several emitter parts which each other shows phase differences. This method provides a suitable synthetic model for near-field region of mobile telecommunication base stations or an emitting alternative procedure for the inquiry of the conformity limits according to DIN VDE 0848 part 383.

Radiation characteristic:

Due to the parameters of the vertical and horizontal directional beam characteristic diagrams are represented, simulated by spherical functions, in the dialogue on the right.
If the checking box "dBi from beam width" is activated, the aerial profit in relation to an isotropic transmitter is calculated on the area of the spherical functions by spatial integration on 0.1% precision. This value can differ from the manufacturer because the angles are frequently indicated to with a fault of some degree. If you want to provide the profit of the manufacturer tightly, you must deactivate the check box.

Loading radiation characteristic of the manufacturer:

With the button "Load ver Pat." and "Load hor Pat." radiation pattern can be loaded. This ASCII files of the extension *.PAT or *.MSI can be seen with a text editor.



Illus. Transmitter parameter dialogue with loaded pattern

The pattern becomes a three-dimensional surface at field calculation which is standardized on the aerial profit and represents the real measured radiation characteristic.
In principle, the aperture angles are ignored at field calculation with loaded pattern. The aperture angles can be calculated by integration from the pattern data with activation of the check box "width from pattern". This is carried out however only during loading of the pattern.
Pattern with the extension *.MSI also contain the frequency and the aerial profit, which are loaded automatically. Therefore it isn't required to activate the options "dBi from beam width" and "width from pattern". Otherwise the manufacturer's indication isn't used but the profit is calculated from the pattern.

Fig. Configuration of Shielding and Reflection

Configuration:

Configuration is done by <Refl./Shield> Button.

Input of transmitter:

The input of transmitter is carried out in the **Geometry Window**. Row zero displays calculation parameters and the number of transmitter used in the geometry. Calculation parameters can be edited by click with the right mouse button on row zero, or with the **Calculation Parameter** item in the **Calculate** menu.

You proceed for producing new Transmitter as follows:

a) execute the menu command geometry | new object (or key Ins), while you indicate the number of desired transmitter. The geometry window shows blank lines initialized with zero position. The correct parameters can be entered into each of these blank lines now.
The line to be edited becomes entering the parameters with click of the right mouse button or with the menu item "edit objects..." in the menu geometry dialed. The dialogue window opening makes the explicit petition of the parameters possible. Not needed blank lines have to be deleted before calculation.

or

b) you execute the menu command objects | transmitter (or click on the assigned Toolbar button) with which you produce a new Transmitter whose parameters you can enter in the seeming dialogue.

Note: Input is only accepted if the dialogue is completed with the OK button. The click with the right mouse button for editing a complete row is only accepted if no range is selected in the geometry window.

After closing the dialogue box you can repeat the procedure for every new transmitter.

Construction by mouse:

In the **Construction Window** transmitter can be created complete by mouse.

This is carried out by the fact that you activate the switch in the Toolbar. You can pull the transmitter by mouse to the desired position, after insertion the parameters as described under point b).
Functions to edit selected transmitter can be found in the local menu.

5.3 Conductor

In this section the geometry data record and the input process for conductor ropes are described. Straight conductors are handled in the same way, except there is no sag.

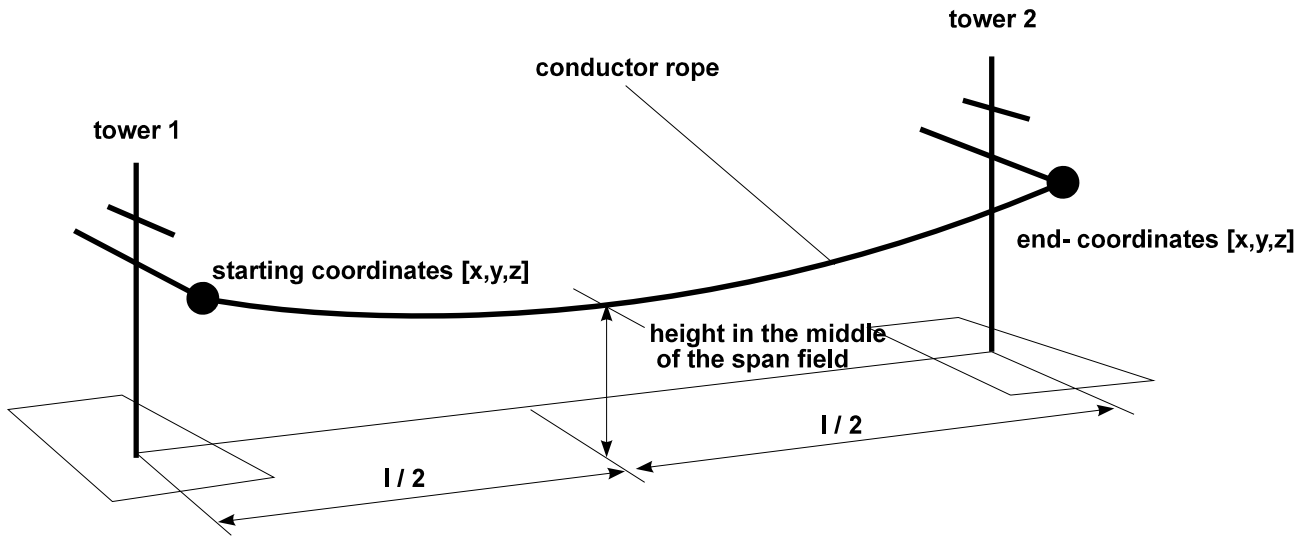


Fig. Geometry of conductor rope

Conductors are determined by the following parameters:

Startpoint X, Y, Z	-	starting coordinates
Endpoint X, Y, Z	-	end coordinates
Height	-	height at mid span
Voltage	-	voltage
Current	-	current
Phase	-	phase angle
Radius	-	radius of conductor
No. Subropes	-	number of subropes
Spacing / Subrope Distance	-	distance between the subropes
Frequency	-	frequency

In the following these parameters and their properties are listed.

Parameters for the position description:

Startpoint X, Y, Z [m]	-	starting coordinates
Endpoint X, Y, Z [m]	-	end coordinates
Height [m]	-	height at mid span

Starting coordinates (end coordinates) determine the point of suspension for the conductor on the first (second) tower. The sag of the conductor is defined by the height of the conductor in the middle between the two towers (see Fig. Geometry of conductor rope).

Electric parameters:

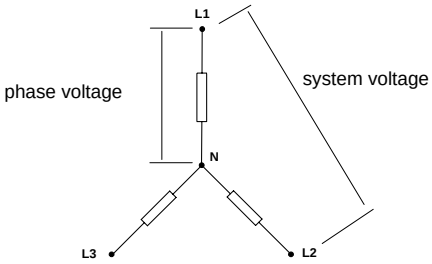


Fig. System and phase voltage

Depending on the setting of the **Voltage** option as **phase** or **system** in the **Technical** dialog or in the **Power T.L. ...** dialog from the **Options** menu, the input of

System Voltage [kV]

(voltage between the phase conductors) or

Phase Voltage [KV]

(voltage between phase conductor and zero conductor)
is required respectively (see Fig. System and phase voltage).

Current [A]	-	current
Phase [°]	-	phase angle

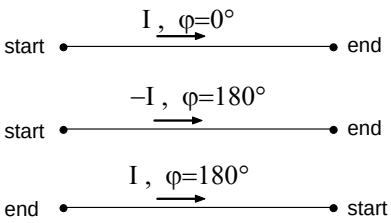


Fig. Current flux (identical cases)

Determines intensity and phase of the current which flows in the conductor from the start coordinates to the end coordinates. The physical current direction is used in **EFC-400**.
A negative value for the current direction corresponds to a positive current direction with a phase rotation of 180 degrees.
Exchanging start and end coordinates of a conductor equals a reversal of the current direction (see Fig. Current flux).

Note: At a frequency of 0 Hz (DC) the phase angle is not defined any more. Therefore the phase will be ignored in this case.

Conductor parameters:

No. Subropes - number of subropes

In case the phase conductor is made of a bundle of conductors, **EFC-400** considers this property by offering the parameter **No. Subropes**. Here the number of subropes can be entered.

The number of subropes has to be larger than zero.

Radius [mm] - conductor radius

Radius must have a value > 0.

Spacing [m] - distance of subropes

The parameters **Spacing** and **Radius** are illustrated in Fig. Bundle of conductors.

Frequency [Hz] **-** frequency

This parameter assigns a frequency to the current of the conductor under consideration. The value will only be considered for calculation if the **Frequency = Free** option in the **Technical** dialog box (**Options** menu) is activated. Otherwise the frequency shown in this dialog box is used. **Frequency = Free** requires a high calculation performance and should only be used for calculations of systems with different frequencies.

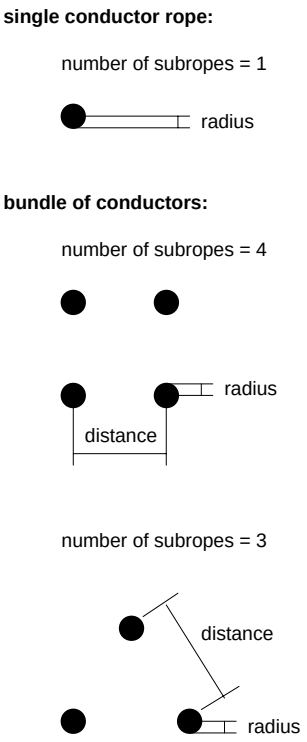


Fig. Bundle of conductors

Input of conductors:

The input of a conductor is carried out in the **Geometry Window**. Row zero displays calculation parameters and the number of conductors used in the geometry. Calculation parameters can be edited by click with the right mouse button on row zero, or with the **Calculation Parameter** item in the **Calculate** menu. In the invoked dialog box you can enter the number of conductors. Other parameters shown here can be neglected at the moment and the dialog box can be closed by a click on **OK**.

The **Geometry Window** shows blank rows which are initialized with zero by default. Into each of these blank rows conductor parameters can be entered. A conductor which will be considered for calculation is only created by input of parameters.

The arrangement of the conductor coordinates is not restricted, with the exception that conductors must not penetrate. Otherwise errors will occur during calculation of the electric field.
Blank rows which are not needed have to be deleted before computation. The number of subropes has to be >= 1 and the radius has to be larger than zero to avoid error messages during calculation.

By a click with the right mouse button on the row you want to edit or executing the **Edit Object...** command from the **Geometry** menu**,** a dialog box appears where you can enter corresponding parameters.

Note: Input is only accepted if the dialog is completed with the OK button. The click with the right mouse button for editing a complete row is only accepted if no range is selected in the geometry window.

After closing the dialog box you can repeat the procedure for every new conductor.

Constructing conductors by mouse:

In the **Construction Window** conductors can be created complete by mouse. Therefore use the **Polyline** command which is introduced later. Functions to edit selected conductors can be found in the local menu.

5.4 Ground Wires

EFC-400 can calculate ground wire currents automatically. The selection of one or two ground wires for each tower is predefined, but you can add further ground wires to simulate disconnected and grounded conductor systems.

For calculation ground wires are assigned to a number of conductors. An interaction is calculated only between the assigned conductors.
If you want to change, delete or renumber a conductor, **EFC-400** adapts automatically the geometry and ground wire currents will be recalculated. Only if new conductors are added to a tower, it is necessary to delete existing ground wires and input new ones.

In principle, ground wires are characterized by the same parameters as conductors. Current, voltage and phase cannot be edited because **EFC-400** calculates them.

Additional parameters are:

Conductors	-	reference to conductors
Earth	-	specific ground resistance
Al/St	-	ratio of cross-sections Al/St

Ground wires are characterized not by radius but by cross-sections Al/St. From this value, **EFC-400** calculates radius and electrical resistance.

The input of ground wires in the **conductor editor** is described in the following. The parameters necessary for automatic computation are queried with an input dialog.

Ground wires are created in the same way as conductors. After having entered the conductor parameters you have to activate the switch **Ground Wire**.

Enter the following parameters:

Conductors	-	reference to conductors

Input convention: First reference conductor - last reference conductor

Note: It is only possible to refer to existing conductors! Please keep in mind that no reference to ground wires is possible!

Al/St	-	ratio of cross-sections

The Al/St value sets the ratio of cross-sections of aluminum and steel of the ground wire in [mm^2/mm^2].

Earth [Ohm*m]	-	specific ground resistance

The default value is 50 Ohm*m.

Startpoint X, Y, Z	-	start coordinates
Endpoint X, Y, Z	-	end coordinates
Height	-	height at midspan
Frequency	-	frequency

The default frequency is 50 Hz.

The input of start/end coordinates and of the height at midspan is carried out analogously to the input of conductors (see section **Conductor**).

Note: The calculation is not restricted to 2 ground wires per tower. In case of more ground wires **EFC-400** calculates the currents if the option **auto induction currents** under **Options | calculation** is enabled.

5.5 Towers

Fig. Tower Manager

Towers can be inserted into the geometry using functions provided by the **Tower Manager**.

Towers are characterized by base area, tower height, span width and number and height of girders. For calculation, **EFC-400** constructs the towers from grounded conductors (see Fig. Tower parameters). The maximum number of standard towers is 100, the maximum number of extended towers is 1000. Towers can be edited and deleted in any order at any time.

Please note that towers in the **Standard Geometry Format** are not assigned to conductors. Therefore the input of towers does not change the properties or parameters of the conductors. Particularly the corresponding conductors are not moved automatically if the tower coordinates are modified.

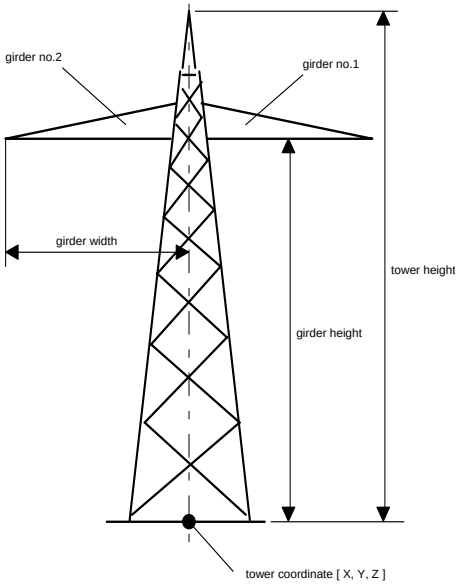


Fig. Tower parameters

Description of tower parameters:

Coordinates X, Y, Z

These coordinates set the position of the tower base.

Tower Height

Defines the distance between base and top of towers.

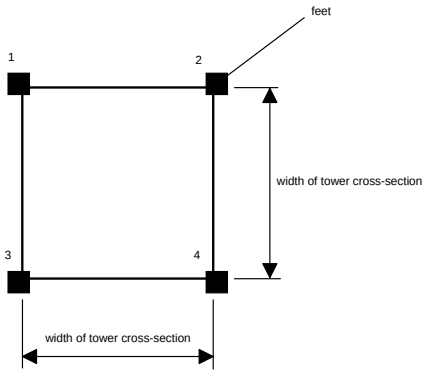


Fig. Tower cross-section

Width at Base - width of base

Angle (X-axis) - angle between tower and X-axis

No. of Girder - number of traverse girders

Left and right girders are counted separately. (The tower in Fig. Tower parameters has 2 girders). The maximum number of girders is restricted to 12.
For input of girders a window is opened where the height and span width can be entered. The span width refers to the longitudinal axis of the tower. (see Fig. Tower parameters).

Number of Feet

Specifies the number of tower feet. The default value is 4. (This value cannot be altered in the current version.)

Creation of Towers

Towers are created by selecting a default type from the tower library and entering its position parameters.

Option: <auto phase config.>

By default the option should be activated. Thus phases on the entire route are standardized and adapted to the phase position of the first tower. This is done by the geometrical position of conductors at towers. The outermost conductor is always connected to the outermost at the next tower and the highest one with the highest one, so that it cannot come to crossovers.
If the option is deactivated, no adjustment of phase positions is made and permutations or twisting between the towers is possible.

<table>
<tr><td rowspan="2">list of the library towers</td><td>switch tower no.</td></tr>
<tr><td>parameter editor</td></tr>
<tr><td>OK Select Delete</td><td>edit girder</td></tr>
</table>

Fig. Structure of the Tower Manager

Tower Input

Open the **Tower Manager** by executing the **Tower** menu command. In the list of library towers the active tower entry is marked. (The tower is outlined in gray until it is selected.) Now you can select a tower by a double-click on the corresponding tower name, or by highlighting an entry and click on the **Select** button. The tower parameters and a tower sketch are permanently displayed.

The **Selected Tower No.** displays the number of selected towers. The parameter editor is deactivated during the selection process. To change parameters of a selected tower, the desired tower can be chosen by the arrow buttons **<** and **>** (**Selected Towers No.**). The parameter editor then switches automatically into the editing mode. The tower figure does not show towers of the library any more but the currently selected tower of the geometry (color blue).

Individual tower parameters can be changed in the editor. To change between input parameters the <Tab> key and the mouse can be used.

After leaving the **Tower Manager** with the **OK** button, the selected towers are inserted into the geometry and will be considered during computation. They will be shown in the 2D-view and Isolines representation, if the **Objects** option in the **Standard** dialog box of the **Options** menu is enabled.

If you want to add a new tower, press the **>** button until **Selected Tower No.** shows a value which is larger than the number of currently selected towers. **EFC-400** then changes the mode automatically. The parameter editor gets disabled and the list of library towers will be activated. Choose a new tower from the list as described before. If all parameters are entered, the **Tower Manager** can be closed with the **OK** button.

Note: The tower sketch displayed in the Tower Manager and the Library Manager always refer to the tower base. The position of the tower base is arbitrary without changing the height of the tower.

5.6 Cable

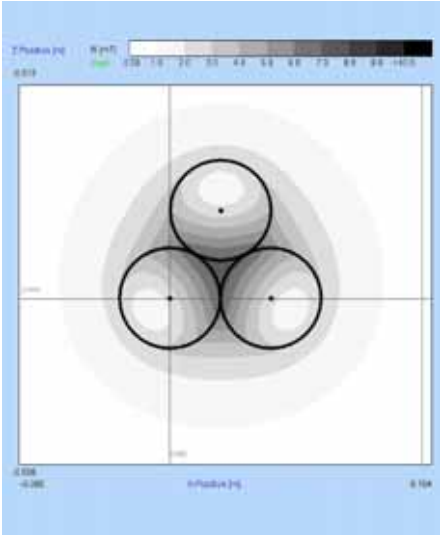


Fig. Cable

Cable can be created in **Standard (conductor editor**) and in **Extended Format** (**line editor**). The first possibility is provided for cable inside of power stations e.g., while the second one is of advantage for earth cable trenches.

In the **line editor** cable get added to the geometry by the **Cable Manager**. The handling is the same as for the **Tower Manager**.
For sections of lines (power transmission, cable or railway) it is only possible to enter the rotation angles inside the plane. For cable lines, constructed in the extended format, the angles of the sections can always be adjusted automatically, without doing this manually after every modification of line positions.

The second angle (against the plane) is only used for cables, which have sections in z-direction. The angle can not be entered manually, but is set by the function **adjust angles/auto adjust** when the check box **allow angle to xy-plane for cables** is enabled.

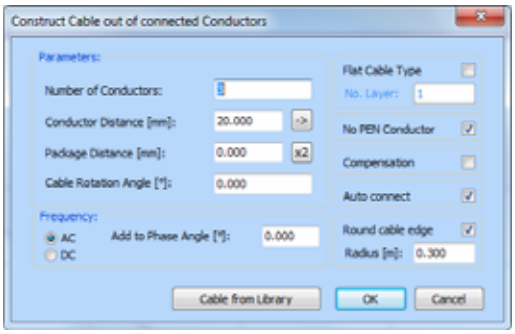


Fig. Construct Cable

For creation of cables in the **Construction Window** use the function **Construct Cable**. First draw a polyline along the desired cable line. Mark these conductors and call **Construct Cable** for conversion into a real cable with multiple phases. You can enter the number of conductors, the distance between conductors and the rotation angle of the cable. The cable can be of flat or round type.

Please note some specialties of the function **Construct Cable**: for the first conductor current and phase are conserved. No. 2 and 3 get phases rotated by 120 degrees (note: in case of only two conductors the phase rotates about 180 degrees). For no. 4 and 5 current and phase get set to zero, when **No PEN Conductor** is not enabled.

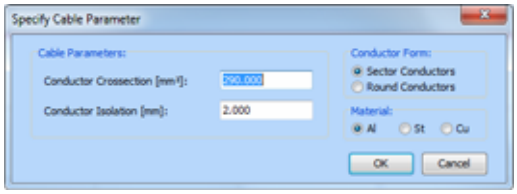


Fig. Construct Cable subdialog

Note: To show the radius of conductors it is possible to activate the function **draw conductor crossection** in mode **transparent** or **filled** (**advanced settings | screen**). At the ends of conductors circles get drawn with the conductor radius. This is of advantage when you want to represent cables in section. Choose transparent to see the field strengths inside the conductors.

5.7 Buildings

EFC-400 simulates buildings with grounded wire-grid models and assumes a negligible field strength inside the building volume.

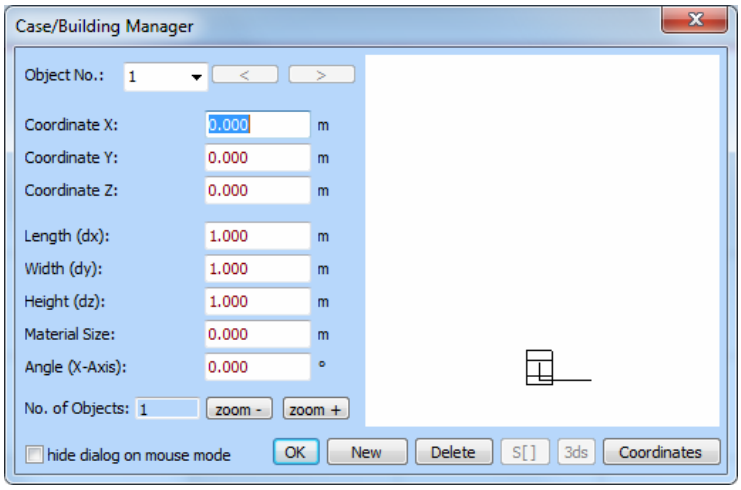


Fig. Building Manager

5.8 Cases

EFC-400 provides the object **case** for components of energy facilities. Conductors inside cases do not create electric field strengths inside or outside the case.

The corresponding menu command can be found under **3D-Objects**. Cases behave in the same manner as buildings. For modification of existing cases, just click on the case with the right mouse button to open the **Case-Manager**.

The advantage of cases is, that the user can better recognize the dimensions of components. When you do not want to use cases, you can enable **ignore block cases** under **advanced settings**. Then no cases are imported during insertion of blocks.
Many functions also work on cases. These are: select/release all, follow connection and select object by cursor, move, copy, edit, stretch, rotate, copy, delete, varia and construct array. Especially cases can be added to blocks, which enables the user to create own component libraries.

Note: by F7 the view of cases can be turned on/off.

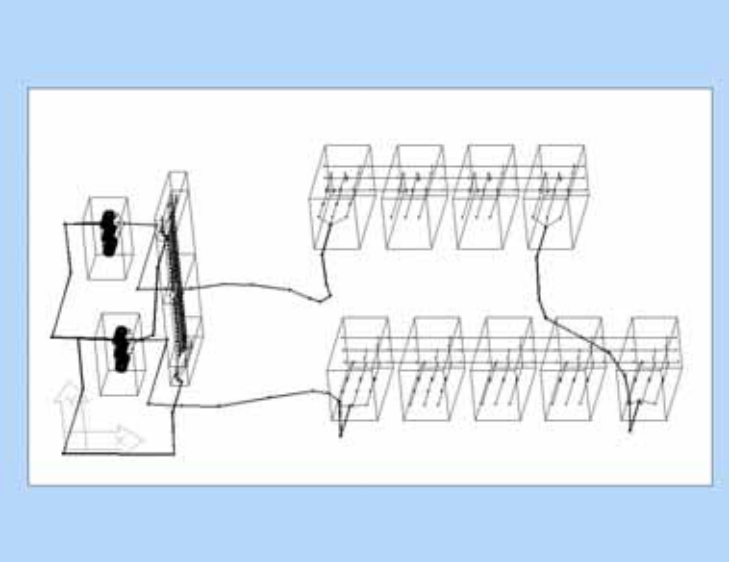


Fig. Geometry with Cases

5.9 Blocks

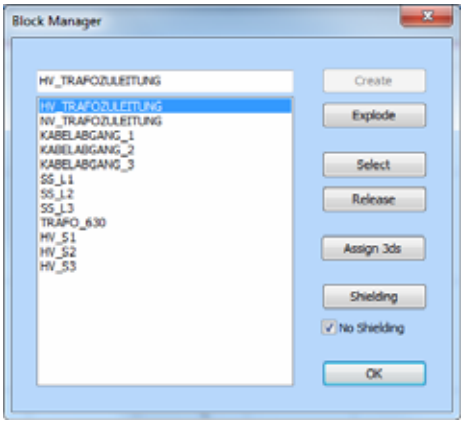


Fig. Block Manager

Blocks are combinations of **EFC-400** objects (conductors, transmitters, buildings ...) and are handled like single objects. The elements polyline, circle, building etc. are combined to sequentially numbered blocks automatically. Each block bears a name which does not change during opening and saving of geometries. Blocks are handled by the **Block Manager**, which provides the following functions:

Create	-	creates block from objects
Explode	-	cancels block definition
Select	-	marks a block
Release	-	unmark a block
Assign 3ds	-	link 3D object
Shielding	-	shielding factor

For blocks you can enter a shielding factor, if isotropy shielding of components shall be applied during computation. The shielding factor can be received by measurements or from the delivered material library. Also shielding is not always isotropy in praxis, this solution is an respectable approximation.

Fig. Block Library

The **Block Library** allows storing of blocks into libraries and makes it possible to import them into a GEO file later on. The following functions are available:

Select Library	-	opens a library
Build Library	-	creates a new library
Delete Library	-	deletes a library
Delete From Library	-	removes blocks
Assign Picture	-	link bitmap
Edit Picture	-	modify bitmap
Assign 3ds	-	link 3D object
Add To Library	-	adds blocks
Insert block	-	inserts a block into the geometry

Note: Double-click on the library block inserts the block into the geometry by mouse. During moving by mouse, the orientation of the block can be varied in steps on 90 degrees by pressing the cursor keys. This feature is also available for the move command. In addition the ortho mode (F8) or the snap grid (F9) can be turned on/off while importing blocks per mouse.

Blocks are combinations of elements. Every element can only belong to a single block (blocks cannot contain blocks!). If you create a new block from all the elements of an existing block, the old block will be deleted automatically. If you want to define several types of blocks based on the same geometry, proceed as follows,

A) highlight the elements you want to combine to the first block
B) create a block
C) store block in a library
D) restart with A)

because the first block is deleted by creating the second block in case the second block contains also elements from the first. If you want to use these blocks later in a geometry, they can be loaded from the library again.

Note: The assignment of library blocks and file names is stored in the BLOCK.TAB files located in the respective library directories. BLOCK.TAB is used only for the documentation and has no further meaning beyond this.

5.10 Geometry Objects

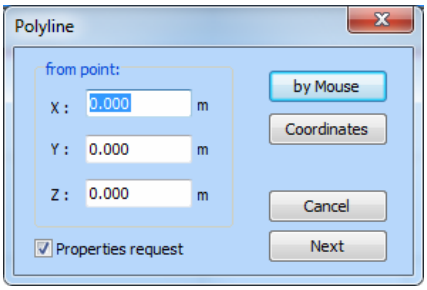


Fig. Polyline

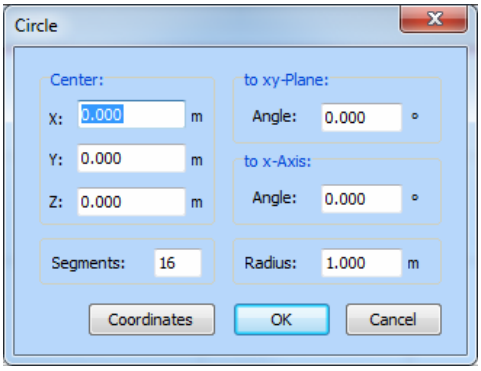


Fig. Circle

Fig. Arc

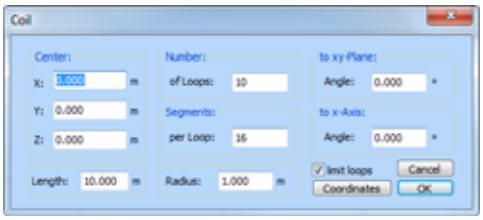


Fig. Coil

EFC-400 provides classes of predefined blocks, with which configurations of objects of unlimited complexity can be created.

Polyline - a course of straight, connected transmitter or conductor

Circle - a circular combination around a defined centre

Arc - circular arc constructed from straight conductors or transmitter

Coil - a coil constructed

Metal Plate - metal plate consisting out of conductor loops

The positions of objects are defined by the coordinates X, Y and Z. Preselection of coordinates is possible.
The objects Circle, Arc and Coil additionally require the input of the number of segments the objects consist of. Two further parameters define the rotation angles of the objects regarding to the plane.

Note: If **limit loops** is enabled the number of windings of a coil is restricted to 10. If a larger number is entered, the current is increased to simulate the additional windings.

For shielding of metal plates eddy currents inside the plate are calculated. Therefore a grid of ground wires is created in the same way as with the array function. The calculation of induction currents (Calculation | Auto induction Currents) computes automatically the current distribution in the plate.

Note: The process is adjusted for 1x1m plates in the near region of conductors. In case of larger plates or greater distance the current distribution is not convergent. Please also remember the power losses, which are written to the file losses.log when the error-log is activated. In addition it is possible to enter a shielding factor manually in the block manager or to calculate the factor by EFC-400 analytically.

6. Loading Data

6.1 Geometry

This section describes how geometries are loaded.

During opening a geometry file the computation data are also loaded, if available. **Ground profiles** are not loaded automatically with the geometry file. After loading a geometry they have to be opened again.

Open	-	opens a geometry
Close Geo	-	closes a geometry

The **Open** command from the **File** menu is used to load complete data records from a geometry file. This menu command is only available if no geometry is loaded. If this option is not available you have to close the current geometry with the command **Close Geo** before you can open a new one.

Insert Geometry ...	-	adds a geometry

To append geometry data to an existing geometry the **Insert Geometry ...** command is used. With this function it is possible to insert objects which are predefined in other files into the current geometry.

6.2 Computation Data

If available, results from a previous computation are loaded automatically with a geometry file. **EFC-400** recognizes independently whether computation data belonging to a geometry file exist or not. If computation data are available, these are displayed without a new computation.

Note: Computation data files cannot be loaded by the user directly but only by loading the geometry.

To combine computation data and geometry files you have to save the data after calculation. Saving is not performed automatically because calculated data can require a large amount of hard disk space. (The computation of single objects is performed so fast, that a saving of the computation data is generally unnecessary.)

The computation data can be reconstructed by **EFC-400** only if the geometry is known. To ensure correct assignment of computation data and geometry data, the corresponding files have the same file date. If the geometry file is changed after storing the computation results the computation results stored before lose their validity and cannot be loaded any more.

Note: In case a geometry file was written over inadvertently without any other modifications, the validity of the computation results can be restored with the special tool **SETTIME**. Follow the given statements and set the date of the computation data file to that of the geometry file. Afterwards the computation data can be loaded together with the geometry again. Additionally the tool **SetFTime** offers the facility to set the file dates of a complete directory (including all subdirectories) to the same date.

6.3 Ground Profiles

Properties of the terrain can be taken into account during computation by loading a ground profile.

Ground profiles are described in form of a XY-table containing altitude values. If necessary, **EFC-400** interpolates coordinates between the given values. (for example, see Fig. Ground profile format)

X\Y	5	9	33	45	60
1	1	2	2	1	0
10	1	2	2	1	0
33	2	2	2	1	1
40	2	3	3	2	2
45	2	3	4	3	2
68	2	3	3	2	2
70	2	2	2	1	1
71	1	1	1	1	1
75	0	0	0	0	0

Fig. Ground profile format

There are two possibilities to connect the ground profile with the geometry data, controlled by the **Geometry Coordinates** option in the **Cataster** section of the **Options** dialog. **Relative** adds the tower altitudes to the ground altitudes. **Absolute** causes that all altitudes refer to the same zero point (NN).

Note: The setting **relative** makes it possible to compare calculations with and without a ground topography. Please ensure, if possible, that the ground profile under towers, girders and in the middle of the span field is flat because the points of suspension and the heights of the conductors in the middle of the span field define the distance to the ground profile.

Loading:

Ground profiles are loaded from the **Geometry** menu. After executing the **Load Ground Profile** function the **File Select Dialog** appears, which displays all available ground profile files with the extension **PRO.** The selected profile is loaded with the **OK** button. If a new geometry file is loaded, any previously loaded profile will be deleted.
If the option **Auto Ground Profile** is enabled profiles with the same name as the geometry get loaded automatically.

Remove:

Clear Ground Profile removes a loaded profile.

Depending on the setting of **View Ground Profile** in the **Cataster** dialog of the **Options** menu the ground profile can be shown as a grey grid in the 3D-view.

File format:

The ground profile data are stored in ASCII format. Any text editor can be used for creating ground profiles.
If you create the ground profile with MS-Excel™ please export the table as text-format with extension **PRO**.

Data format:

A ground profile consists of a matrix with distance and altitude values. You can choose any distance. The values do not have to be equidistant. The table entries describe the altitude values.

In the example of Fig. Ground profile format the altitude value Z in the Point P (X = 45 m / Y = 33 m) is 4 m.

If the file is created with a common editor you can use two cell terminators

1. To change to the next cell (horizontally) the TAB key can be used
   (Corresponds to the Excel™ text format)

2. The cells can be separated by blanks

Generally RETURN is used as line terminator.

A comment can be entered in the first cell. The comment must not contain blanks or TAB's.

Example correct: X/Y[m]
wrong: X/Y [m]

6.4 Import of Background Maps

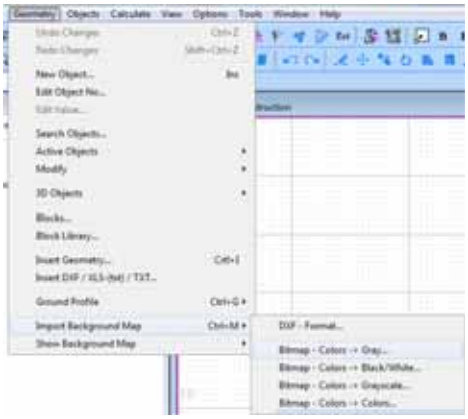


Fig. Background Map

Background maps can be loaded via the **Import Background Map** command from the **Geometry** menu.

Import formats

There are import formats available:

DXF	Drawing Exchange format
PCX	PC Paintbrush-files
JPG	JPEG files
BMP	Bitmap files
TIF	Tiff files

It is possible to reduce the current color format to grey scale, 256 colors or black and white format. (see chapter **Color settings**).

Import process

Fig. Specification dialog

At the first import of PCX- and JPG-background maps position and scale of the map have to be adjusted. For this purpose **EFC-400** automatically opens a dialog box in which coordinates and length can be entered. On the base of these data **EFC-400** creates a specification file with the extension REF, which is assigned to the background map. When loading the background map the next time, the parameters will be loaded automatically.

Note: Background maps can also be added to vertical views. This can be used to show installation components behind the computation data.

Auto Background Map

If the **Auto Background Map** menu item is activated in the **Geometry** menu, a background map which is already defined (REF-file present) is automatically loaded together with the geometry data file. If background maps are available in several formats, they will be loaded in the following order: **DXF** before **PCX** before **JPG ... .**

Action <Move 2 Coord> <2 Coordinates> <4 Coordinates>

After selection of coordinates by mouse this enables to shift, fitting in or scaling the map.

On-Top Background Map

If the **On Top** menu entry is enabled, the background maps are drawn in front of the computation data, otherwise they will appear in the background.

Show Background Map

The display of background maps can be switched with the **Show Background Map** item in the **Geometry** menu for the following views:

2D-plot
Isolines
Construction

Note: The display of the background map is enabled by default .

Keep Map always

The map remains and is not changed when loading a new geometry. Enable the option if you want to use one map for several geometries.

Scale Calculation Area to Map Size

The computation area gets automatically adjusted to the map size if the option **Scale Calculation Area to Map Size** is enabled. This also effects DXF-maps if the geometry is empty during loading of the map.

DXF-Scaling

Under **Advanced Options | Import** the ratio of drawing units to meter can be set. Default is: 1 drawing unit = 1 m. In case of drawings from power stations in units of mm's (scale =>1:0.001) these can be used directly without conversion by changing the setting.

6.5 Experimental Data Process

EFC-400 offers the facility to import measured data, which are displayed as points.
Measurement data are treated fully equally to the calculation and can be represented with or without geometry and computation data. Simply call **New** and load your measurement data. You can change the representation area as well as the plane and insert the data into a topography. With the B- and E-speed buttons you can change between B and E field.
Interpolation of measurement data is possible in addition. Therefore enable the option **Interpolate Data** before loading the data.

Within the **Experimental Data** menu, one of the following import modes can be selected:

a) Manual Entry

In a dialog box the X, Y, Z-coordinates and the field strength (B ,E) can be entered. It is possible to save these data afterwards in a database (*.XML).

b) Import Points

Imports ASCII-spreadsheets (*.MES) containing 5 columns which are named as follows:

X Y Z B E

Every line contains a data point. The number format requires a dot to separate the fractional digits. The individual numbers have to be separated by blank characters or tabulators. The lines are terminated with RETURN.

c) Import Array

Imports a spreadsheet (*.MES) in the following format:

-	-	Y-axis	-	-
-	-	-	-	-
X-axis	-	B or E	-	-
-	-	-	-	-

Number format and separators correspond to b). The first cell can contain a comment (without blanks or tabs). The Z-coordinate is set to zero.

d) Import Database

Imports data created in a).

A prerequisite for the import of measured data is an already loaded geometry. After performing the calculation, the measured data are displayed. Opening of a new geometry resets measured data. The import of data records is additive up to a limit of 10000 data points.

With the setting **relative** the point size varies with the window width of the graphic window. If Size mode = **absolute,** the point size is constant.

Scaling factor:

For representation of measured data a scaling factor is applied which is 100% by default. Changing the factor, data measured at a certain power can be normed to maximum power. Please note that the factor effects both, E and B-field.

Measurement Data Table:

When more then one measured data set exists for an project it is possible to create a table with the projects name and extension *.MDT. In any line of the MDT-file the name of the data set is followed by a blank and the insertion point and angle (x-, y-, z-coordinates and angle, all separated by blanks).

Note: With enabled option **Auto Data**, measurement data get loaded with the geometry automatically.

Remove Measurement Data:

Clear Data removes loaded measurement data.

6.6 Database Interface

EFC-400 contains an interface which communicates with a XML database. The database is activated with the **File | Database** menu entry. Saved file names appear in the file history. The extension is:

*.XML XML - Format

The EFC-400 database format offers a complete alternative to the EFC-400 Geo format. Note: only in LF mode for NF objects valid!. The used databases contain all information on the geometry. This allows you to modify geometric information with a separate database program. In this way, the danger of file corruption is diminished, compared to using a text editor. However, there are disadvantages:

1. database is larger than Geo-files (+100%)
2. open/save of the database is slow
3. the insertion of a geometry is possible only for Geo-files

The last point is not important because you can convert Geo and database format into each other at any time.

7. Editing a Geometry

7.1 Transmitter and Conductor

For editing transmitter and conductor, the functions **Edit Objects...**, **Delete...**, **Rotate...** and **Edit Value...** in the **Geometry** menu are used.

To edit a geometry selecting of objects is necessary. This can be done in 2 ways:

1. The Geometry Window provides extensive possibilities for selection. By a click with the left mouse button you can select and deselect rows, columns and single fields.

2. By clicking within the **Construction** window with the left mouse button directly on an object (or opening a frame) this object is selected (or deselected).

   Note: The direction of pulling determines whether only objects inside the frame (from left to right) or also crossing objects (from right to left) get selected.

   Note: Mouse actions are also possible in 3D when the 3D-viewpoint is rotated.

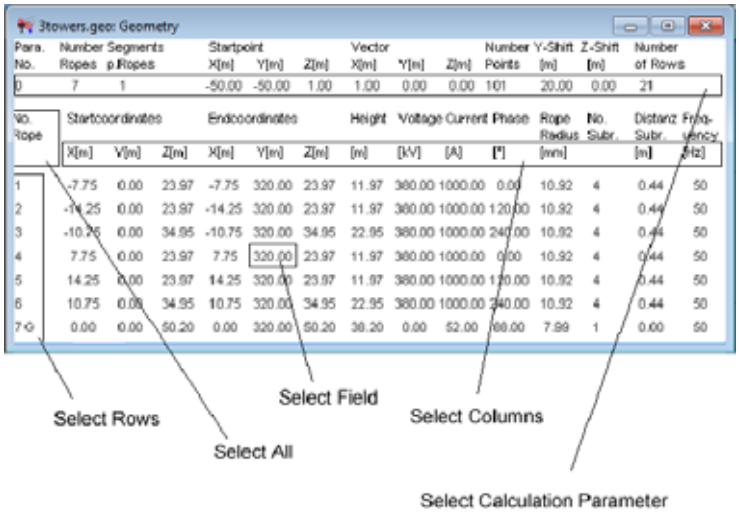


Fig. Geometry Window

Select all:

Double-click with the mouse on the **Geometry** or **Construction Window** selects all objects. Next double-click deselects all objects.

Selection of rows:

Click with the mouse cursor on the number of the row you want to select. If you want to select several connected rows, hold the left mouse button and drag the mouse over the required number of rows.

Selection of columns:

Click on the column head (e.g. y [m]) with the left mouse button.

Selection of fields:

Click directly on the field you want to mark with the left mouse button.

To mark several ranges you can repeat the marking operation as often as you want.

By a click with the right mouse button on selected objects, the edit dialog can be activated.

Extended selecting function with mouse control:

If you want to edit e.g. the parameters of objects which are not listed directly one beneath the other in the **Geometry Window**, you can proceed as follows:

Select all objects you want with the left mouse button in the **Construction** window. Alternatively select the object number (red) with the left mouse button in the **Geometry Window**. Afterwards mark the column with the current parameter by a click with the left mouse button. **EFC-400** marks only parameters of objects selected before.

Mark Connected Objects:

Use select **MARK CONNECTED OBJECTS** while click on objects in the **Construction** window and press the **Ctrl** key. All connected objects are highlighted.

Mark Blocks:

Use **MARK BLOCKS** pressing the **Shift** key while clicking on objects in the **Construction** window. Blocks get marked completely.

Edit an Object using 'Edit Object..':

After clicking on the **Edit Object...** entry from the **Geometry** menu a **Request Box** is opened where you can enter the number of the object you want to edit. By entering the row number the corresponding object is selected. The input dialog is activated by <ENTER> or the **OK** button (see Fig. Input dialog box). The dialog displays the current parameter and its unit. A parameter can be selected and modified with the mouse. With **OK** you can confirm the modifications. You can cancel your inputs by pressing the corresponding button.

When more then one object is selected before calling the function, the edit boxes are empty. After entering values these get set for all marked objects.

Note: To edit a certain object just click on it with the right mouse button.

Usage of the function Edit Value...

To use the **Edit Value...** function, at least one field in the editor of the **Geometry Window** has to be selected.

Note: When selecting parameters ensure that the units of the parameters are identical and compatible.

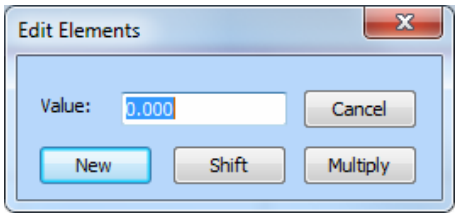


Fig. Edit value

By clicking on a selected parameter field, the field is deselected.

An input box is opened which requires the input of a relative value (**Add.**), an absolute value (**New**) or an multiplication factor (**Multiply**).

Fig. Rotate

Usage of the functions Rotate, Copy and Move

Before using these functions, the objects you want to work with have to be selected.
By clicking with the right mouse button a local menu is opened where you can invoke the function you want. It is also possible to invoke the functions directly from the **Geometry** menu.

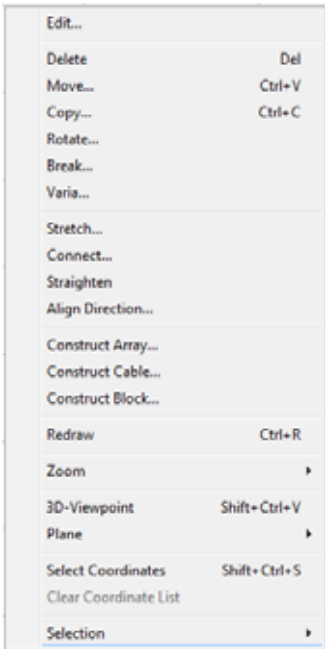


Fig. local menu

The **Rotate** function can be used to rotate objects:

If the **Rotate** function is used to rotate objects, the complete marked object selection is rotated around a specified point or the centre of gravity of the start-, end- or mid-coordinates of the selected objects. **Turn Around** turns each object about 180 degree.

The **Rotate** function should not be applied to several object selections simultaneously because the centre of rotation is calculated by taking into account all starting points.

Usage of the functions Copy and Move

The **Copy** function copies the highlighted objects.

With the **Move** function a group of objects can be moved.

Usage of the function Stretch

On separated objects stretch acts the same as the command move. But when selected objects are connected to others (unselected ones) they get stretched while the connections still hold. This function enables quick changes on an existing geometry because the gaps between moved objects have not to be connected anymore. You may benefit of this function especially while constructing power stations.

Usage of the function Connect

The function connects cable constructed by **Construct Cable** with other components of the geometry automatically.
Therefore select the complete geometry and execute **Construct Cable**. If cables constructed by **Construct Cable** are available inside the geometry, no question is shown: insert new conductors or modify existing ones? Instead **Connect** is executed directly and creates the shortest connections between cable ends and marked components. In praxis this means that all connections can be created in one step!
Only cable ends are processed which are not connected yet. Thus the function can be invoked several times without damage. When only a part of a cable and a component is selected only these get connected.
If no cable is available, the function connects conductor by conductor. You have the choice between: connecting already existing conductors or to insert new conductors into the gaps.

Usage of the function Straighten

Marked objects get stretched to lines. Any slag is removed. You can also enable the option **Auto Straighten** which causes only straight objects to be allowed. This is of advantage in case of power stations.

Usage of the function Break

The function divides an object in several parts (from 2 up to 100). Alternatively you can break objects at contact points.

Note: While constructing complex geometries for example you can first create one object for a certain connection. After breaking the objects in parts you can stretch these parts to the desired route.

Usage of the function Varia

The function allows to scale objects up or down in size. Also **Varia** can mirror objects at axis or points.

Usage of the function Align Direction

The function **Align Direction** corrects the orientation of connected objects automatically. It is possible to choose between: a) processing only selected objects or b) orientate all connected ones, also if not selected, to a selection of objects. Additionally this function can execute automatically during correction of currents according to Kirchhoff law.

Usage of the function Align on Grid

When a snap grid is activated all selected objects get placed on the grid.

Usage of the function Construct Array

The function multiplies the number of elements in several directions of space.

Usage of the function Construct Cable

The function creates a cable with several phases out of a polyline. The number of conductors per cable is free. You can construct a 8-times connection or more in one step.

Usage of the function Search Objects

This function allows to search objects which matches one or more parameters.

7.2 Towers

<table>
<tr><td rowspan="2">List of Library-Towers</td><td>SwitchTower No.</td></tr>
<tr><td>Parameter-Editor</td></tr>
<tr><td>OK Select Delete</td><td>Edit Girder</td></tr>
</table>

Fig. Tower Manager scheme

Towers are edited with the **Tower Manager**. If you call up the **Tower Manager,** the list of library towers is active and the position of **Selected Tower No.** allows the selection of new towers immediately. The parameter editor is deactivated during the selection operation.

If you want to select a certain tower from the list of already existing towers, you can use either the keys <PgUp> and <PgDn> or the arrow buttons **<** and **>**.

<PgUp> and **>** - change to the tower with the next higher tower number
<PgDn> and **<** - decrease the tower number

Selected Towers No. displays the number of the currently selected tower.

The parameter editor is activated if you change to a selected tower. Then the **Tower Bitmap** does not show library towers but the currently selected tower of the geometry (color blue).

If the desired tower is selected, you can work on the tower parameters with the integrated parameter editor. With the cursor keys you can change between the entry fields. Except the parameter **Number of Feet** all tower properties can be changed.

With the **Delete** function, the currently selected tower can be removed from the geometry. This deleting operation is irreversible.

If a tower already contained in the geometry is to be replaced by a tower of another type, you have to delete that tower to insert the new type from the library.

Note: The **Tower Library** chapter describes how you can insert your own towers into the library. They will appear as default towers in the Tower Manager. All you have to do is to assign the corresponding position parameters (XYZ, Angle)

8. Editing in the Line Editor

8.1 Lines

Structure of the Line Editor

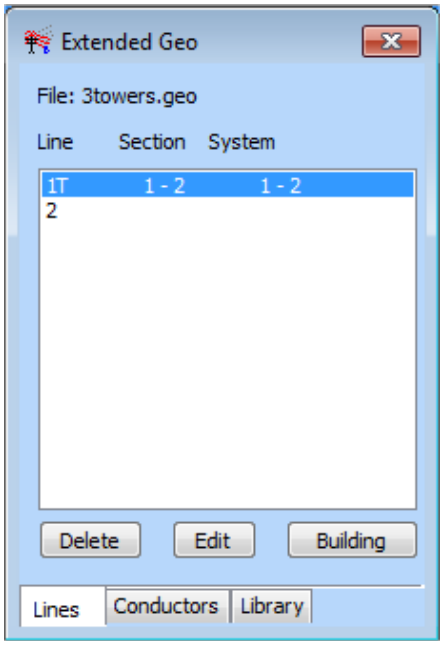


Fig. Line Editor

The name of the geometry data file is displayed in the upper part of the **Line Editor**. The list window in the centre shows the objects already contained in the geometry. The highest line number always corresponds to an *empty* line as long as the maximum line number is not exhausted. By double-click on the highest entry, the **Tower Manager** (or **Cable** or **Railway** Manager) is invoked. Here you can create a new line by selecting objects.

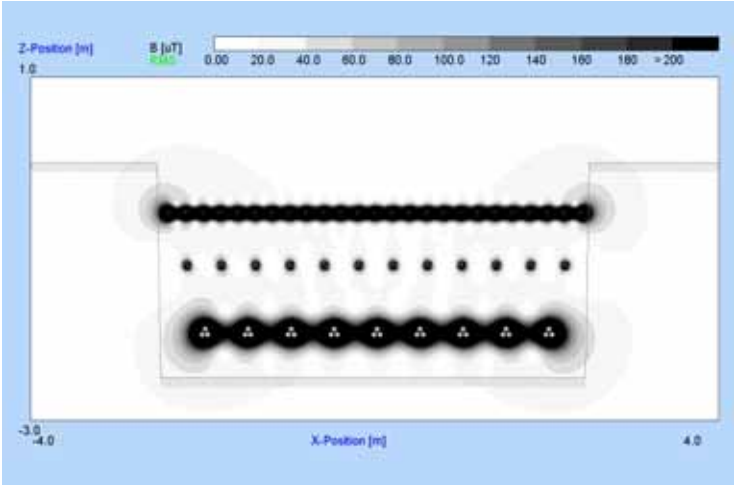
You can choose between a transmission line (power transmission or cable) with three-phase current systems or a railway line with independent currents on the conductors. The identification is carried out via the characters **T**, **C** and **R** behind the line number. In the latter case the currents of every single conductor have to be adjusted separately, in contrast to transmission lines. These facts are emphasized by using the additional names **symmetry** and **asymmetry**. However, in both cases the same geometry elements can be used. If you want to simulate an asymmetric three-phase system, e.g. an 1-kV cable, you must declare it as a railway line.

At first glance, this may seem confusing. Please note that for **EFC-400** the only difference between the operating modes **transmission line, cable line** and **railway** lies in the additional degrees of freedom for currents and voltages!

Note: In the following chapters the term transmission lines will be used to denote railway lines as well as transmission lines.

Quick mode for cable and transmission lines

For projects where the user only wants to compute the field strengths of one span field or one cable, it is possible to select only just this one tower or cable type in the Tower Manager.
Since at least 2 towers are needed for a span field, **EFC-400** does not give an error message leaving the Manager with OK ("at least two towers needed for line"), but creates a span field of 300 m length, centered on x-axis, automatically.
Also several parallel lines can be simulated in this way. Just change the x- or z-coordinates before pressing OK. To compute the field strengths on an vertical section it is only needed to choose the xz-plane which automatically lies in the middle of the span field.



Special features in the Line Editor

After the construction of a transmission line additional functions are available in the **Line Editor**.

A complete transmission line can be deleted with the **Delete** button. The selected line will be removed without further inquiry!

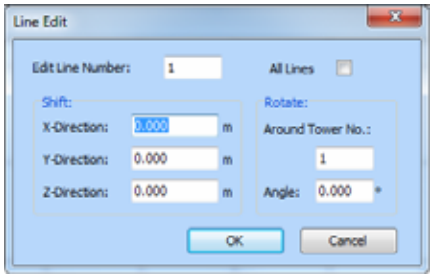


Fig. Line Edit

With the **Edit** button a dialog box is displayed that provides editing functions with which a transmission line can be moved or rotated. To do this you have to specify the line number and the manipulation mode. It is possible to rotate and to move transmission lines in one step.
The **Rotate** function requires input of the number of the tower representing the rotation centre and of the rotation angle in degrees. The transmission line can be rotated around any tower which belongs to the current line.
For the **Shift** function the shift along each of the three axis X, Y, Z in 3D space has to be entered in meters.

8.2 Towers

In the **Line Editor** there are no isolated towers or conductors. The geometry is created by the positioning of towers into the computation area. **EFC-400** uses your individual configurations for the corresponding conductors.

Fig. Tower Manager

The list window in the centre of the Line Editor shows the objects already contained in the geometry. The highest line number always corresponds to an *empty* line. By a double-click on an entry, the **Tower Manager** is invoked. Here you can add new towers to the line. For a transmission line at least two towers need to be selected. Otherwise when leaving the **Tower Manager** by OK, **EFC-400** automatically creates a span field of 300 m length.

Note: If you delete all towers in a transmission line, the line is deleted and the following line numbers are decreased accordingly.

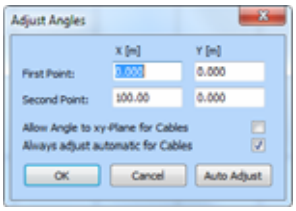


Fig. Adjust Angle

The structure of the **Extended Tower Manager** and the meaning of the parameters largely correspond to these of the **Tower Manager**. There are some new buttons:

System Config - opens the System Configuration Window

Cond. Config - opens the Conductor Configuration Window

Adjust Angles - opens the input dialog

Adjust Head - point of suspension of the lowest conductor

Change Tower - opens a dialog providing functions for exchanging towers in a transmission line

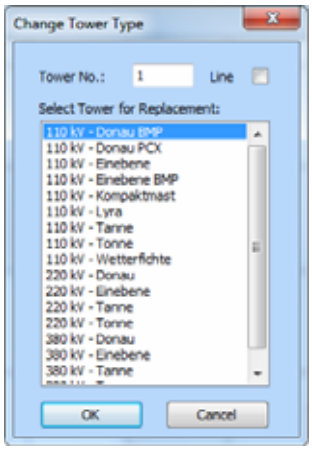


Fig. Change Tower Type

With respect to the tower parameters the following differences to the **Standard Tower Manager** exist:

Tower Height - tower height

If this parameter is changed, all girders and coordinates of the conductors are moved by the same amount. The distance between these objects and the top of the towers remains constant. Only the distance to the base changes.

No. of Girder - number of girders
No. of Feet - number of tower feet

These parameters cannot be altered in the **Extended Tower Manager.** To change them, you have to configure a new tower in the **Library Manager.** The same holds true if you want to change the tower height independently of the coordinates of the conductors.

Creating a transmission line

To select a tower from the list of library towers, click on the desired tower or use the cursor keys <Up> and <Down>. Press the **Select** button to append the tower to the transmission line. A tower can also be appended by double-click on it.

This procedure can be repeated until all towers are selected. Since no conductor geometry can be calculated from the coordinates of only one tower, at least two towers have to be entered.

Now we proceed with the input of tower parameters. Use the arrow buttons **<** and **>** and the keys <PgUp> and <PgDn> to change between towers of the transmission line.

Towers which are selected can be positioned by altering the values displayed in the parameter entry field. The parameters of the systems are adopted together with the tower parameters of the selected library towers. If tower specific system parameters (as e.g. the point of suspension of a conductor) are to be altered, you can use the <PgUp> or <PgDn> keys to change between the selected towers until the desired tower is shown. By the **Conductor Config** button the **Conductor Configuration Window** is entered to modify points of suspension of the current tower exclusively.

For creation of a transmission line from single towers the following additional points have to be taken into account:

The system configuration is always defined by the first selected tower in a transmission line. In addition to the number of systems and ground wires configuration parameters are voltage, current, phase angles, etc.

A transmission line can only consist of towers with identical numbers of conductors and ground wires. Otherwise the error message **Inconsistent Tower Configuration** appears -

which indicates that you tried to add a tower with wrong configuration to the transmission line. (Fig. Error)

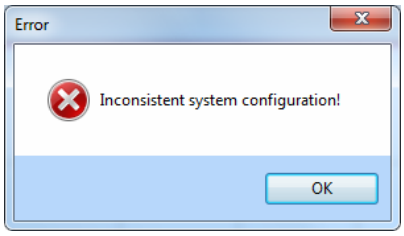


Fig. Error

Note: An effective method of working is to configure all tower types occurring in the transmission line with the **Library Manager** before you insert them into the transmission line. Then you have to enter only the coordinates and the tower height while creating the transmission line.

Insert a tower

Towers can be inserted and deleted at any position within a transmission line. The tower is always inserted at the current position. The following towers are moved accordingly.

If line position 1 is selected in the **Tower Manager** and if a new tower is selected, it is inserted at the beginning of the transmission line.

Option: <auto phase config.>

By default the option should be activated. Thus phases on the entire route are standardized and adapted to the phase position of the first tower. This is done by the geometrical position of conductors at towers. The outermost conductor is always connected to the outermost at the next tower and the highest one with the highest one, so that it cannot come to crossovers.
If the option is deactivated, no adjustment of phase positions is made and permutations or twisting between the towers is possible.

Adjust Head

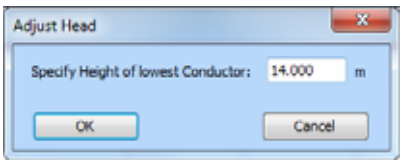


Fig. Dialog Adjust Head

A dialog box which displays the point of suspension of the lowest conductor appears at the call of the **Adjust Head** function. The complete tower head moves if you change the entry. The lowest conductor is set to the new value after confirming the setting by a click on **OK.**

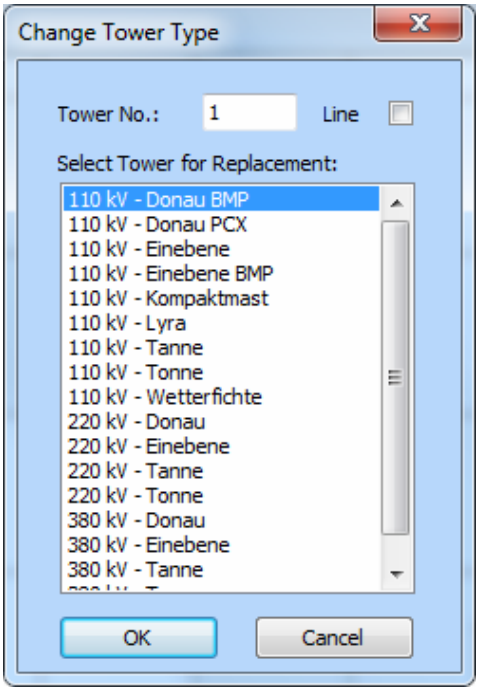


Fig. Dialog Change Tower

Change Tower

This function is invoked with the **Change Tower** button of the **Tower Manager** and allows the exchange of a single tower or all towers of a transmission line. New towers are inserted so that the point of suspension and the ground clearance of the lowest conductor remain unchanged. The other points of suspension change according to the new tower configuration. The conductor configuration and the electrical parameters are held constant so that the influence of two different tower types on the ground field strength can be compared directly.

Note: If you want to change the phase configuration as well, you only need to make the changes in the system configuration window for a single tower, since these changes are automatically applied to the whole transmission line.

8.3 Cable

Cable can be created in **Standard** and in **Extended Format (line editor)**. The first possibility is provided for cable inside of power stations e.g., while the second one is of advantage for earth cable trenches.

In the **line editor** cable get added to the geometry by the **Cable Manager**. The handling is the same as for the **Tower Manager**.
For sections of lines (power transmission, cable or railway) it is only possible to enter the rotation angles inside the plane. For cable lines, constructed in the extended format, the angles of the sections can always be adjusted automatically, without doing this manually after every modification of line positions.

The second angle (against the plane) is only used for cables, which have sections in z-direction. The angle can not be entered manually, but is set by the function **adjust angles/auto adjust** when the check box **allow angle to xy-plane for cables** is enabled.

8.4 System Configuration

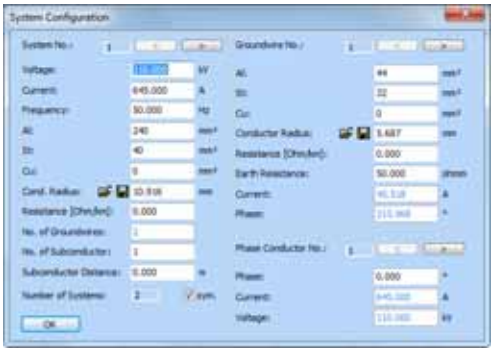


Fig. System Configuration Window

The **System Configuration Window** consists of three different areas. The area **System** is on the left side, the area **Ground wire** is at the top and the area **Phase Conductor** is at the bottom of the right side.

Usage

You can move between entry fields with the mouse or with the <TAB> key.
The arrow buttons **<** and **>** and the keys <PgUp> and <PgDn> are used to change between different systems, viz. ground wires, if more than one of these objects exists.

Domain of parameters

All parameters of the **System** area are independent of towers. This is meaningful because a conductor including current, voltage and phase relation does not change from tower to tower.
With activated option <sym.> all 3 conductors of the system have same voltage and current, otherwise the values for each conductor can be different.

Editing parameters

The meaning of individual parameters is described in the **Data Input** chapter.

Conductor parameters of library towers can generally be left as they are. It is not necessary to modify a completely configured library tower to achieve correct results.

However, we will frequently encounter a situation in which identical tower types in a transmission line are only different in their height over ground (including girders with mounted conductors). The input of the tower height has been adapted for this case (see previous chapter) so that a modification of the tower height moves the complete tower head.

To move a single conductor, it has to be selected with <PgUp> or <PgDn> or the **< >** buttons. The new value can be entered after selection of the corresponding parameter by mouse.

8.5 Conductor Configuration

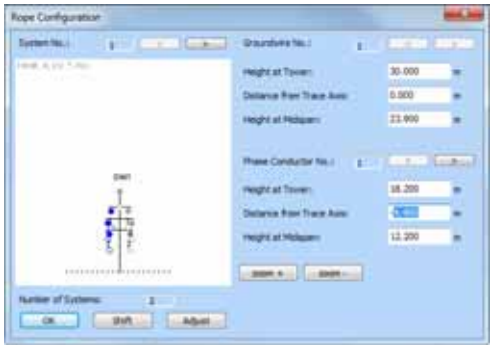


Fig. Conductor Configuration Window

The line parameters which can be entered in the Conductor Configuration Window depend on each tower.

Domain of parameters

The points of suspension and the ground clearance of conductor can vary from tower to tower. Therefore, these parameters refer only to a single tower (viz. span field). All coordinate details are considered in relation to the tower bases.

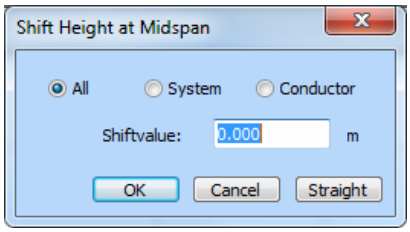


Fig. Shift dialog

The **Shift** function in the **Conductor Configuration Window** allows an easy adjustment of the line sag. The ground clearance of several conductors can be adjusted in the current span field. After invoking this function, a dialog box appears (Fig. Shift dialog) where the shifting can be entered in meters. The domain of the **Shift** function is defined by 3 options:

All	-	all conductors are shifted
System	-	a system is shifted
Conductor	-	one conductor is shifted

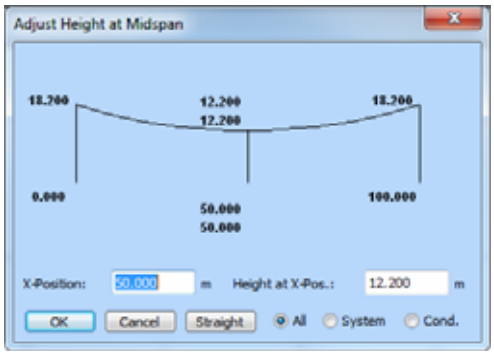


Fig. Adjust dialog

If the ground clearance is not known at the centre of the span field but at another position, a computation can be carried out with the **Adjust** function. This function calculates the ground clearance at any distance from the first tower.

Action switch STRAIGHT

With the **STRAIGHT** button of the **Adjust Height At Midspan** function the sag of conductors and ground wires is set to zero.

8.6 Relation to the Conductor Editor

A geometry can contain both standard and extended elements. The processing is carried out separately in the **Conductor** or **Line Editor**.
If a geometry contains a combination of both formats, a warning message is displayed in the corresponding windows to point out the existence of foreign elements to the user.
In the **Line Editor** there is no risk to change standard elements because the access will be denied. However, conductors and ground wires of extended elements will be shown also in the **Conductor Editor.** In order to distinguish these, they are shown in grey and are marked with an "x". A manipulation of these conductors can cause undesirable effects. If the conductors are moved, for example, they may not be in the correct tower position any more, although they are still connected with the tower. This action is irreversible in the **Line Editor**.
In certain situations, however, you may wish to perform this kind of manipulation. Under certain circumstances, complex applications cannot be solved exclusively in the **Extended Format**. The **Extended Format** offers advantages with regard to the comfortable construction of whole line sections, but the degrees of freedom are larger in the **Standard Format**. It can be of advantage to create the basic elements of a geometry in the **Extended Format** and to subsequently convert it into the **Standard Format**. This function is offered by **EFC-400** if the **Conductor Editor** is invoked while extended elements are present. Note that this process is not reversible.
This feature can be used, for example, if you want to remove a single conductor from a three-phase current system.

9. Computation

9.1 General Computation Parameters

In this chapter the input and the function of the computation parameters are explained.

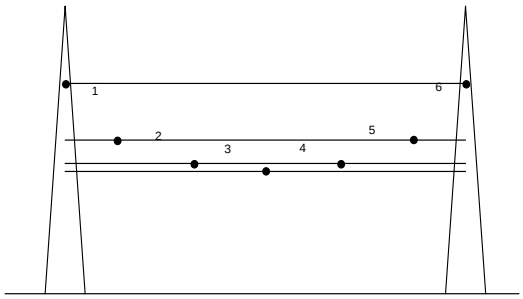


Fig. Line segment = 1

General computation parameters which control the computation are displayed in row 0 of the **Geometry Window.** They determine the segmentation and the computation area. To edit these parameters, select the **Calculation parameters** item from the **Calculate** menu.
(Or click with the right mouse button on row 0)

General computation parameters are:

Segments per Object - segments per object

With **Segments per Object** the number of segments is assigned.

HF mode: Segments per Objects=1 means that the sphere functions start from the centre of transmitters. Higher segmentation causes deviation of transmitter into emitter parts which fields get super positioned with better approximation in the near field region.

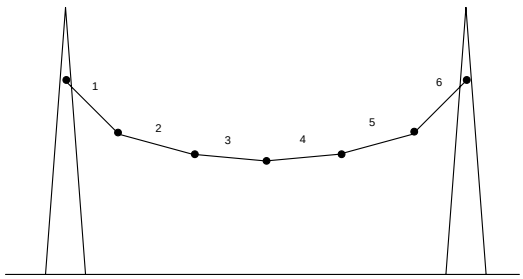


Fig. Line segment = 6

LF mode: a special case is the input of Segments per Object = 1. This would correspond to a straight conductor. The program adjusts the height of the conductor in the considered coordinates instead.
This procedure corresponds to the **method of the infinitely long straight conductor** with the difference that **EFC-400** uses conductors in the length of the span width. The field component in line direction therefore is zero by definition. The precision of the computation, however, is altogether better than for cases of only 2,3,4... segments. The same segmentation is normally applied to towers as well.

Computation area - number of calculation points

The computation area is defined in two different ways:

(1) with a spatially located unit vector + offset
(2) by two key points of a rectangle + cell size

The mode is set by the **Emission Frame=On** or **Off** option in the **Cataster** dialog of the **Options** menu (**On** corresponds to case 2), or with the button **Mode** in the **Calculation parameters** dialog, in which the **History** is also available.

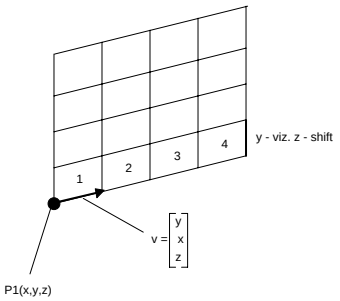


Fig. Vector definition

1. EMISSION FRAME OFF

The input of start and end-point of a spatially located vector is carried out:

Startpoint	-	starting point of the vector
Vector	-	direction of the vector

The vector may have any orientation (in praxis it will have only an X-component). By the additional input of an offset

Y-Shift	-	offset in Y-direction
Z-Shift	-	offset in Z-direction

either in Y- or Z-direction the default cell is defined. The multiplication of this cell in vector direction is indicated as:

Number of Points	-	number of cells in vector direction + 1

The number of rows in Y- or Z-direction is defined by:

Number of Rows	-	number of rows in Y/Z-direction + 1

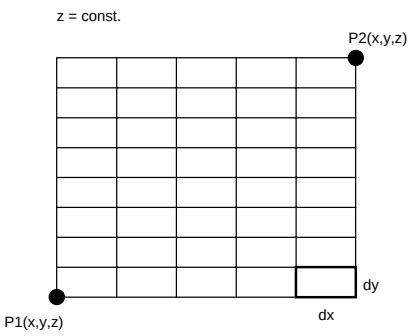


Fig. Definition of an Cartesian frame

2. EMISSION FRAME ON

A Cartesian grid is defined by input of two edge points and the cell size:

Startpoint	-	key point on the left below
Endpoint	-	key point on the right above

The cell size is defined by:

dX-Size	-	cell size in X-direction
dY-Size	-	cell size in Y-direction

The grid is always orthogonal to the X- and Y-axis. Oblique-angled grids are not possible.

Note: The z-coordinate of Start- and Endpoint is always relative to the ground, if a ground profile is loaded.

Additionally possibilities exist to modify the calculation area with the following commands:

xy-Plane, xz-Plane, yz-Plane

The functions turn the calculation area to the desired plane and adjust the size to the actual geometry automatically.
The corresponding button in the **Calculation parameter dialog** is stressed. If you adjust the calculation field by manual petition, the corresponding button is also stressed. You always have the survey which plane is just hired.

After a change to the xy-plane the plane lies normally on a height of z=1m. During change from xy- to xz- or yz-plane, the plane is rotated around the zero point. This means vertical planes pass through the zero coordinate. But when you have selected a coordinate in the plan view by cursor, the rotation of vertical planes is done around this point. With this you have an easy feature to position vertical planes around e.g. power stations.

The position of the plane is shown in the 2D-view, the Isoline graphic and the construction window. The position can be disabled under **Options advanced settings**.

Set to View

After zooming the calculation area can be set to the actual size by **Set to View**.

Refine / Enlarge

The buttons **Refine** and **Enlarge** refine or rough the grid automatically.

Double Calculation Area

The command **Double** enlarges the calculation field altogether at a constant grid size.

Over, under, in front, behind, left and right

Places the computation area accordingly in 0.2 m distance to housings of geometry, and conductors if activated.

Note: If the shown area in the **Proportional Frame View** is greater than the calculation area, the calculation area is marked by a pink frame.

9.2 Special Parameters

In addition to the general computation parameters there are further parameters which are described in the following.
Examples how to use these parameters are given in the following chapters and in the **Case Studies** chapter.

Options Extended

Interpolation Points - number of interpolation points

The number of all computation points is defined by the computation area. The total number is:

Number of Points * Number of Rows.

Interpolation Points determines the number of points which are interpolated. If **Interpolation Points** is set to zero, all points are calculated. **Interpolation Points = 2** calculates only every third point, for example. In other words: Two points are interpolated in between.

Note: The interpolation is executed in rows**.** The number of possible points per row is

n * (interpolation of Points +1) + 1.

If the default **Number of Points** differs, **EFC-400** chooses the nearest value. This has the consequence that the total number of points changes and the end-point is moved. If you have planned a computation area to X = 100 m, it is reduced to X=99 m under certain circumstances. You can avoid this effect by moving the end-point or choosing another interpolation setting.

Dynamic Interpolation

The estimated error occurring during polynomial interpolation is displayed in the status window. To use the advantages of interpolation and to simultaneously minimize the error, the **Dynamic Interpolation** function calculates every interpolation point again, if the error exceeds 0.1%.

Auto segment - automatic segmentation

This function exclusively serves to compute the electric field strengths of complex geometries, e.g. crossing conductors. In these cases, the simulation of the charge distribution requires a sufficiently fine segmentation. It is possible to adjust the segmentation or to choose the automatic adjustment, with respect of the preselected segments per tower. By default **Auto segments** should be turned off otherwise the segment number might grow unnecessarily.

Sparse Matrix Inversion

EFC-400 offers a special procedure to invert the potential coefficient matrix which uses the fact that occasionally the matrix has only a few non-vanishing elements. This always happens if spacious computation fields with several conductors are considered. **Distance Limit** defines the maximum interaction distance between two objects. The **Sparse Matrix Inversion** uses this limit to perform a faster inversion.
This is only of advantage if several span fields are calculated and **Distance Limit** is set.

Distance Limit

The user can define the largest interaction distance with the parameter **Distance Limit**. This implies that only those geometry elements are taken into account for every point of the space which lie within a sphere with radius **Distance Limit**.

The **Distance Limit** function checks the actual distance to objects. A setting of 100 m, for example, means that the field strength of a transmission line is calculated only within a distance of 100 m from the outer object. This procedure offers a considerable speed advantage for large areas.

Overlap x factor

The field strengths of points within **Distance Limit** are computed on the basis of all objects within the distance = (**Distance Limit** * **Overlap x factor**). Without **Distance Limit** the Overlap x factor does not have a meaning. If the Overlap x factor is too small, this can lead to "points/teeth" within the range of the outside ISO-lines, whereby the maxima are concerned however never.

Options Technical

Time-Dependent Field - time-dependent field strengths

EFC-400 calculates the field strengths as RMS-values. With the **Time-Dependent Field** option it is possible to consider the field strength at any time **t**. **t** is defined by the phase angle if there exists a fixed frequency. If there is a mixture of frequencies, **t** is entered in [ms]. In order to allow negative field strengths, the X-axis is moved.

Frequency - frequency mode

With **Frequency** a fixed frequency (16 2/3, 50, 60, 300, 400 Hz) or a mixture of frequencies (free) is set. If you choose a fixed frequency, all frequency values of the individual conductors are ignored, in contrast to the setting **Frequency Free**. This setting should only be used if a geometry with several frequencies has to be calculated, otherwise computation time will increase unnecessarily.

Conductive Ground - ground influence

If **Conductive Ground=On** the ground influence is considered during calculation, which is necessary, for example, for transmission lines. The setting **Off** ignores the ground influence and can be used, for example, for installations inside buildings.

Voltage Type - phase- or system voltage

Defines whether voltage is interpreted as outer conductor to outer conductor (system) or as a conductor to earth (phases) value.

Options Power Transmission Lines

Calculate Tower Region

Considerable field strengths which are not present in reality can arise - because of the method of equivalent charge - in the immediate proximity of the tower feet. If you turn off the **Calculate Tower Region** option, the direct range (tower feet distance * Sqrt (2)) is not calculated around the tower feet.

Segments per Tower

Usually towers are segmented (option is set to **Auto**) as conductors. If you choose, for example, 20 segments, a tower of the type "Einebene" consists of 120 segments. If there are too many span fields, the machine capacity may be exhausted. You can prevent this by fixing **Segments per Tower**. Per default this value is set to **Auto**.

Voltage Type

Defines whether voltage is interpreted as outer conductor to outer conductor (system) or as a conductor to earth (phases) value.

No Segments for straight Objects

Prevents segmentation of straight conductors at E- and dB(A) computation for acceleration.

Ext. Geometrie Format

Has the same function as change between Lines and Conductors in geo window.

Tower to Earth Resistance

Specifies the transition resistance between towers and ground which is added to the ground wire resistance, whereby the ground wire currents decrease.

9.3 Performing a Calculation

A prerequisite for executing a computation is a loaded or entered geometry data record. If necessary, a ground profile can be under laid in addition. (Attention: Existing ground profiles are deleted by loading a new GEO-file.)

You start computation with the **B-Field** command (viz. **E-Field**) from the **Calculate** menu. **EFC-400** only performs a calculation if the data record is modified. If you want to force **EFC-400** to recalculate the geometry, the current computation data have to be rejected at first with the **Reset Data** command from the **Calculate** menu. You can start computation afterwards with the **B-Field** command (viz. **E-Field**) from the **Calculate** menu.

EFC-400 checks whether the size of the computation area can be realized before starting calculation. **EFC-400** chooses one of 3 memory modes, depending on the size of the computation area:

S - Small Memory Mode

Up to 15000 points,
RMS, peak and components are held simultaneously in memory,
uses conventional pointers.

L - Large Memory Mode

Max. Points = 1/4 of free main memory
either RMS or peak in the memory,
uses global memory in the protected mode.

XL - Extra Large Memory Mode

Max. dots = 1/12 of free hard disk capacity
either RMS or peak in the memory,
swapping data to disk.

The memory mode and the free memory are displayed during the computation. After a first computation of the electric and magnetic fields the data are held in temporary files so that the complete main memory is available for new computations. For the same reason there is no simultaneous computation of RMS and peak in the **Large Memory Mode**.

For the computation of all data records (B, BP, E, EP) in the **Large Memory Mode**, the calculation has to be executed 4 times. After computation the switches

RMS and Peak

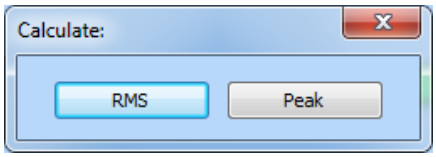


Fig. Computation Selection Box

of the Computation Selection Box are not used any more for the new computation but for changing the display (as long as the geometry data remain unchanged).
If **EFC-400** recognizes that the geometry has changed, the current data record is deleted and **E-** as well as **B-field** has to be calculated again.
An abort of the computation can be carried out with <ESC> at any time.

Note: The Extra Large Memory Mode is optimized for swapping of **EFC-400** computation data without considerable speed loss (only 5-10% increase of computation time). The evacuation model will positively affect the display of the graphic windows.

9.4 Optimization of the Computation

For optimization of computation time, it is important to know the options of **EFC-400** and to understand the computation operation. The computation can be accelerated by:

Reducing the number of segments: Errors can be increased

Reducing the computation area, viz. the number of points: This may under certain circumstances lead to a considerable gain in speed. A high density of points is in fact only required orthogonal to the line direction.

Increasing the interpolation points: Increases the error disproportionately and should be used only together with **Dynamic Interpolation**. Attention: Too many interpolation points cause a speed loss because the errors even in areas far away from geometry elements will get so large that **Dynamic Interpolation** calculates every point.

Decreasing Segments per Tower: Increases the speed

Sparse Matrix Inversion and/or Distance Limit: Increases the calculation speed only if several span fields are present.

Choosing a fixed frequency: Considerable acceleration

Please take into account that the above actions can increase the error of calculation (but not necessarily).
If you choose too many interpolation points, this is easily recognized from the jaggy course of the curves. With complex geometries, however, this need not be so obvious. The user should have a look at the case studies, in which the difficulties are explained.

9.5 Special Functions in LF Mode

A) Function OPTIMIZE PHASES

Fig. Dialog Optimize Phases

This function can only be applied to Transmission or cable Lines. An optimization of the phase setting is possible in two ways:

Method a) Optimization of a tower configuration from the library:

This facilitates the optimization of a tower type before a transmission line is created with it. A temporary span field will be created and the field strength at a cross-profile in the middle of the span field is calculated which has twice the width of the span field. The cross-profile has a height of 1m (from the tower base) and consists of 51 computation points.

Usage: Invoke the **Tower Library** from the main menu or the toolbar (attention: The **Tower Library** is only available if a geometry is opened.) Load the library you want and change the configuration of the desired tower. Highlight the tower with the mouse or with the cursor keys. Change to the **Conductor Configuration** of the tower. You see a schematic drawing of the conductor configuration on the left side. The conductors are numbered incrementally according to their phase angles. The **Optimize Phases** button is on the lower right. Press the button and, if necessary, change the settings in the dialog box before you confirm with **OK**. **EFC-400** calculates all possible permutations of phase configurations after that and adopts the best. If the schematic drawing has not changed, the most favorable configuration was already available. Now you can use this tower for the construction of your transmission line.

Note: Without saving the library, the phase configuration will be preserved only until you exit **EFC-400**!

Method b) Optimization of a transmission line (which can consist of different tower types):

Method b) allows the optimization of the phase configuration of a transmission line with regard to the field strengths in any area, which can lie outside the transmission line and whose altitude is variable. For an intersection of conductors it is possible, for example, to optimize two transmission lines in succession to get minimal ground field strengths. This task is solved internally by computing the field strengths in the complete computation area for all permutations of the phase configurations. The time problem is solved by calculating the complete area and subsequent zooming into critical areas. With the **Set to View** function the computation area is specified. Optimization of the phase configuration is only obtained with reference to the field strengths of this part of the computation area. The optimization is even faster if only a cross-profile is calculated.

Usage: Open an geometry which contains at least one transmission line. Select the transmission line you want to optimize in the **Line Editor**. Invoke **OPTIMIZE PHASES** from the **CALCULATE** menu and, if necessary, change the settings in the appearing dialog box before you confirm with **OK**. **EFC-400** successively calculates the field strengths for all possible permutations of phase configurations in the complete computation area. The best combination is automatically calculated again after termination.

Note: You should minimize the computation area and reduce the number of points as far as possible. Note that **EFC-400** calculates 6^(number of systems -1) computation cycles! You can abort the computation with <ESC> at any time.

Criteria for optimization of the phase configuration are

- Integral or maximum value

Method a):
1) optimization on the integral of the field strengths of a cross-profile.
2) optimization on the maximum value of a cross-profile.

Method b):
As 1) and 2), but referring to every profile or an area (vertically or horizontally) obtained.

- B or E-field

Applicability of the methods a) and b):

Generally you can optimize on E and B only in succession. The actual voltage, phases and currents are used as defaults. Phase angles can have values differing from 0, 120, 240. **EFC-400** only exchanges the assignment of phases to the conductors within a system according to the possible combinations. Method a) optimizes only the phase configuration of one tower of the library, regarding the field strengths below the span field at an altitude of 1 m over the ground. A transmission line which consists of different tower types can also be optimized by using method b). For optimization the chosen computation area is considered. This offers the user every conceivable possibility - however, it requires great care. Some selected examples should illustrate this:

- If you optimize the phases for an area next to a transmission line, the ground field strengths of the phase configuration is probably asymmetric. The ground field strengths directly below the transmission line can be lower with another phase configuration.

- If the phases are optimized for a certain span field of a transmission line consisting of different tower types, the field strengths of the other span fields can be increased. This is also valid if an intersection of two transmission lines is optimized.

- If you want to optimize the phase configuration of a certain transmission line to the minimum value, you have to ensure that the transmission line under consideration is responsible for the maximum amount of field strengths within the computation area. Otherwise you have to optimize the integral of the field strengths or to limit the computation area to the range next to the desired transmission line.

To summarize: For a single transmission line it is of advantage to optimize the tower in the **Library Manager** and to specify the phase configuration of the transmission line accordingly. In the case of several transmission lines running side by side, only method b) is successful.

Phases optimization: Worst-Case

The search for the phase configuration causing the lowest field - **best** - is set per default. With - **worst** - the configuration causing the highest field is searched for.

Note: The phase configuration can be distributed by random with the function **Randomize Phases**.

Note: The results of phase optimization are saved to the file Phases.log if the error-log in turned on.

Phases optimization: "fix Rotation"

During permutation of the phases these are only rotated and are not reflected, which is faster. To really detect all cases the option should be deactivated.

B) Function KIRCHHOFF LAW

This function checks all nodal points of connected conductors for

current sum
frequency
phase
voltage

All end and starting points of conductors with a distance of less than 0.001 m are considered as *electric in contact*. The connection of conductors at other positions (e.g. in the middle of the conductor) is not considered as an electrical contact. If an error occurs, a message box appears, which points to the kind of error. All inconsistent conductors are then highlighted.

C) Function CORRECT KIRCHHOFF LAW

The function **Correct Kirchhoff Law** sets the currents on conductors and is helpful for the construction of power and terminal stations. You have to mark a selection of conductors and execute **Correct Kirchhoff Law**.
Depending upon active conductors the two possibilities exists (setting of active conductors is the recommended way!):

a) no active conductors

The conductor with the highest current is considered as feeding point. A group of connected conductors is only allowed to have one feeding point. The current on all other conductors is not important because they get overwritten with the right values of current and phase. To achieve asymmetric power distribution, parts of the geometry can be processed one after another.

b) with active conductors

The concept of <u>active</u> and <u>passive</u> conductors simplifies the construction of power and terminal stations enormous. Conductors whose current is set, are assumed to be active while those without current are passive.
EFC-400 takes active conductors as feeding points and calculates the current distribution on all passive ones with the function **correct kirchhoff law**. The properties active and passive are basic properties of conductors, which get conserved during operations as copy, move, load or save like all other properties.
When the default **auto administration** mode is turned off, the state of conductors is not touched during current modifications by the user. Then you have to set the active or passive state manually (**set active** or **set passive**). The exception are conductors with no current, which remain always passive.

In praxis work is like this: on the high voltage side of a power station you set one cable gear to 400 A and the other to 382 A. On the low voltage side the feeding points are the transformer candles with 909 A. Then the current distribution of the complete station can be calculated with the function **correct kirchhoff law** in one step.
Also it is possible to define the outgoing currents of the low voltage distribution. EFC-400 summarizes the currents and calculates the right currents for the collection bars and the transformer.

Note: If the option **All Currents Positive** is enabled, all directions of conductors and currents are automatically corrected for positive currents only.

Note: Errors can result when identical (double) conductors exists. These conductors can be removed automatically by the option **Clean Identical Conductors** in the **Correct Kirchhoff Law** dialog.

Note: When executing the function **Correct Kirchhoff Law** it is possible to define a dividing ratio. With ratio 1:1 the current distribution is as normally expected. If the ratio differs, the current is divided in terms of the ratio at every node. You can use this feature to achieve asymmetric power distribution on components.

D) Function TEMPERATURE ADJUST

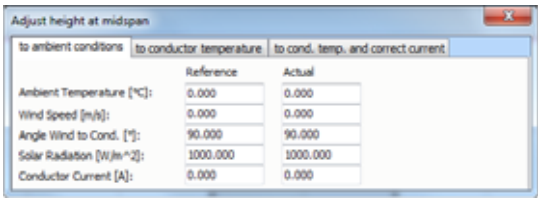


Fig. Adjust Temperature Dialog

With the initial setting of a reference for outdoor temperature and current, this function calculates the sag difference for an entered temperature. The new ground clearance of the conductors at the middle of the span field can be shown with **INFO** or accepted with **ASSIGN**. The function is only available in the **Conductor Editor** and affects only highlighted conductors. The previous ground clearance can be restored by invoking the function again with exchanged parameters (reference - actual values).

E) Function Height at Midspan

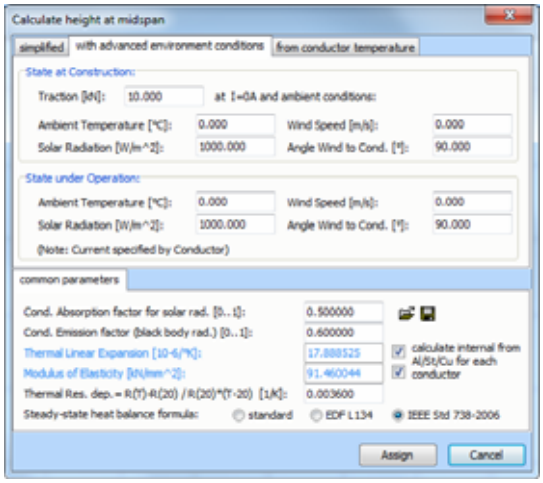


Fig. Calculate Height at Midspan

The **Height at Midspan** function calculates the state equation of highlighted conductors. The parameters are

> **pulling force of the conductor** [kN]
> at air **temperature** [C]
> and current = 0 A

from which the sag without load is determined. With the further details

> current **air temperature** [C] and
> current **wind speed** [m/s]

and the conductor current **EFC-400** calculates the absolute ground clearance in the middle of the span field. The previous value of the ground clearance is replaced irrevocably.

10. Representation of Data

EFC-400 offers different possibilities to represent the calculated data. The complete computation area will always be represented.

Note: To compare several computations it is possible to open another instance of EFC-400 on your PC. In anyway, during construction of a new geometry you should only work with one instance.

10.1 Selection of the Computation Data

The computation data are selected with the **B-Field**/ **E-Field** menu commands and the computation selection box (regarding RMS, Peak).
After a computation of the magnetic field in the **Small Memory Mode** the data records which are to be represented are selected by

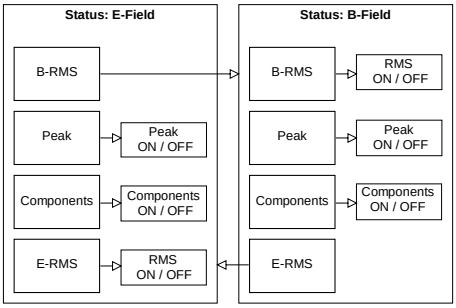


Fig. Small memory mode

Show RMS	-	B-RMS
Show Peak	-	Peak
Show Components	-	Components (Bx, By, Bz)

from the **View** menu. It is also possible to select no data record so that an empty diagram is displayed.
By selecting **E-Field, EFC-400** starts the computation of the electric field (if no data exist). After completion you can use the menu commands

E-Field	-	E-RMS
Show Peak	-	Peak
Show Components	-	Components (Ex, Ey, Ez)

to select a data record.

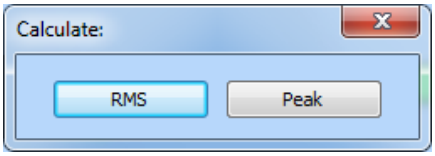


Fig. Computation selection box

If your computation area contains more than 15000 points, **EFC-400** switches into **Large Memory Mode** for reasons of memory optimization. The components of the field strengths are thus not available any more. Computation is carried out only for RMS or Peak data records. Therefore, a computation selection box appears after selecting **B-Field** or **E-Field** in which the desired data record can be chosen.
Renewed selection of a menu item does not cause any modification of the representation.

10.2 Construction Window

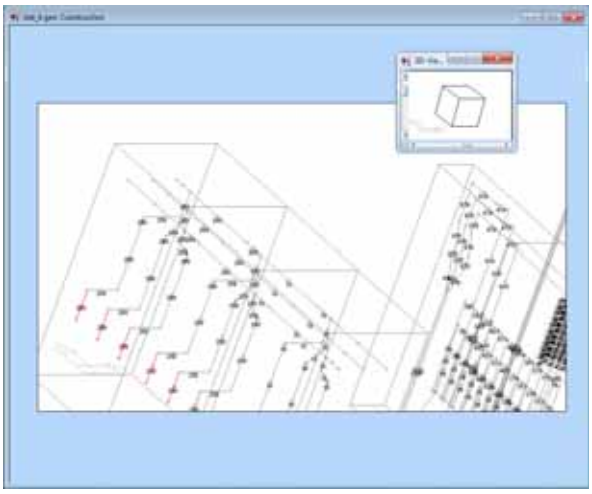


Fig. 3D-view of the construction

You can view the geometry from any arbitrary 3D viewpoint. Elect the command **3D-Viewpoint** from the main menu or the local menu. All construction functions, particularly Select-, Move-, Copy By Mouse e.g.. are fully functionable. By moving in the 3D space you can read the relative coordinates as usual. The moved objects always lie in the plane of the actual calculation area. For the construction of complex plants you can view those from every viewpoint and also work on them. The cube and the coordinate symbol always clarify the viewpoint.

The rotation is always local. When you zoom a certain region and rotate the viewpoint, the rotation is done around the zoomed geometry parts.

The following tools are helpful during construction:

Object Direction

With F3 the directions of transmitter and conductors is shown by small arrows.

Active Objects

The data of transmitter and conductors can be shown in the construction window (F4). In LF mode EFC-400 draws all active conductors in red while the passive ones remain in grey.

Colored Phases

The phases of objects can be colored in the construction window (F5). Indifferent objects (with phases different from 0, 120 or 240 degrees) are shown in grey.

Snap Grid

The **Snap Grid** gets activated by F9 - snap grid on/off. The snap grid is available in any 3D-viewpoint, but is only drawn in plane view.

10.3 X/Y-Representation

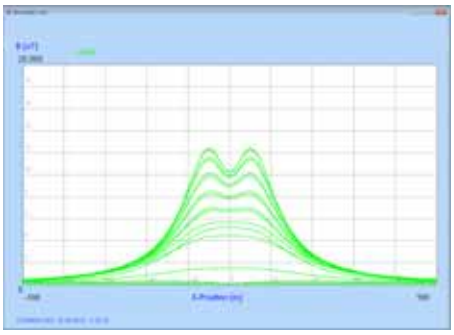


Fig. X-representation

The X-representation draws a projection of the computation data on the X-axis, the Y-representation on the Y-axis.
The computation of the 3TOWERS.GEO file is represented in the following figures in several ways.
If you have calculated data along a straight line, you will see a single profile. After computing an array, several superimposed profiles will appear.

In the graphics XYZ and Statistics any kind of computation area can be represented.

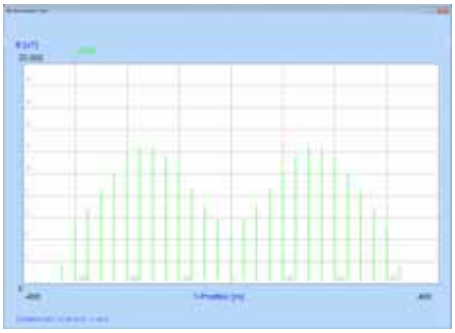


Fig. Y-representation

10.4 Z-Representation

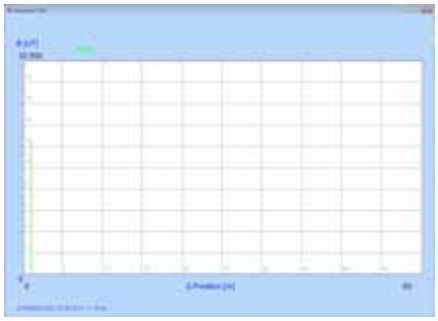


Fig. Z-representation

The Z-representation shows a projection of the computation data on the Z-axis. At first glance, this may seem unusual. Since the computation area normally lies at a constant altitude (e.g. 1 m), all data are superimposed on a line whose altitude corresponds to the maximum field strength.

EFC-400 allows calculation of slanting or vertical computation areas where the Z-representation sometimes is useful.

10.5 2D-Representation

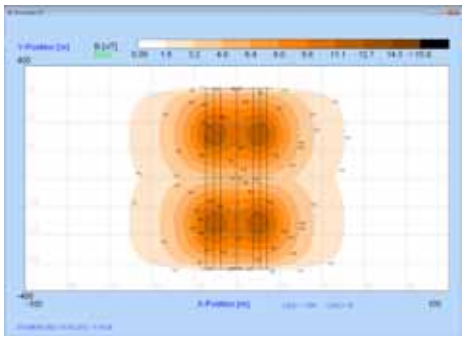


Fig. 2D-representation (horizontal)

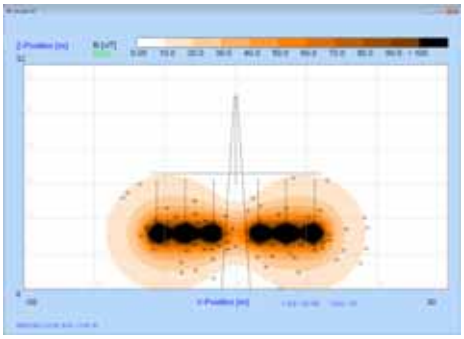


Fig. 2D-representation (vertical)

In the 2D-representation **EFC-400** shows a projection of the data records onto the XY-, XZ- or YZ-plane. In the XY-plane the viewpoint can be rotated.
The field strengths between two equipotential lines are filled out in one color. A 10-level color gradation will always be displayed which can be adjusted by the user. To do this, the **Colors** command from the **Options** menu must be executed. It is also possible to assign the same color to several levels.

The **Zoom** function is enabled in the 2D-representation mode, but it is only available if:

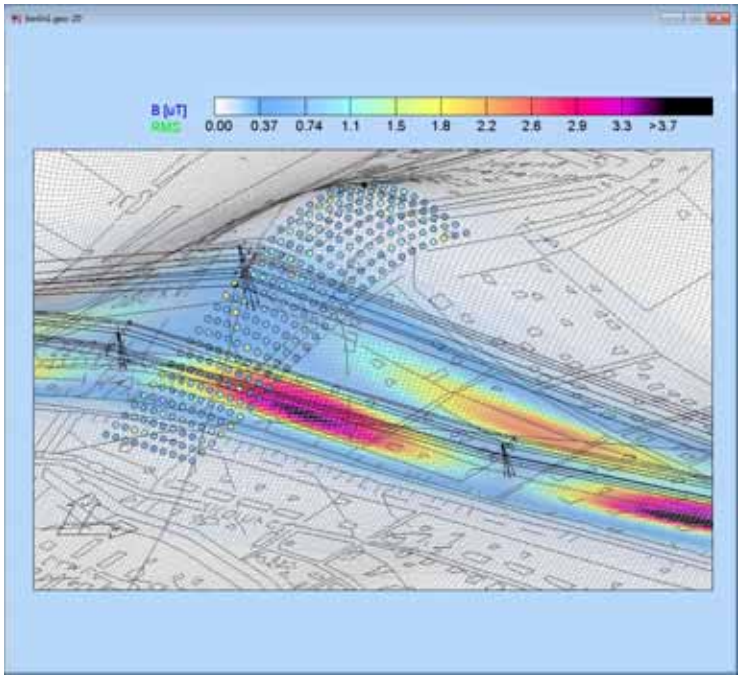
a computation area exists (more than a single row)

and the following conditions are fulfilled:

a) horizontal area (dz = 0, z_shift = 0) or a vertical plane parallel to the X-axis (dy = 0, y_shift = 0)

b) array is Cartesian (dy=0)

Rotation of the 3D-viewpoint is possible for the 2D view. Just select '3D-viewpoint' from the local menu and turn the appearing cube. You get a real 3D surface plot then. As shown in the picture the surface includes the ground profile (if switched on) with the topography on top.



Measurement data can be added to the calculation data or can be shown without calculation or even without any geometry. The width of the mesh is adjustable under the item screen of the advanced settings sub menu.

Frequently **EFC-400** has only a rough grid of computation points in the 2D-representation. Therefore, **EFC-400** interpolates intermediary points to cover the whole area. Depending on the amount of data, **EFC-400** uses one of several adapted graphic routines to ensure that large data sets are only displayed in screen resolution.
For quick representation it is possible to turn the graphic interpolation of and show the raw computation data via the option **Raw Data in 2D-View** from dialog **Advanced Settings | Screen**.

Optimization of the display build-up:

The display of the 2D-representation can be accelerated by setting the variable **two step paint=on**. After that the 2D-representation is roughly drawn by EFC-400 in the first step and the grid is refined in the second step to match the screen resolution. However, this method is chosen only, if the grid of the computation points is 4 times cruder than the screen resolution. This frequently happens when you zoom and leads to a considerable acceleration of the representation. The default setting is **ON**.

10.6 Isolines

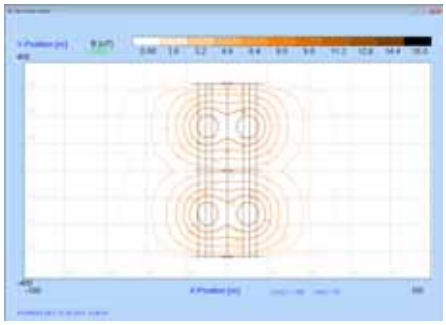


Fig. Isolines

The Isolines representation essentially corresponds to the 2D-representation. However, the ranges between the lines are not filled.

For color settings and prerequisites of the Isolines representation please consult the previous chapter.

Because of the extremely fast computation of the Isolines it is possible for a line to contain a color pixel from the adjacent color step. However, this concerns only the representation. If you export the data, this effect does not occur.

The zoom is also available in the Isolines representation in case the requirements described on the previous page are fulfilled. During Isolines export **EFC-400** turns the zoom off automatically.

10.7 3D-Representation

Fig. 3D Virtual Reality Interface

The 3D-representation displays the computation data in the **Virtual Reality Interface**, where you also can modify the geometry like in the construction window.

Note for old 3D-representation: If the option for drawing ground profiles in the **Cataster** dialog of the **Options** menu is switched on, the profile is drawn in gray. An altitude value referring to the Z-axis is displayed at the right hand side of the frame. Scaling is always carried out so that the altitude of the profile is 1/10 of the display screen axis.

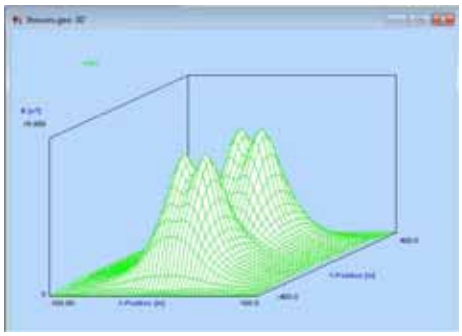


Fig. old 3D-representation (Hidden Lines)

10.8 Statistics

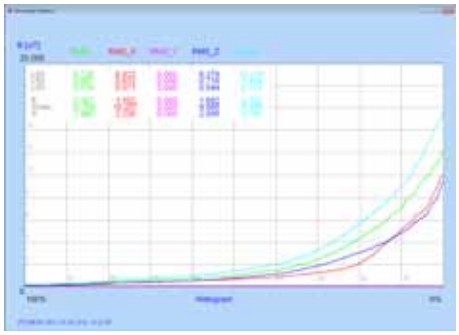


Fig. Statistics

All data are sorted and displayed by size in the statistics mode. For example, we can see which field strength is exceeded on 40% of an area.
Additionally, some useful details are shown, such as:

mean average value
maximum value
L50-Percentile
L05-Percentile
L95-Percentile
standard deviation

Note hat the statistical results are only exact if the program is in **Small Memory Mode**. Otherwise **EFC-400** only samples 15000 random points from the data record.

10.9 Assigning a Title

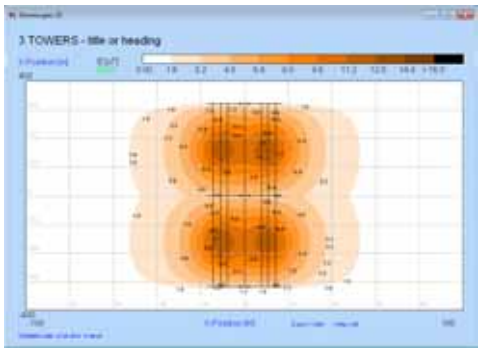


Fig. Representation with a heading

If the **Title** option in the **Standard** section from the **Options** dialog is activated, the title defined in the same dialog is displayed in the graphic window. The sub title can consist out of 240 character.

10.10 Scaling Data

Per default **EFC-400** scales the data records to the maximum. In the **Small Memory Mode** the maximum is taken from the **Peak**-data otherwise from the last computation.
This applies to all modes of representation with the exception of the XYZ-representation and the statistics.

If you want to scale the data to an arbitrary value (e.g. to a critical value), you can enter this value in the field **Max Data Scaling** of the **Extended** section from the **Options** dialog. This is particular useful if you want to create Isolines in predefined intervals.

If you have enabled the **Grid** option in the **Standard** section of **Options** dialog, **EFC-400** deposits the data with a fine scaling grid. For this grid, **EFC-400** chooses integer numbers, decades etc.

10.11 Options

You can control the representation of data with the following options:

Fig. Dialog **Standard**

Section **Standard**

Frame fine scaling grid (on/off)

3D Grid 3D-graphic as net (on) or only as lines

Hidden Lines hidden lines in 3D-graphic (on/off)

Objects drawing of objects (on/off)

Title title in the diagram (on/off)

Fig. Dialog **Extended**

Section **Extended**

Max Data Scaling Scaling to a predefined value or to the maximum value (AUTO)

Fig. Dialog **Cataster**

Section **Cataster**

View Ground Profiles Display of ground profiles

Proportional Frame View Same scaling-ratio in X- and Y-direction

10.12 Zoom

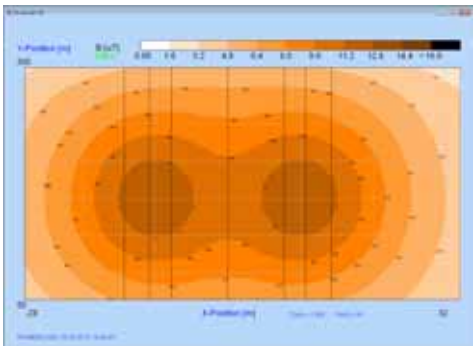


Fig. Zoom of a graphic

In the 2D-representation you can activate the zoom mode. By executing the **Zoom** command from the **Tools** menu you can select one of the following sub-menu items

All	restores the original screen size (no zoom)
Previous	restores the previous enlargement view
Window	a clipping rectangle can be drawn with the mouse which defines the new display area

to adjust the screen scale to your wishes.

When a certain part of the geometry is zoomed, it is possible to move the view to follow cables e.g. by pressing the cursor keys (->, <-, ...).

11. Saving Data

11.1 Geometry

Geometry data are stored in two ways. On one hand they can be saved with the **Save Geo as ...** item or with the **Save Geo** item from the **File** menu.
On the other hand, a geometry data file is created with the same name when storing the computation data.

Procedure when saving the geometry with the **Save Geo as...** menu item:

Open the **File** menu in the main window and select the **Save Geo as ...** menu item. Afterwards the **File Select Dialog** appears where you can enter the name of the geometry data file. In the **File Select Dialog** all files with the Extension GEO in the working directory are listed. You can store the current geometry under a new file name or overwrite an already existing geometry. To overwrite an older file, select the file name from the list and push the **OK** button. To create a file with a new name, enter the file name in the field with the name **Filename**. The Extension can be left out.

Save Project As

When working on complex projects, including maps, measurement data e.g., the complete project can be duplicated using the function **Save Project As**.

Delete Project

You enter the name and EEC-400 deletes all files belonging to the project.

11.2 Database

Saving the geometry data is also possible in XML format. See the **Database Interface** chapter.

11.3 Computation Data

Saving of computation data is possible in the **main window** with the menu items

Save Data as...	-	saving with a new file name
Save all Data	-	saving of B- and E-field data
Save Data	-	saving the current dataset

from the **File** menu.

The computation data are saved in binary file format with the extensions ***.E**, ***.B**, ***.EP** and ***.BP**.

Type	Large Memory Mode	Small Memory Mode
*.E	RMS-data E-field	complete E-field data
*.B	RMS-data B-field	complete B-field data
*.EP	Peak-data E-field	-
*.BP	Peak-data B-field	-

The corresponding geometry file is stored under the same name when saving the computation data. This is necessary because the computation data record contains no geometry information and the computation data cannot be displayed without the necessary geometry.

The connection between computation data and geometry data is ensured by assigning the same date to the corresponding files.

If a geometry file, to which computation data have already been appended, is stored under the same name, the computation results stored before lose their validity and cannot be loaded any more.

Note: If a geometry file is written over inadvertently before the necessary modifications have been carried out, the validity of the computation results can be restored with the special tool **SetTime.** Follow the instructions given by the program and set the date of the computation data file and the geometry file to the same value. After this operation the computation data are automatically loaded with the geometry again.
Additionally to the program **SetTime** (synchronization of two files), the tool **SetFTime** is delivered with **EFC-400**. **SetFTime** enables the setting of the file date of all files in a directory including all subdirectories.

With the **Save Data** menu item you can store the displayed data record (only one single data record is stored).

The data will be saved as *.B or *.E files, if **EFC-400** is in the Small Memory Mode. Files of the type *.B *.E, *.BP and *.EP are created in the **Large Memory Mode** depending on the calculated data records.

The **File Select Dialog** automatically sets the correct extension of the saved file. The user just has to enter the file name. No other extension will be accepted.

The **Save all Data** menu item saves all of the computation data, even if they are in the background. All E- and B-field data can be stored in one step in this way.

Compressed data format

EFC-400 offers the facility to store the computation data in a compressed file format. To do this you have to set the variable **compress mode = ON**. With **compress limit = x** you can set a value below which EFC-400 will reject computation data. For example, if you want to neglect all field strengths data below 0.1 µT (or 0.1 V/m), **compress limit** has to be set to 0.1. **EFC-400** compresses data only if a volume decrease of at least 50% is obtainable. **EFC-400** independently distinguishes between normal and compressed data records. If you frequently use large computation areas containing only a few transmission lines, the required volume can be reduced to 10% or less.

12. Printing Data

12.1 Graphics

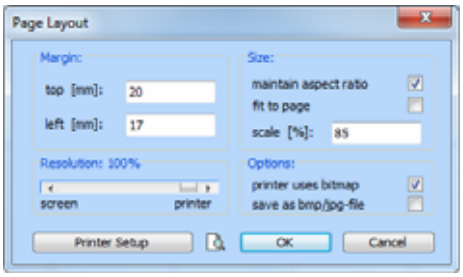


Fig. Printer Setup Dialog

The content of the active window is printed by the **Print** item from the **File** menu. Printing is carried out with the presently selected Windows™ printer driver, which can be set in the **Printer Setup...** dialog. The **Printer Setup...** item is available in the **File** menu.

Additionally the hardcopy function (<print>-key) can be used to create screen captures, which can be inserted in other documents (by using the clipboard).

The **Resolution** option of the **Printer Setup...** dialog determines whether the screen resolution (Screen) or the printer resolution (Printer) is used for printing.

Pen Size setting

This feature enables the setting of the pen width. The line widths refer both to the printouts and to the lines in the graphic windows. With the **PEN SIZE** command from the **OPTIONS** menu line widths can be adjusted:

0 - Shedding line
1 - 1 pixel
2 - etc.

During the installation of **EFC-400** in the standard configuration all pen widths are set to zero. This leads to good results on all display screens and most printers.
Depending on resolution (printer/screen) it may happen that lines are missing on B/W printers. On laser printers this problem can be solved by selecting the format **HPGL**.

13. Data Export

13.1 Overview

Data calculated by **EFC-400** can be exported as ASCII files for the purpose of further processing (e.g., creating presentations or statistical evaluations). Specific export formats are available for the programs MS-Excel™ and Stanford Graphics™. For processing of the computation data the Isolines graph can be saved in DXF file format (e.g. AutoCad™).

When using the **Export** item from the **File** menu, **EFC-400** exports the visible data. The following table shows the possible modes of exports depending on the representation mode.

		Representation			
		XYZ-axis	2D-view	3D-view	Isolines
Export type	ASCII Array (*.TXT)	x	x	x	
	Isolines (*.DXF)				x
	Hatch Pattern (*.DXF)				x
	2D-Solid (*.DXF)				x
	XYZ data (*.DXF)	x			
	4D-Color Array (*.TXT)			x	
	Vector Array (*.TXT)			xx	
	BMP / JPG / WMF	x	x	x	x
	Copy To Clipboard	x	x	x	x

x any setting of the **Options** parameters is possible

xx a requirement for vector export is the following setting in the **Technical** dialog in the **Options** menu:

Time-Dependent Field = On

Note: The fractional digits for the export can be adjusted.

13.2 ASCII Export (TXT)

The ASCII export is available for the representations of X, Y, Z, 2D and 3D by executing the **ASCII Array** command from the **Export** submenu. The file name can be entered in the **File Select Dialog.** (The Extension *.TXT is predefined).

The ASCII export saves the currently visible data of the views X, Y, Z, 2D and 3D. The data are stored in a tabular form, so that they can be imported by many programs (e.g. MS-Excel™, see appendix B: Data formats).

a) **X, Y, Z-representation:**

a table of two columns with coordinates and computation data

b) **2D-** and **3D-graph**:

an array of the computation data with
X, Y-coordinates

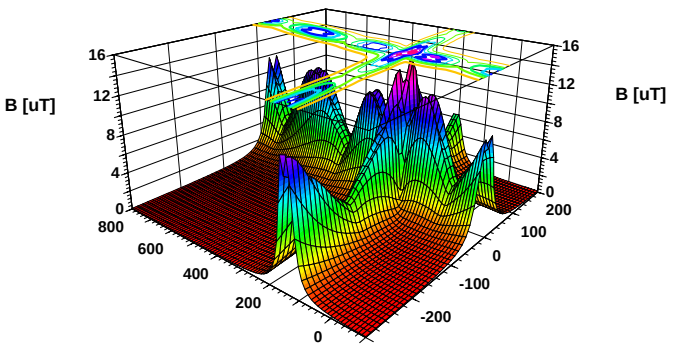


Fig. Stanford Graphics Surface-Plot

This figure was created with the software Stanford Graphics™ using the ASCII-export of the 3D-view. (geo file: 11TOWERS.GEO).

13.3 DXF Export

Isolines

The Isolines export is invoked with the **Isolines** item in the **Export** submenu. The **File Select Dialog** allows input of the file name. (The extension *.DXF is predefined).

EFC-400 redraws the Isolines graph subsequently and determines the coordinates of the individual Isoline-segments. **First Layer Number** is the number of the layer which contains the first Isoline step. It is defined in the **Cataster** dialog from the **Options** menu. The further Isolines are numbered serially (10 layers altogether). **EFC-400** sorts the Isoline segments to polylines and saves these with a resolution of 0.001 m on hard disk. This operation can take some time, especially for large computation areas. Please note that a sufficiently fine computation area grid has to be selected because resolution errors in the Isoline structure may occur otherwise.

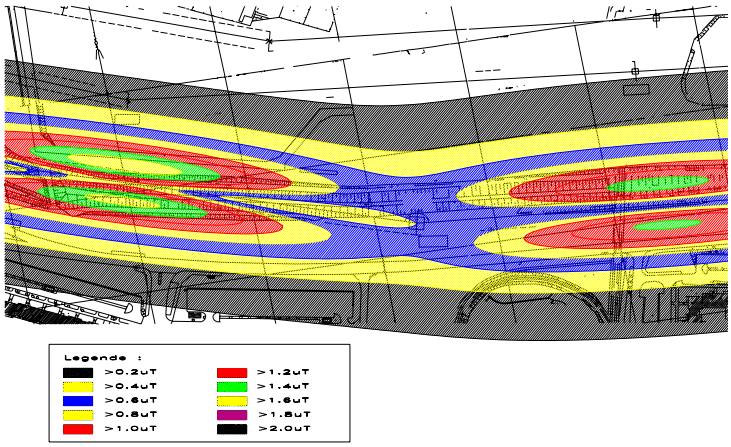


Fig. Transmission line section with Isolines in AutoCAD™

Note: Scaling of the Isolines is adjusted in the **Extended** dialog with the variable **Max Data Scaling**.

EFC-400 uses the default EFC-400.DXF file for exporting and inserting polylines in the DXF file format. EFC-400.DXF is an empty AutoCAD™ drawing, which contains already predefined layers (1-10). This guarantees that the Isolines imported into AutoCAD™ have predefined colors. If you need another color gradation, the layers can be changed afterwards.

It is also possible to replace the EFC-400.DXF file completely.

Note: The EFC-400.DXF file must be available for the export, otherwise errors may occur.

Note: In case of huge calculation areas the isoline export is slow because of sorting the segments to polylines. When polylines are not needed, choose the mode **Unsorted Isolines** (Options | Advanced Settings | Export) which is much quicker.

HATCH PATTERN

This function exports a horizontal hatch pattern which fills the areas within the Isolines. The separation of the lines corresponds to **dy** viz. **z-shift/y-shift**. The third coordinate of the hatching lies in the computation plane. Conductors, transmitter and towers are not exported even if they are visible. Please use the **Export Geometry** function for this purpose.

2D SOLID

This function exports the computation data as filled rectangular areas (SOLIDS). The resolution can be determined by the user, the raster of computation is predefined. If a higher resolution is set, **EFC-400** interpolates intermediate rectangles analogously to the 2D-plot. (objects are exported with **Export Geometry**)

Note: In the case of large data records and high resolutions the export file can become very large. If necessary, the smaller files of the DXF HATCH-PATTERN export function can be preferred.

Note: AutoCAD™ R12 fills SOLIDS only in the top view. In other views merely a clipping of the area appears.

XYZ data profile

This export facilitates the saving of cross-profiles including coordinate systems in the DXF file format. The data are written on the layer DATA.

3D - 2D DXF format

Data in the DXF-format are exported as 3D-objects by default: Transmission lines are built in the drawing (xy-) plane and Isolines lie in the computation plane. Therefore you will see only a color line after a computation of a horizontal section, provided that you do not exit the top view of your CAD application. Because some graphic programs do not offer a 3D-representation, you can switch the DXF-export with the variable

3d dxf export = on/off

to reduce the format to 2D. The export data will then be rotated by **EFC-400** and projected to the xy-plane (z=0). Additionally, the import of 2D-objects is substantially faster in many applications. Always use the 2D export if you only want to embed data in text files etc.. Use the 3D export if you want to work on or to represent the **EFC-400** objects in the three-dimensional view.

13.4 4D-Color-Array (TXT)

The 4D-Color-Array export is in agreement e.g. with the program Stanford Graphics and is invoked by the **4D-Color-Array** item from the **Export** submenu.
Subsequently the file name is requested in the **File Select Dialog.** (The extension *.TXT is predefined.)

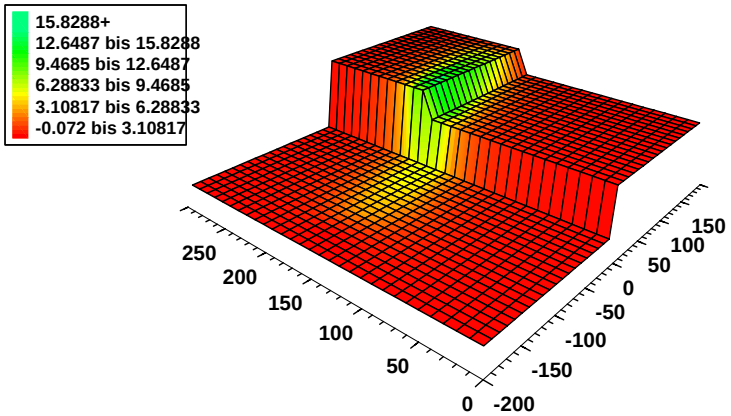


Fig. Surface with field strength data in color coding

In this example a span field on a simple ground profile is simulated. The represented surface corresponds to the grid of those points which have a constant ground clearance of 1 m. The magnetic induction is displayed on this surface as color information.

13.5 Vector Export (TXT)

The vector export can be started with the **Vector-Array** item from the **Export** submenu.
You can enter the file name in the **File Select Dialog.** The extension *.TXT is predefined.

The following setting is a prerequisite for the vector export in the **Technical** dialog of the **Options** menu:

Time-Dependent Field = On

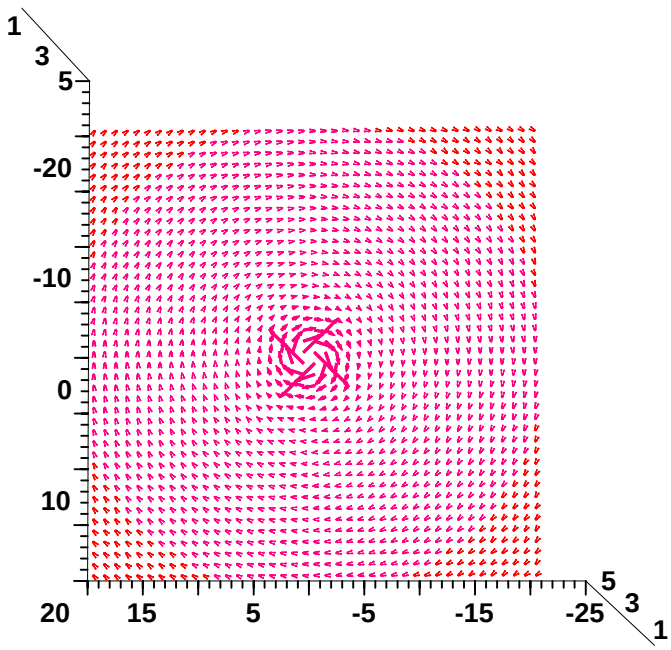


Fig. Vector plot

This figure was created with Stanford Graphics™ and represents the magnetic rotational field of a conductor perpendicular to the drawing plane. The raster of vectors corresponds to the computation area of **EFC-400**.

13.6 BMP Export

Every graphic window and the geo-window can be saved as a bitmap. The color depth of the bitmap depends on the settings of the graphic board, with the exception of the 64k-colors mode in which saving of bitmaps is not possible.

13.7 WMF Export

The **EFC-400** graphic and geo-windows can be saved as Windows Metafile (WMF). Analogously with the command above the currently activated window is saved.

Note: Do not use the WMF format for the 2D-view because the file may become very large. It is a better idea to save the 2D-view as bitmap.

13.8 Copy to Clipboard

The **EFC-400** graphic windows can be copied as a bitmap into the clipboard at any time.
The **Copy to Clipboard** command is available in the **Export** submenu and in the pop-up menu (right mouse button on graphic windows). The shortcut is: <Ctrl+Ins> or <Ctrl+C>.

14. Tower and Cable Library

14.1 Editing the Library

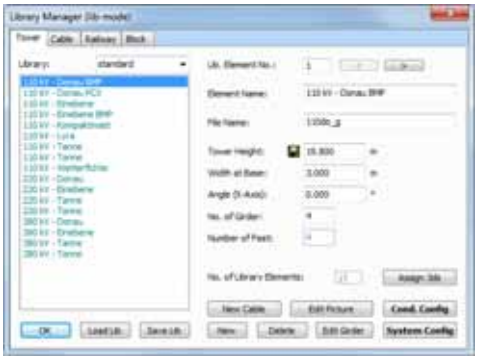


Fig. Library Manager

Libraries are managed by the **Library Manager**, which is invoked by executing the **Library** command from the **Object** menu.
It is necessary to open a geometry before you can open the **Library Manager.**

The following functions are available in the **Library Manager:**

<**PgUp**>, <**PgDn**>, **"<"**-button, **">"**-button	-	changes between the elements of a library
OK button	-	exits the Library Manager
Load Lib button	-	opens a library
Save Lib button	-	saves alterations of a library viz. saves a library with a new name
New button	-	creates a new element
Delete button	-	removes types from library
Edit Girder button	-	working at girders
<**TAB**>	-	changes between entry fields

Procedure for editing a library element:

Initially the focus is on the list of the library objects in the **Library Manager**.

You can change between the individual types with the **><**-buttons and the <PgDn> <PgUp>-keys.
If you want to select a certain element from the list, you can identify it by its name or its **Library Element No.**

Delete removes the currently selected library element.

With the **New** function a new type can be inserted. (see the **Adding own types** chapter).

title bar	
library	tower selection
list of library-towers	parameter-editor
buttonbar	

Fig. Library Manager Scheme

If you have modified a library without saving, the modifications are only valid during the current working session (see section **Saving Library**).

Editing of parameters:

If the desired type is selected, you can enter the parameters with the integrated parameter-editor. With the cursor keys you can change between the parameters.
The only restriction compared to the **Tower Manager** is that the position parameters **Coordinate X, Y** and **Z** cannot be entered (predefined to (0,0,0)).

The parameters to enter are:

Element Name	-	name of element
Tower Height	-	tower altitude
Width at Base	-	width of the base area
Angle (X-axis)	-	angle to X-axis
No. of Girder	-	number of girders (max. 12)
Number of Feet	-	number of the tower feet (default = 4)
Filename	-	name of the *.PCX, *.GEO and *.TOW file

A more detailed description of the parameters is given in **Tower** section of the **Data Input** chapter.

The access to the integrated conductors of the library towers is possible with the buttons **System Config** and **Conductor Config**.

Fig. System Configuration

System Configuration

The important functions are:

New/Delete	-	adds or removes tower systems
No. of Subropes	-	input of the number of subropes
No. of Ground wires	-	input of the number of ground wires

If a new tower is created, the following points should be kept in mind:

The sum of conductors and ground wires is at most 26 for a tower (8 systems and 2 ground wires).

The number of the ground wires is entered in the editing field **No. of Ground wires**. To add ground wires, you only have to increase this parameter. Decreasing of this parameter deletes ground wires.

The conductors of new systems (or new ground wires) lie at the base of the tower immediately after their production. It is necessary to adjust their positions manually.

A conductor can be specified via the ratio of cross-sections Al/St or via the input of the radius (the radius has priority).

With activated option <sym.> all 3 conductors of the system have same voltage and current, otherwise the values for each conductor can be different.

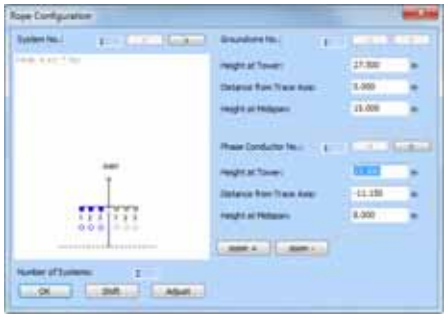


Fig. Conductor Configuration

Conductor Configuration

The **Conductor Configuration** in the **Library Manager** is identical to the **Conductor Configuration** of the **Tower Manager** except for the missing **Adjust** button. The difference is caused by the fact that the **Library Manager** is used to configure library towers, while the **Tower Manager** handles towers of the geometry.

14.2 Load / Save

Load:

A library which is loaded in the **Library Manager** is available in the **Tower Manager** (e.g. **Cable** or **Railway Manager**). If you want to insert objects into the geometry which are not contained in the current library, you can open a new library with the **Library Manager**.
Instead of replacing the old library with the new one you can also **ADD** a library from another path to the existing one.
For a quick change of libraries there is a **Change Lib** button inside the object managers.

To open a library, proceed as follows:

Change to the **Library Manager** and press the **Load Lib** button. You will see a dialog which shows a list of the presently available libraries. Select one of the libraries and push the **OK** button or interrupt the loading process with the **Cancel** button. After finishing the loading process you can edit the loaded library or change to the **Tower Manager** with **OK**.

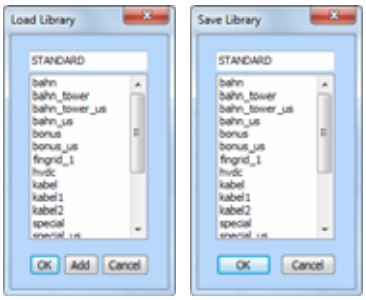


Fig. Load and Save Dialog

Save:

If you have modified a tower library and want to save it with a new name, you can use the **Save Lib** button.

A dialog which displays the available libraries will appear at the call of the **Save Lib** function. Select a library name to overwrite an existing library or enter a new name (confirm with **OK**).

Note: Creating a library is a complex operation which is provided by the **Save Lib** function. A directory with the same name as the library is created. A library is deleted by removing the corresponding directory with a conventional file manager.

14.3 Adding your own Types

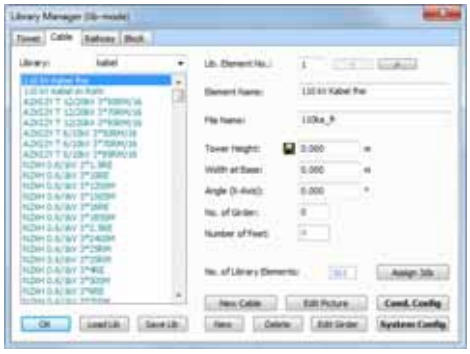


Fig. Library Manager

You can include new types in the library with the **Library Manager**.

A library can contain a maximum of 500 objects. If there are less than 500 objects available in the library, the **New** button can be used for creating new towers (e.g. the **New Cable** button to create a new cable).

Creation of a type variant:

If you want to create a variant of a type already contained in the library, change to the existing type with <PgUp>, <PgDn>, the arc buttons, or the mouse. Then execute the **New** function. A duplicate of the current type is created.

The duplicate contains the object parameters of its predecessor.

Note: The parameter file name is set to TOWERXXX per default where XXX is a number corresponding to the position of the new type in the list of available objects (1..500).

If the library is saved with the **Save Lib** function, a type geometry file (*.TOW), a geometry file with conductors and a PCX-bitmap or BMP-file are created. The new files have the name which is displayed in the parameter editor. You should enter a meaningful name for the parameter **filename** to be able to easily assign the files later.

title bar	
library	tower selection
list of library towers	parameter-editor
button bar	

Fig. Library Manager Scheme

The Fig. Library Structure shows the directories in which the type files are stored.

After the new type is created, you can modify its parameters with the parameter editor. The focus is on the field for the element name input. Please enter the name the type shall have in the library.

The input operation is explained in detail in the **Tower** section of the **Editing a Geometry** chapter.

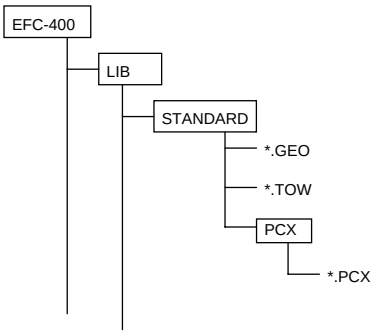


Fig. Library Structure

Creating of a new type:

If you want to create a type of which no variant and no figure exists in the library, you should proceed first in the same way like creating a variant. Save the library with the **Save Lib** function. To assign a new figure to the new type, it is necessary to understand the principle according to which **EFC-400** archives libraries:

For each library, a directory is created which has the same name as the library itself. This directory contains the files *.**TOW** and ***.GEO.** The type bitmaps are stored in a sub directory of the library with the name **PCX** or **BMP** (see Fig. Library Structure).
If you want to insert your own bitmap into the library, double click on the actual picture or push the **Edit Picture** button. The **WF-Paint** tool (or your own tool specified under **advanced settings | tools**) opens, to allow you modifying or replacing the picture by a new one. If there was not picture you get an empty bitmap.

Creating a new bitmap:

If you have a picture of the desired object, you can digitize it with a scanner. In case the type is available in a CAD program, export it as bitmap. Convert the image file to the BMP-format and adjust the size of the file to 320x340 pixel.
After you have prepared the BMP file, copy it to WF-Paint and replace the old image file with the new one.

Creating of a new cable type:

A new cable is generated by the command **New Cable**. The appearing dialog is the same as **Construct Cable**. It allows to specify the conductor section from which EFC-400 calculates the conductor distance.
If the option **No Ground Wires** is enabled only conductors are created. The number of conductors is then always restricted to an multiple of 3.
Cable can be created with phase **Compensation** (see corresponding check box). Otherwise the cable represents the worst-case.

15. Configuration

15.1 Load / Save

EFC-400 saves the configuration set by the user in the EFC-400.CFG file when exiting the program. This guarantees that you can continue your work with the same configuration at restart.

If you want to save the present configuration under a new name, you have to choose the **Save Config...** item from the **Options** menu. The **File Select Dialog** will ask you to input the file name. By confirming with the **OK** button, the configuration is stored and can be loaded at any time.

To load a configuration the **Load Config** command from the **Options** menu must be selected. The appearing **File Select Dialog** lists all existing configuration files. The new configuration is loaded by selecting it with the mouse and confirming with the **OK** button.

Configuration files are ASCII files on which you can work with an ordinary text editor. Take care, however, not to change the structure (do not insert empty lines).

Note: Should you have deleted the EFC-400.CFG file by mistake, the configuration file is created automatically with the standard values the next time you start the program.

15.2 Automatic Configuration

By activating the **Automatic Configuration** item from the **Options** menu you define that the configuration is stored and opened simultaneously with the geometry data file.

In this way, you can use a configuration which is customized for the specific geometry:

a) when storing the geometry, a CFG-file with the same name is created.

b) when opening a geometry, the corresponding configuration is opened automatically.

Note that all parameters except **Automatic Configuration** are set when loading a configuration automatically.

Automatic Configuration has a special function within the batch mode. With the configuration file the calculation settings belonging to the geometry are set automatically. In this way it is ensured that during the consecutive computation in the batch mode, the right configuration is always loaded.

15.3 Templates

When creating a new geometry you can select a predefined **Template**. Templates are available for power transmission lines, cable, power or terminal stations. All basic settings are already given for that specific case. To avoid the template question while creating new geometries, disable **Options | desktop | template on new**.
The function **New Project** always calls the template dialog and opens the Project-Info.

Saving your own templates

In addition you can save your own templates containing your actual settings. Therefore execute **Options | save template** and your settings get saved. Templates can be found in the sub directory template.

15.4 Color Settings

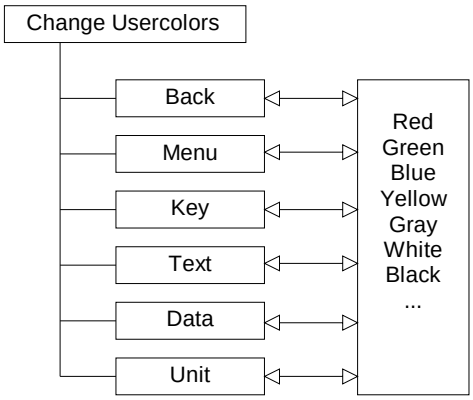


Fig. Change User Colors

You can specify the user interface of **EFC-400** according to your needs and choose the color gradation of the 2D-representation with the color settings.

To carry out a color modification choose the **Colors ...** item in the **Options** menu.

To change the background color, for example, select the color option **Back** with the mouse and change the color by using a color box or adjusting the RGB-values.

Color option	Hotkey	Meaning:
Back	B	background
Map	M	map color
Hotkey	H	hotkey color
Text	T	text color
Data	D	data
Unit	U	units of diagrams

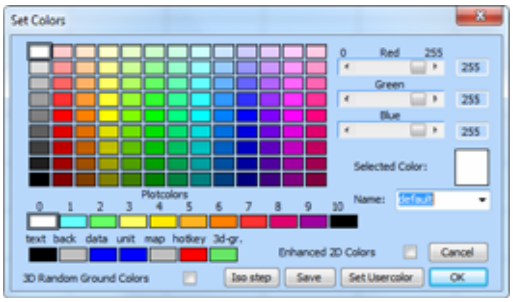


Fig. Color Dialog

The procedures for the other color settings are the same. You can leave the dialog with the **OK** button.

Note: If you have set the text color to the background color, the text is not visible anymore. Restoring the old settings is difficult now. You can solve this problem by leaving **EFC-400** and deleting EFC-400.CFG.

The color boxes labeled with the numbers 0 to 10 are used to adjust the user-defined printing colors of the 2D and Isoline representation (see Fig. Color Dialog).
The ranges marked with the numbers 0-10 correspond to the 11 scaling ranges.

Color setting of background images

If a color image is loaded in 256-color mode, **EFC-400** tries to adapt the color palette to its own palette. Because the palette used by EFC-400 has priority for the representation of the Isolines, color purity errors may occur. The quality of the adjustment on the system palette depends on the setting of the variable **Adjust to Palette** = on/off. Note that a higher quality setting causes a longer screen build-up time. The best results can be achieved in 64k- or true color mode.

Update of background colors

If **EFC-400** runs in 256-color mode the change to another Windows™ application (also using a 256-color palette) leads to a change of the current palette. This has the consequence that the 2D- and Isolines-plots are temporarily represented with wrong colors. If **EFC-400** is activated again, it immediately restores the original colors (without redrawing). If you also want **EFC-400** to adjust the color palette for the background, the setting

Update Palette = ON

has to be entered (only necessary in the 256-color mode). The colors can still differ slightly from the original foreground colors with this setting, but the agreement is better. A disadvantage is that the 2D-, Isolines and Construction views are redrawn (if open) when activating **EFC-400**.

15.5 Fonts

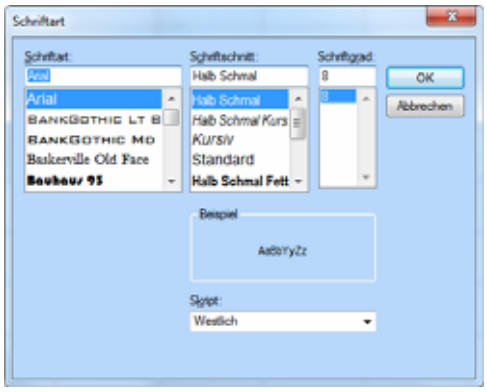


Fig. Dialog Fonts

Fonts can be chosen freely for geo- and graphic windows. The size of the fonts cannot be altered. By executing the **Fonts** command from the **Options** menu the selection dialog is activated (see Fig. Dialog Fonts).
To display the other windows, **EFC-400** uses the font Arial. If you have removed this font from your Windows™ environment, you have to install it again.

16. Options

16.1 Standard

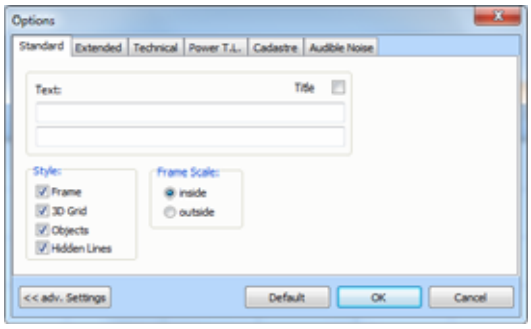


Fig. Standard Dialog

The standard dialog offers basic options for the control of the graphic windows:

Frame	fine scaling grid (on/off)
3D Grid	3D grid (on/off)
Objects	display of objects (on/off)
Hidden Lines	3D-view with hidden-lines (on/off)
Title	title text (on/off)

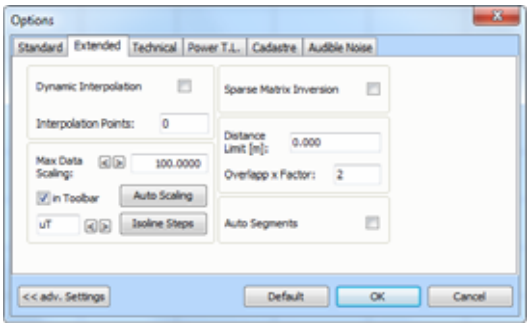


Fig. Extended Dialog

16.2 Extended

The **Extended** section provides functions for increasing the computation performance:

Interpolation Points	number of interpolation points
Dynamic Interpolation	dynamic interpolation algorithm
Auto Segments	auto segmentation for E-field calculations
Sparse Matrix Inversion	inversion of a sparse matrix
Distance Limit	distance limit for interaction
Overlap x Factor	local safety factor for distance limit 2 to 10
Max Data Scaling/ Auto Scaling	user defined scaling and user units

Note: If **Auto Scaling** is deactivated, a declaration of the unit can be carried out. The units apply to the representation and the export of computation data. The units are saved together with the geometry so that they are preserved for the renewed loading.

16.3 Technical

The **Technical** section provides functions for applications in technical/scientific subject areas.

Fig. Technical Dialog

The **Technical** offers the following features:

Voltage Type	phase or system voltage
Time-Dependent Field	instantaneous values of the field strength
Momentary Phase Angle	phase angle of the calculation if time-dependent field is activated
Crossection AL/ST	alternative input of the cross-section ratio or the radius of the conductor
Conductive Ground	conductive ground (on/off)
Fixed frequency .../ Free frequency	choice of fixed frequencies: 0, 16 2/3, 50, 60, 300 400 Hz for all conductors or free, individual frequency for every conductor

16.4 Power Transmission Lines

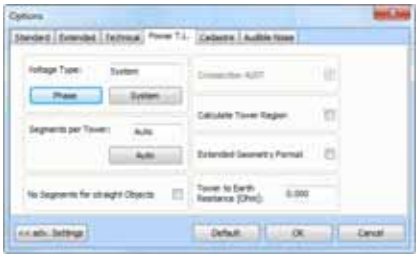


Fig. Power Transmission Lines Dialog

The **Power Transmission Lines** section offers functions for the easy handling of high-voltage lines.

Voltage Type	phase- or system voltage
Segments per Towers	automatic or fixed segmentation of towers
Crossection AL/ST	alternative input of the cross-section ratio or the radius of the conductors
Calculate Tower Region	calculate area below the tower (on/off)
Extended Geometry Format	choice between **Conductor** or **Line Editor** (only LF)
Tower to Earth Resistance	transition resistance between towers and ground
No segment for straight Objects	prevents the segmentation of straight conductors during calculation of E field and dB(A) for acceleration

16.5 Cataster

The **Cataster** section supports export of Isolines as well as options for the processing of ground profiles.

- Import of ground profiles

Geometry data and ground profiles can be combined with absolute or relative coordinates.

- Import of DXF files

Import of topographical background maps in the DXF file format.

- Isolines

EFC-400 calculates Isolines and connects them with drawings in the DXF file format. The Isolines are combined to polylines in a layer to simplify post-processing.

Fig. Cataster Dialog

The **Cataster** dialog provides the options:

First Layer Number	input of the first layer for the export of Isolines
Geometry Coordinates absolute/relative to Ground Coordinates	sets the geometry coordinates relative to ground altitudes
Emission Frame	definition of the computation area as a Cartesian raster
Proportional Frame View	display of the computation area with equal X/Y scale
View Ground Profiles	representation of the ground profile (on/off)

16.6 Audible Noise

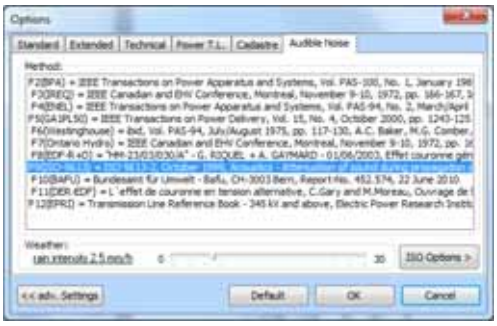
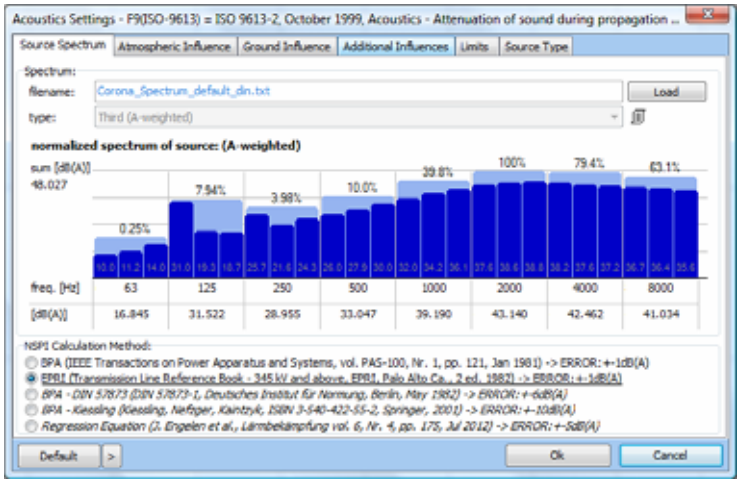


Fig. Audible Noise Dialog

The **Audible Noise** section allows selection of a method for calculating audible emissions from transmission lines and terminal stations. The methods are referenced and can be read out of the literature.

Also it is possible to define the weather conditions.

Using the button 'ISO Options >' you can open a dialog for configuration of detailed acoustical settings.



16.7 Colors

The **Colors** section provides a range of functions for the presentation of results and background maps.

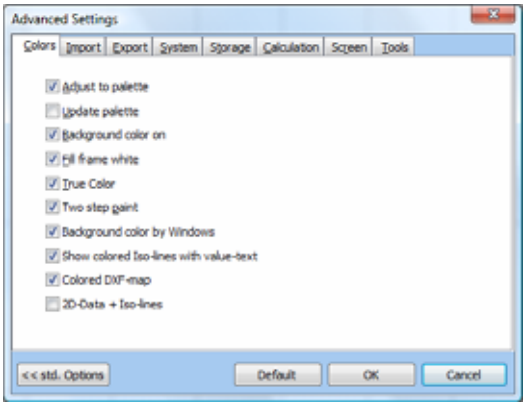


Fig. Colors Dialog

Adjust to palette -
With 256 system colors, colors are adjusted to the palette (default=ON)

Update palette -
When it comes to changes of the palette under 256 system colors, there will be a new drawing (default=ON)

Background color on -
The background color of the windows can be adjusted manually (default=ON)

Fill frame white -
The data area is colored in white (default=ON)

True Color -
Switches on unlimited system color steps (default=ON)

Two step paint -
Accelerates the drawing of figures by using two steps

Background color by Windows -
Adjusts the background color of the construction- and 2D-window to the Windows background color

Show colored Iso-lines with value-text -
Adds the corresponding values to the 2D- and Iso-view

Colored DXF-map -
Imported DXF background maps are displayed in colors instead of grey

2D-Data + Isolines -
Draws a grey separation line between the 2D color steps

16.8 Import

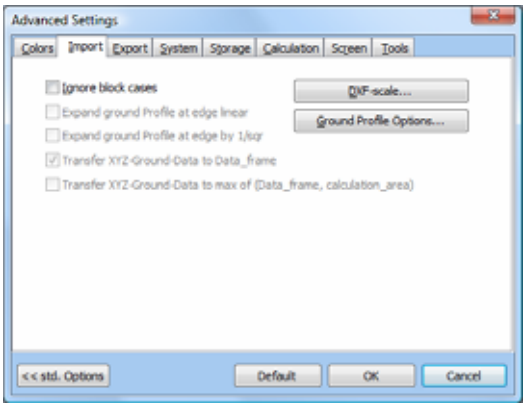


Fig. Import Dialog

The **Import** section provides settings regarding the import of geometries and ground profiles.

Ignore block cases -
During the import of blocks, cases and buildings are ignored (default=OFF)

DXF-scale -
Setting of the size of a drawing unit (i.e. scale) of dxf-maps to adjust the size (default=1:1)

Ground Profile Options -
Options regarding the import and representation of ground profiles

The lines represented in grey only serve to display information and cannot be used. The settings can be changed by using the corresponding options in the **Ground Profile Options** dialog.

16.9 Export

The **Export** section offers various options regarding the export of data in different file formats.

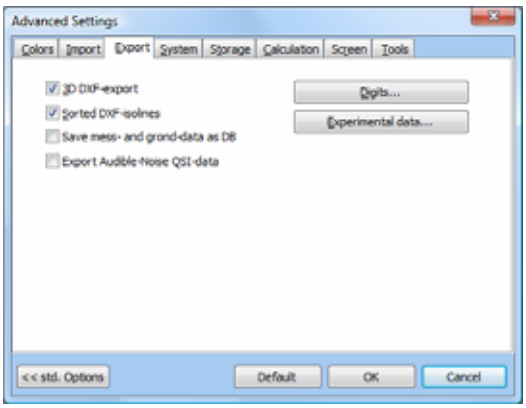


Fig. Export Dialog

3D DXF - Export -
Export DXF data as 2D or 3D (default=ON)

Sorted DXF-Isolines -
'Sort Isolines' sets the order in which lines are drawn in other programs (default=ON)

Save measurement- and ground-data as DB -
Confirmation if data should be saved or not (default=OFF)

Export Audible-Noise QSI-data -
Opening the QSI data export interface after the computation of noise levels

Digits -
Number of decimals that are used for the export to dxf, txt and ASCII format

Experimental data -
Settings regarding the presentation of experimental data in EFC-400 and for the export

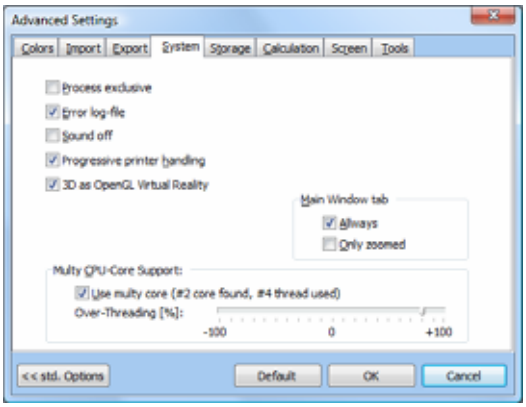


Fig. System Dialog

16.10 System

The **System** section offers options to vary system parameters influencing the computation and the use of hardware.

Process exclusive -
Doesn't unlock any system times for other programs (default=OFF)

Error log-file -
Creates an error protocol in form of an error.log file in the work directory

Sound off -
Deactivate system internal warning tones

Progressive printer handling -
Printing has highest priority (default=ON)

3D as OpenGL Virtual Reality -
The geometry is represented in a virtual Reality in the 3D window. As an alternative the results are presented as a three-dimensional diagram after the calculation.

Main Window tab -
Defines when the register, which shows which windows are opened in the program, can be seen

Multy CPU-Core Support -
Activates or deactivates the use of multy core processors. The number of calculation processes can be determined as well.

16.11 Storage

The **Storage** section offers functions concerning the saving of data.

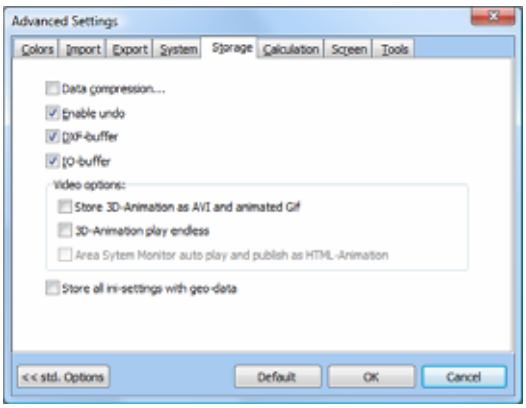


Fig. Storage Dialog

Data compression -
Calculation data are compressed (default=OFF)

Enable undo -
Defines whether executed construction steps can be undone or not

DXF-buffer -
Acceleration by buffering dxf-drawings (default=ON)

IO-buffer -
Acceleration by buffering data (default=ON)

Store 3D-Animation as AVI and animated Gif -
Stores an AVI or Animated Gif file automatically when the video is played in the 3D-window

3D-Animation play endless -
Animations are repeated in the 3D-window until the animation is stopped

Store all ini-settings with geo-data -
An ini-file is stored with all settings in the same directory as the geo-file

16.12 Calculation

In the **Calculation** section different parameters that effect the calculation method can be varied.

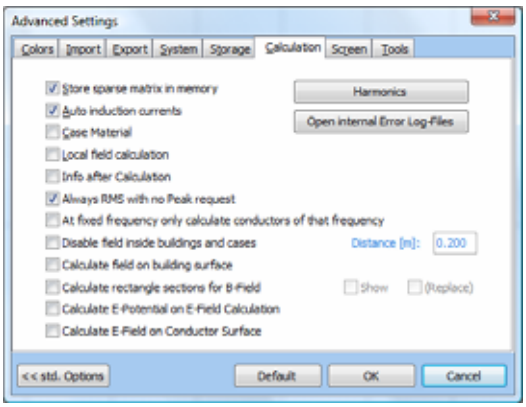


Fig. Calculation Dialog

Store sparse matrix in memory -
The matrix is processed in the memory instead of being sourced out to the hard drive in order to save time.

Auto induction currents -
Calculation of induction currents regarding every conductor

Case Material -
Calculate induction currents for cases with material strength

Local field calculation -
If possible, the field is recalculated locally only

Info after calculation -
Displays a window which contains information such as the duration of calculation after the computation

Always RMS with no Peak request -
The RMS value is always calculated, without showing a query before every calculation.

At fixed frequency only calculate conductors of that frequency -
The calculation only takes into account the conductors that have the frequency provided in the standard options

Disable field inside buildings and cases -
The magnetic field within buildings and in the defined area around buildings is not shown

Calculate field on building surface -
Calculation area is fitted to building contours instead of intersecting the buildings

Calculate rectangular sections for B-Field -
If conductors have a rectangular instead of round cross-sections, it's taken into account at the B field calculation

Calculate E-Potential on E-Field Calculation -
Shows the potential instead of the E field

Calculate E-Field on Conductor Surface -
Calculates the surface field strengths in addition. The results can be found in the file noise.log in the work directory.

Harmonics -
Opens the dialog in which calculation settings can be carried out to the harmonic contents

Open internal Error Log-Files -
Shows the log-files from the work directory

16.13 Screen

With the help of the **Screen** section the representation of the construction and data window can be adjusted.

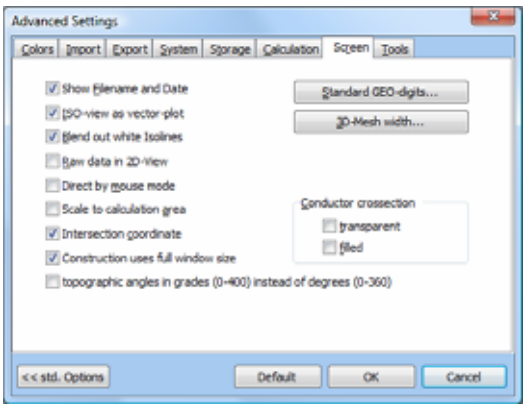


Fig. Screen Dialog

Show Filename and Date -
Displays for the current file name, the date and time in the construction window and in the result presentation

ISO-view as vector-plot -
Draws isolines as vectors instead of pixels

Blend out white Isolines -
Hides isolines/areas whose color is white in the color scale in the result representation out. This should be activated if a background map is loaded.

Raw data in 2D-View -
Fast and direct result information displayed for the calculated grid points without connecting these linearly

Direct by mouse mode -
Only allows the input of objects via mouse and not via coordinates

Scale to calculation area -
Opens the construction, Iso- and 2D-window with the size of the calculation area if the option ‘Standard Desktop’ is turned off

Intersection coordinate -
In the 2D and isolines window the intersection coordinate and the applied frequency mode is displayed in the lower part

Construction uses full window size -
Removes the margin of the construction window so that a larger part of the geometry can be edited

Topographic angles in grades (0-400) instead of degrees (0-360) -
Activating angle input of 0-360 or 0-400 degrees

Conductor cross-section -
Defines whether the cross-cut of conductors shall be represented, transparent or filled

Standard GEO-digits -
Determines the number of decimals of data in the geometry window

3D mesh width -
Determines the grid of the rotated 2D view

16.14 Tools

The **Tools** sections provides functions to manage the options for additional tools.

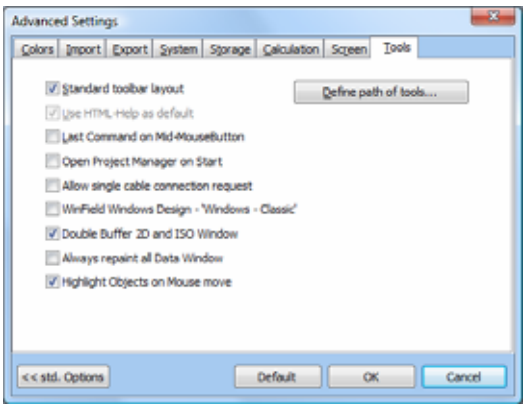


Fig. Tools Dialog

Standard toolbar layout -
Standard is horizontal (default=ON)

Use HTML-Help as default -
Uses the Windows standard help (default=ON)

Last command on Mid-Mouse-Button -
Repeats the command which was executed before at click on the middle mouse button (or the mouse wheel)

Open Project Manager on Start -
The Project manager opens at program start

Allow single cable connection request -
Cables don't connect entirely but separately (default=OFF)

WinField Windows Design - ' Windows - Classic' -
Switches Windows 2000 design on (default=OFF)

Double Buffer 2D and ISO Window -
The 2D- and the Isolines-window are buffered twice which increases the drawing speed

Always repaint all Data Window -
Redraws all data windows (2D-window, statistic window, etc.) when one of the windows is updated

Highlight Objects on Mouse move -
Highlights objects out if the mouse pointer points at them

17. Case Studies

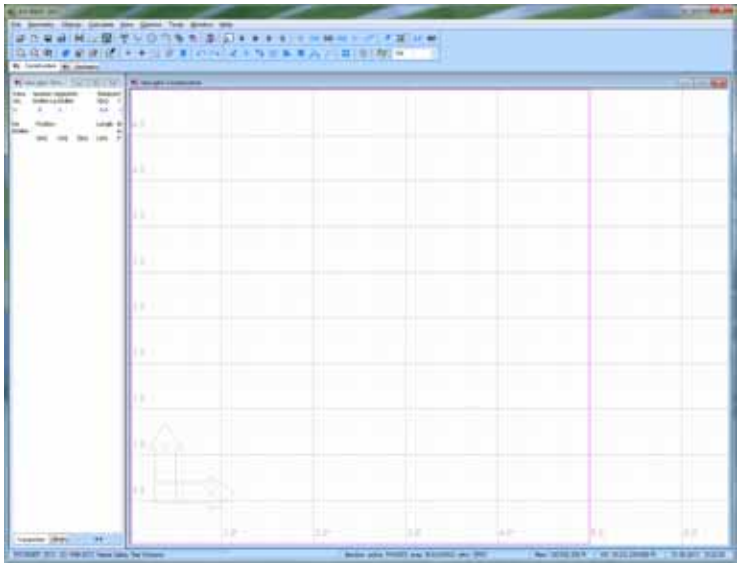
17.1 Transmitter

This section explains a computation of transmitter with different beam characteristics.

Step 1:

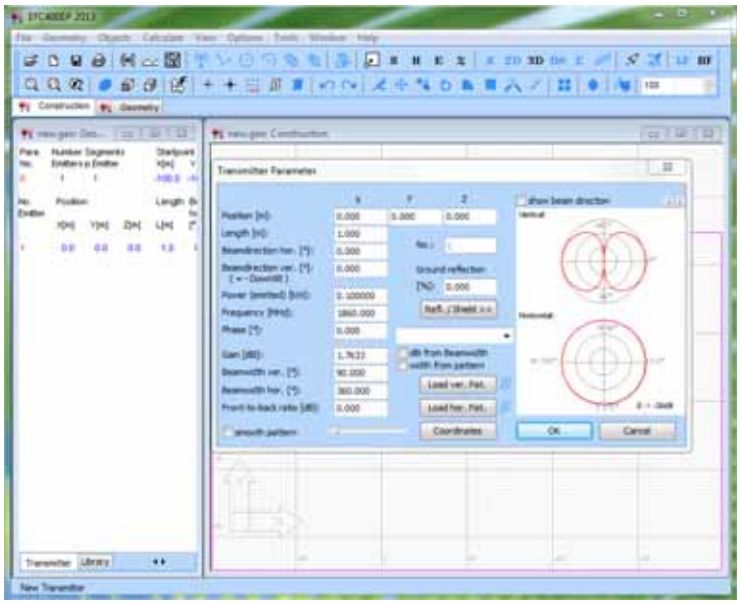
Execute the command **NEW** and select the template "**Transmitter**". The template "**Transmitter**" already contains the most important settings.

The empty **Construction Window** appears on the screen with activated snap grid (see status line: commands **F3**-**F9**). The **Geometry Window** doesn't contain any transmitter entry yet:



Step 2:

Click on the button to exclusively execute actions by mouse i.e. without coordinate query. By click on the button construct a new transmitter (see status line), whose characteristics you can enter in the seeming dialog:

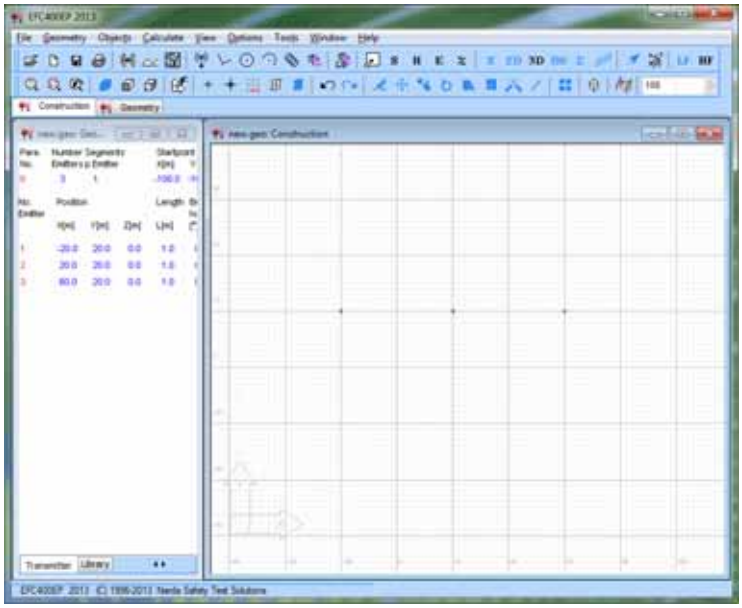


Confirm the dialog with **OK** and pull the mouse to the desired location in the **Construction Window**. Click with the left mouse button to drop the transmitter (right button means abort).

Step 3:

After already two other transmitters have been constructed these appear in the **Construction Window** like represented below. For the second and third transmitter a **horizontal beam width** of 60 degrees was entered. For the third transmitter enter a **front-to-back ratio** of 20 dB and a **horizontal beam direction** of 30 degrees.

At any time you can edit the properties of the transmitters afterwards by a click with the right mouse button on these. Alternatively the possibility exists to mark one or several transmitters (left mouse button or pulling up of a frame) and to execute the command **Edit** from the **Context menu** (right mouse button on the free area) or to click on the button.

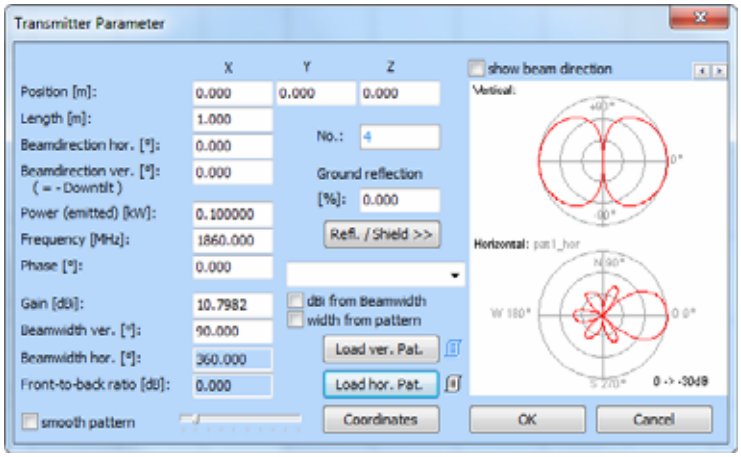


Note: If you want to **Move** or **Copy** objects you must mark these before you can execute the corresponding command. During moving, the mouse button isn't held pushed down. Instead an arbitrary start-point (1st click) and end-point (2nd click) of the movement is set. The operation is similar to AutoCad.

Step 4:

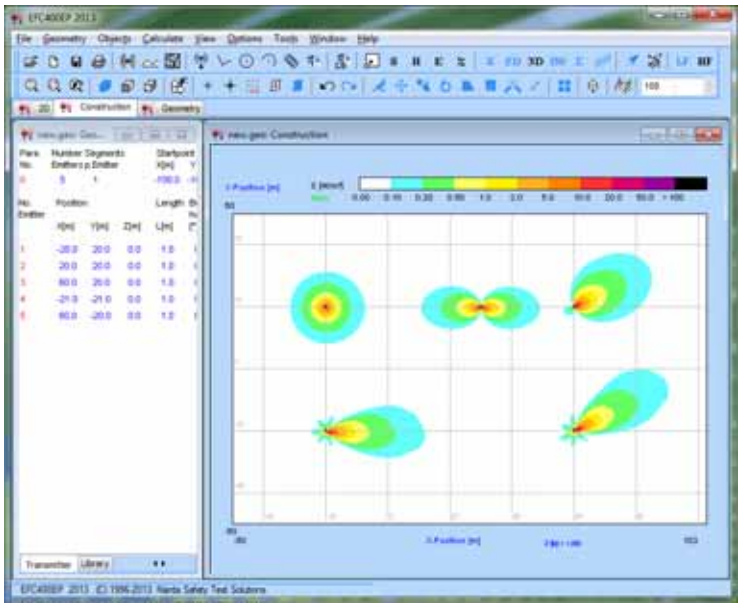
As described insert the fourth and fifth transmitter and assign the horizontal directional beam diagram **"Pat1_hor.Pat"** by the **Load hor. Pat.** Button. For the fifth transmitter in addition enter a **horizontal beam direction** of 30 degrees.

A *.PAT file is an ASCII table containing angles and dB-values. The *.MSI files are a standard format which contains the horizontal and vertical pattern as well as further characteristics of the antenna.



Step 5:

To calculate the **Power Density** click on the S button. You receive the following representation and can adjust colors and ISO-line steps in the **Options menu**.



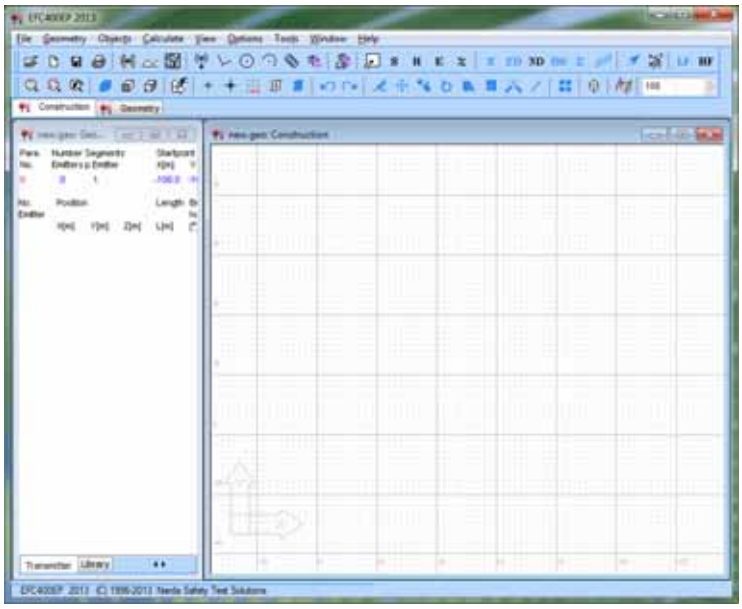
17.2 Directed Emitter

This section explains a computation of an directed emitter with the influence of ground.

Step 1:

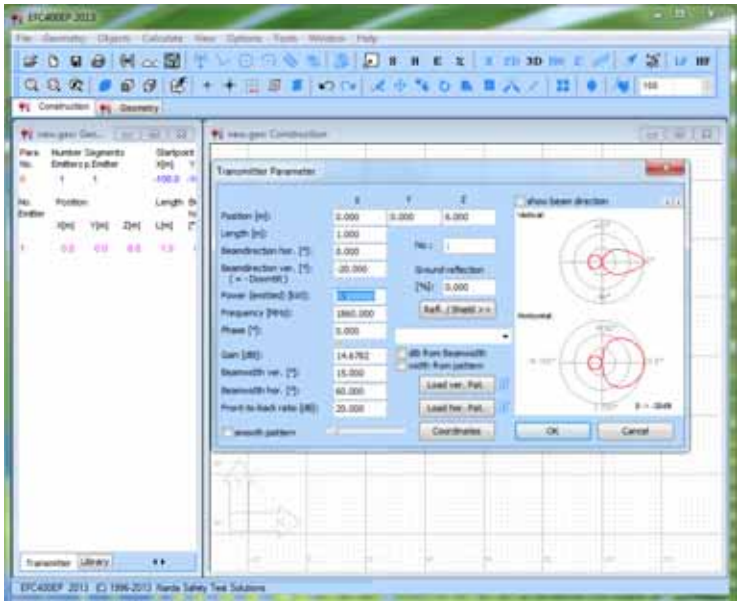
Execute the command **NEW** and select the template "**Emitter**". The template "**Emitter**" already contains the most important settings.

The empty **Construction Window** appears on the screen with activated snap grid (see status line: commands **F3**-**F9**). The **Geometry Window** doesn't contain any transmitter entry yet:



Step 2:

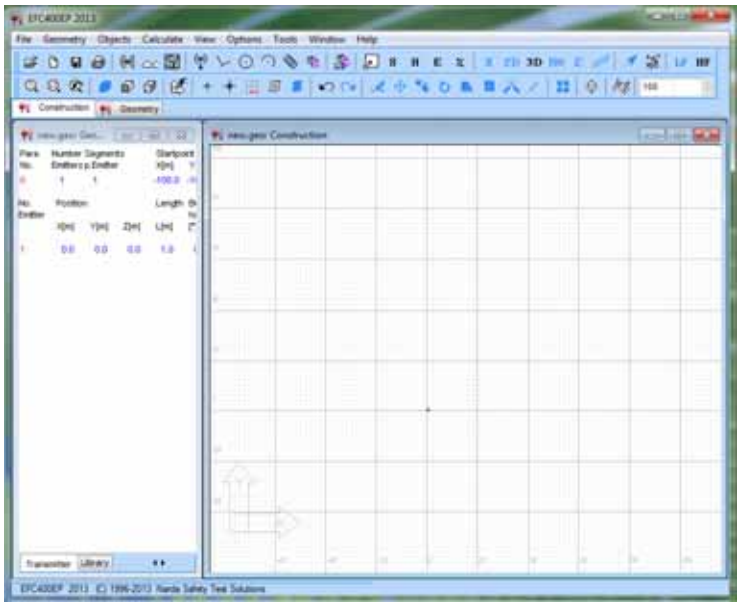
Click on the button to exclusively execute actions by mouse i.e. without coordinate query. By click on the button you construct a new transmitter (see status line), whose characteristics you enter in the seeming dialog, like represented below. The directional beam diagram calculated from the characteristics is shown simultaneously. Check this according to your petitions.



Confirm the dialog with **OK** and move the mouse to the location (0,0,0) in the **Construction Window**. Click with the left mouse button to drop the transmitter (right button means abort).

Step 3:

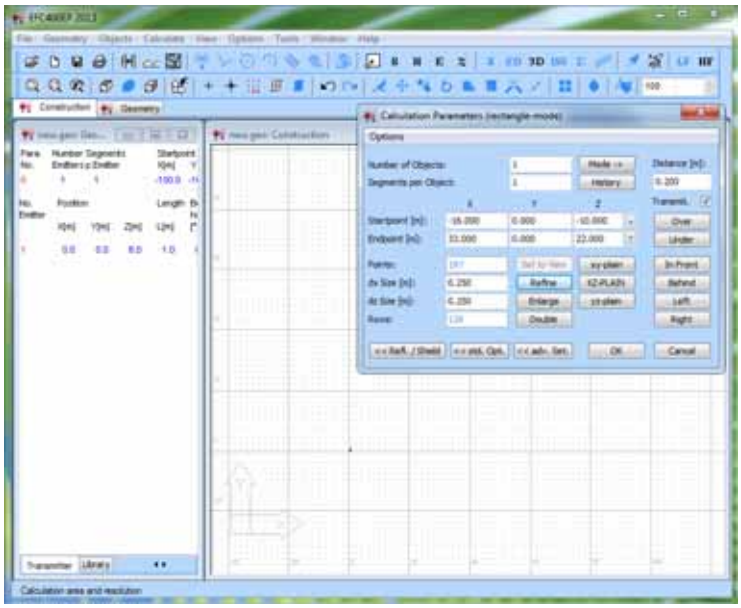
You get the following view:



Click on the button to change to the side view.

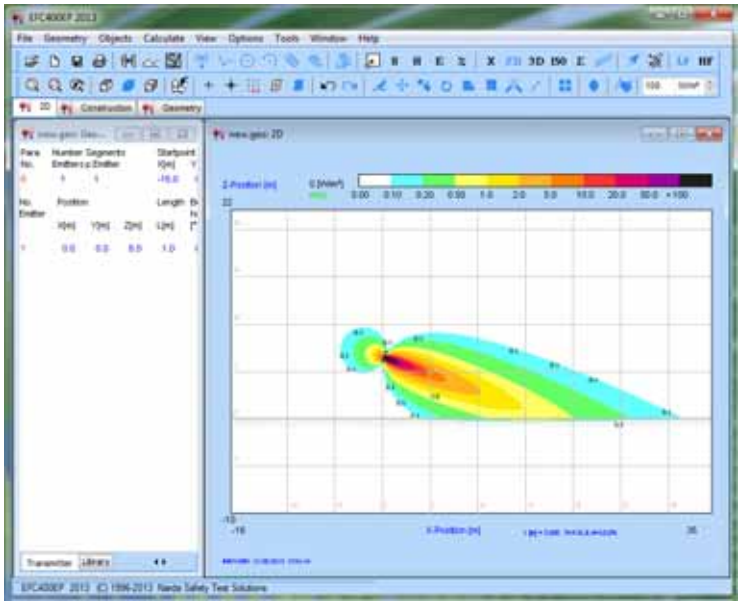
Step 4:

In the side view you extend the calculation field (with pink frame marked) by the fact that you call the dialog for adjusting the **Calculation Parameter** and continue 3 times clicking on the **Double** button.
Set the X end-point to 33 m and click 2 times on the **Refine** button to set the calculation grid to 0.25 m size:



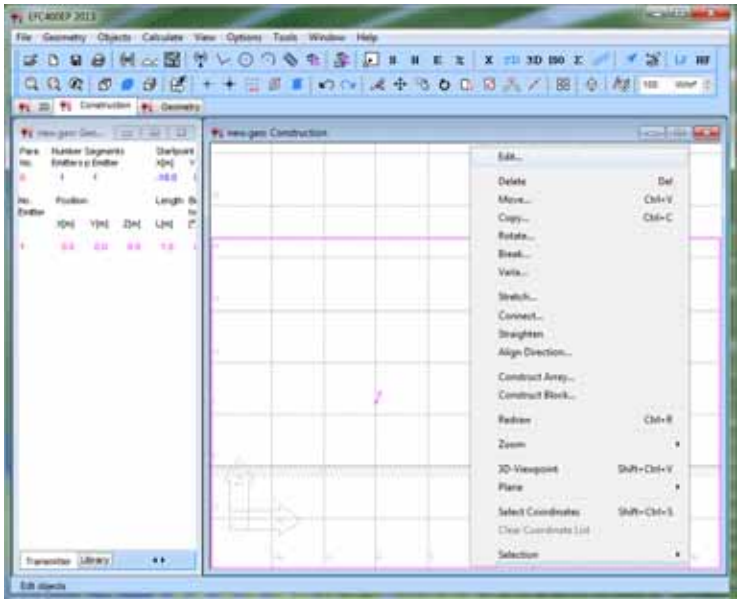
Step 5:

To calculate the **Power Density** click on the S button. You receive the following representation:



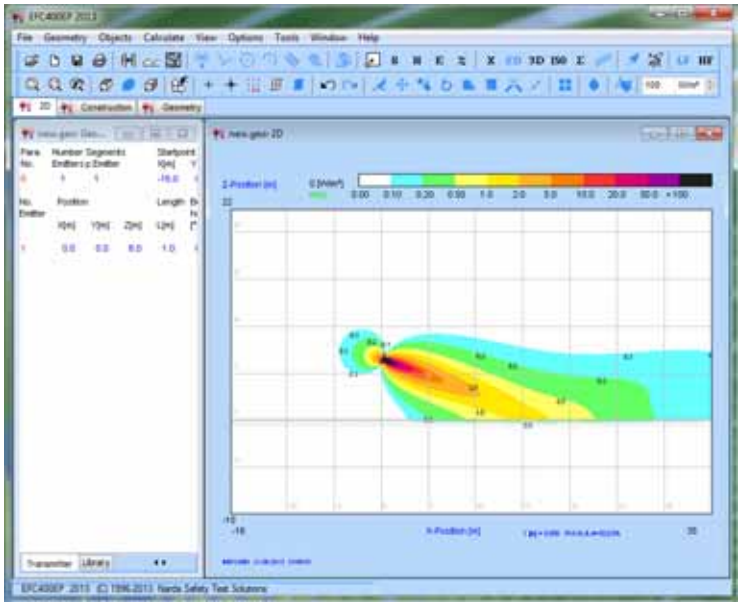
Step 6:

To take into account the influence of the ground, change to the **Construction Window**, mark the emitter by pulling a frame up and with the right mouse button click on the free area to call the **Context menu** to execute the command **Edit**. The **Transmitter Parameter** dialog appears in which you enter a **Ground Reflection** of 50%.



Step 7:

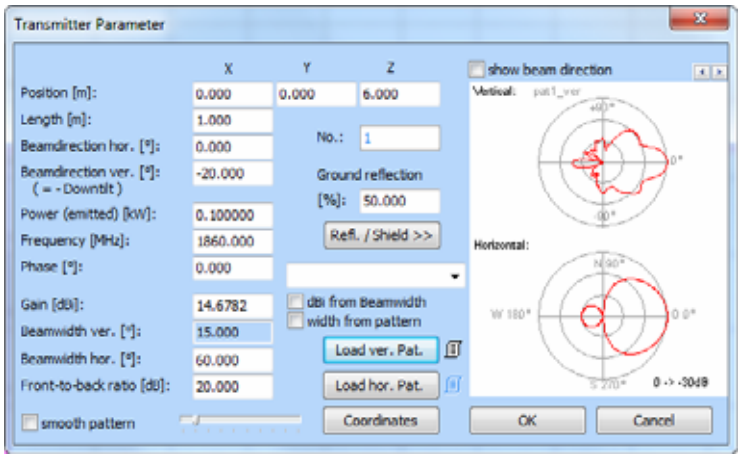
Click on the **S** button to calculate the **Power Density** again. You receive the following representation:



Step 8:

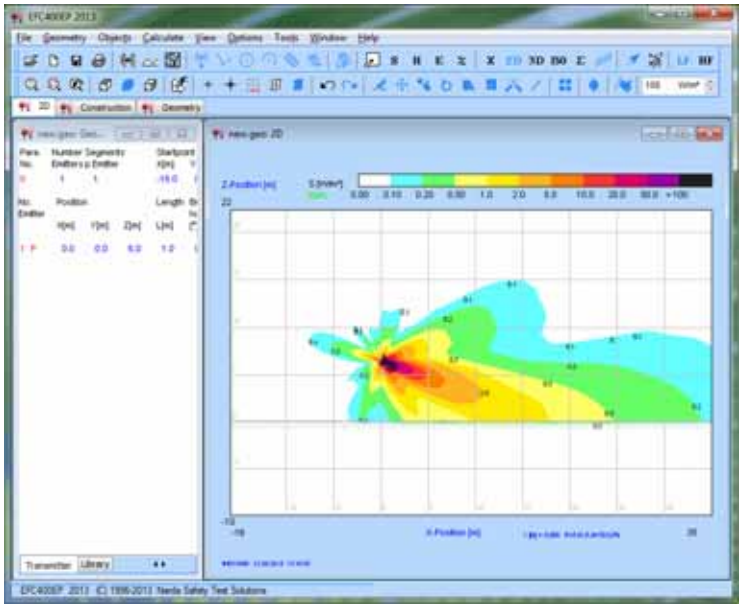
Edit the emitter once more as already described and by the **Load ver. Pat.** button load the vertical directional beam diagram **"Pat1_ver.Pat".**

A *.PAT file is an ASCII table containing angles and dB-values. The *.MSI files are a standard format which contains the horizontal and vertical pattern as well as further characteristics of the antenna.



Step 9:

For a new calculation of the **Power Density** click on the **S** button. You receive the following representation which takes into account the directional beam diagram and a reflection of 50% at ground:



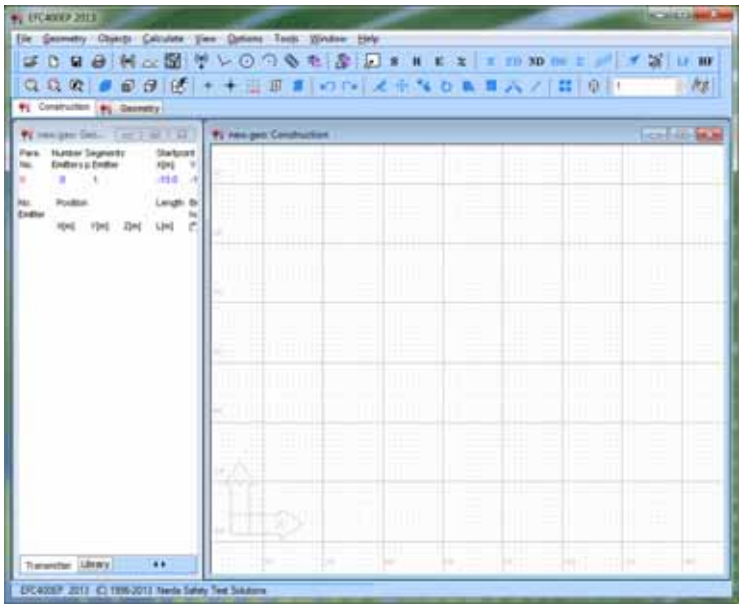
17.3 Mobile Phone and Base Station

This section compares a mobile phone with a tele-communication base station.

Step 1:

Execute the command **NEW** and select the template "**Handy**". The template "**Handy**" already contains the most important settings.

The empty **Construction Window** appears on the screen with activated snap grid (see status line: commands **F3**-**F9**). The **Geometry Window** doesn't contain any transmitter entry yet:

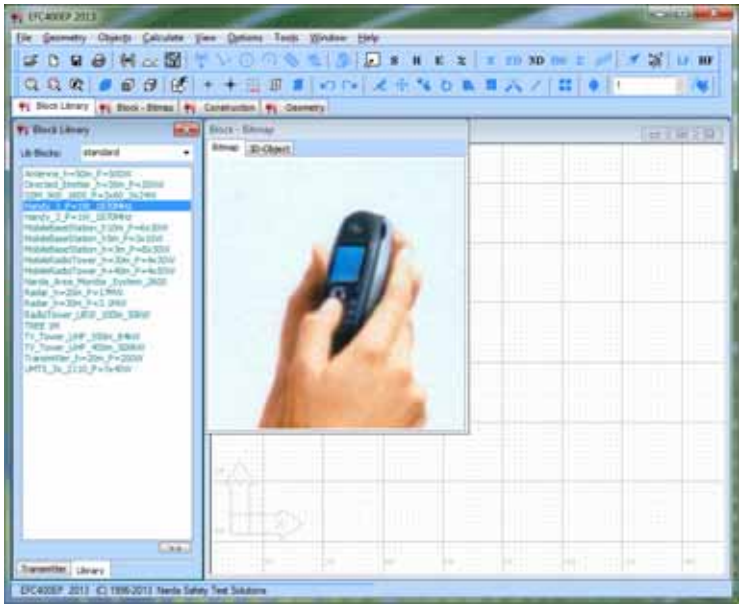


Step 2:

Switch over the **Geometry Window** from the **Transmitter view** to the **Library view**. With the selection box you can choose different libraries with predefined objects.

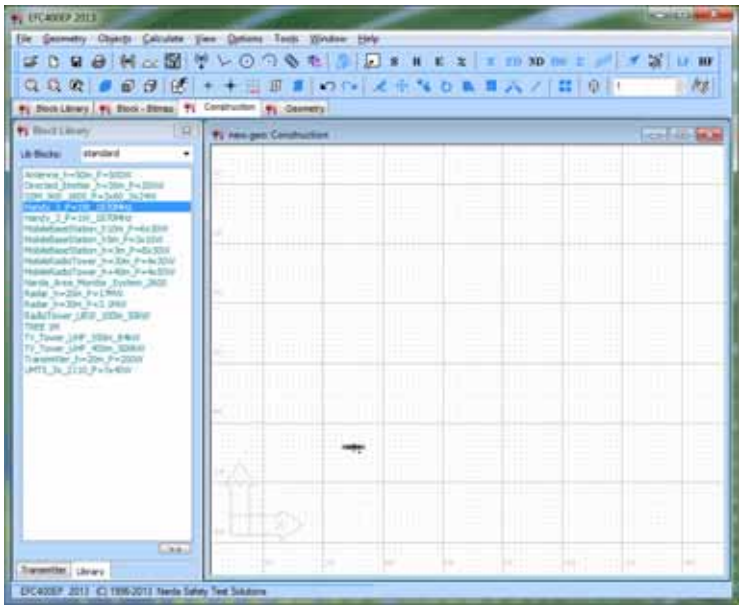
Note: You can expand the library view with the >> button. Then on the right side you will see the blocks already contained in the geometry and the objects you have constructed.

Please mark the object "**Handy_1_P=1W_1870MHz**" in the library "**Standard**". By double-click on the entry insert the block into the construction window. The coordinates are shown on the right below. You drop the block by a click with the left mouse button (right button means abort).



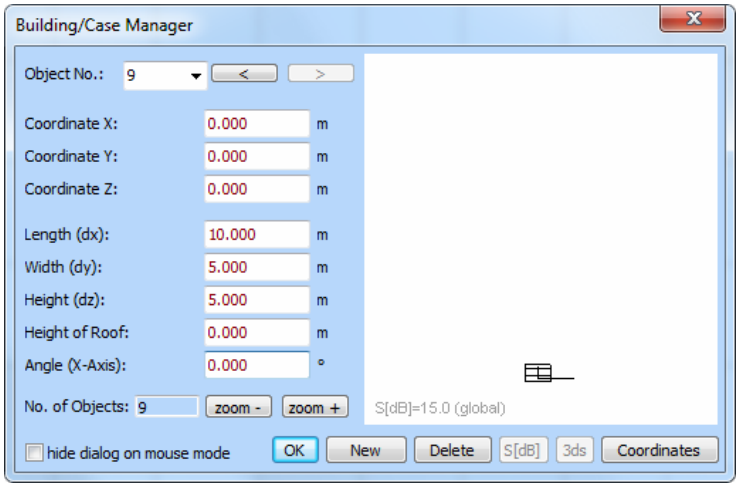
Step 3:

You get the following view:



Step 4:

Click on the button to exclusively execute actions by mouse i.e. without coordinate query. Generate a new building by click on the button and enter 5 m respectively for width and height in the appearing dialog.



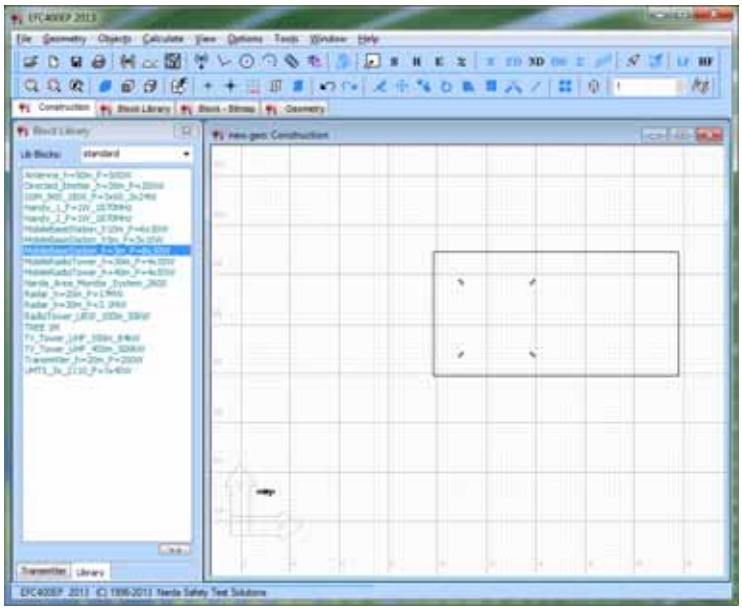
Confirm the dialog with **OK** and pull the building to a location as represented in the next step. If you like to change the position afterwards, you mark the object (left mouse button or pull up of a frame) and execute the command **Move** from the **Context Menu** (right mouse button on the free area).

Note: If you want to **Move** or **Copy** objects you must mark these before you can execute the corresponding command. During moving, the mouse button isn't held pushed down. Instead an arbitrary start-point (1st click) and end-point (2nd click) of the movement is set. The operation is similar to AutoCad.

Step 5:

Next you put a base station on the roof of the building. Therefore elect the entry "**MobileBaseStation_h=3m_P=8X30W**" in the library "**Standard**". Insert the object into the **Construction Window** by double-click.

While moving the object in the construction window by mouse, press the **Ctrl-Key** and pull the object to a height of 5 m while watching the coordinates on the right below.
(Attention: the object does not move. Only the cursor moves!)
Let the **Ctrl-Key** off again and pull the base station over the building as represented in the following graphic:

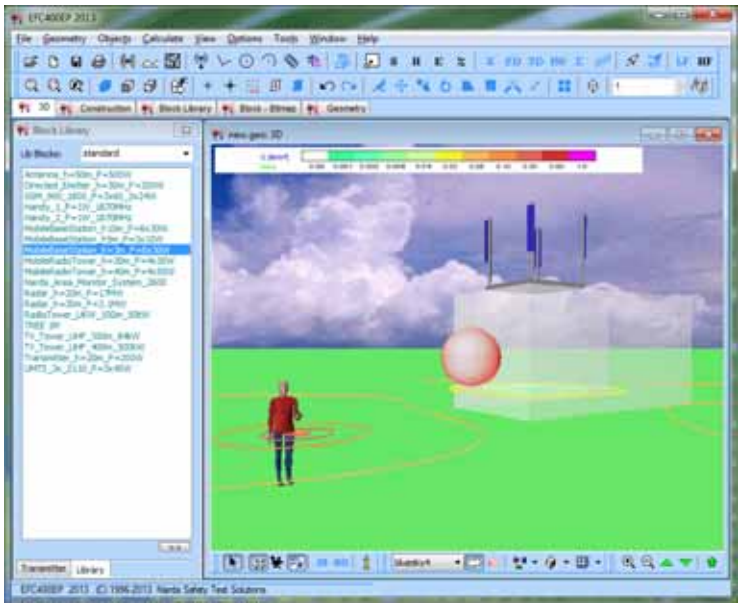


Step 6:

By click on the 3D button you see the construction in the **Virtual Reality view**. The pink ball represents the aim of view. The navigation is carried out with the local toolbar:

or through movement by mouse. All three mouse buttons are occupied and the **Ctrl-Key** causes motions in Z-direction. You are in the choice mode and can work on objects with the right and left mouse button - just like in the construction window - provided that the button is pushed down. Please take into account, that you cannot move objects directly. You must mark these first before commands such as **Move**, **Copy** etc. can be executed.

After calculation of the **Power Density** S and turn on of the ISO-lines with the ISO button (from the local toolbar of the 3D-window) you receive the following representation:



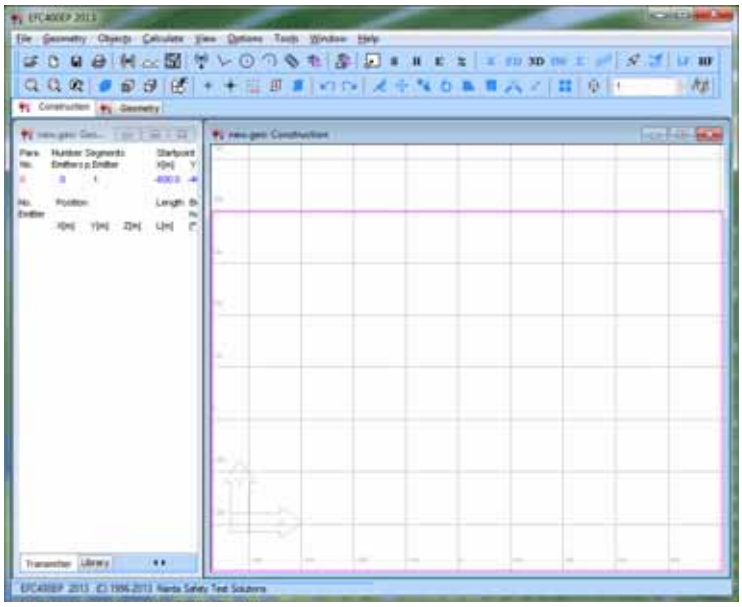
17.4 Radar

In this section computation is performed for radar equipment.

Step 1:

Execute the command **NEW** and select the template "**Radar**". The template "**Radar**" already contains the most important settings.

The empty **Construction Window** appears on the screen. The **Geometry Window** doesn't contain any transmitter entry yet:

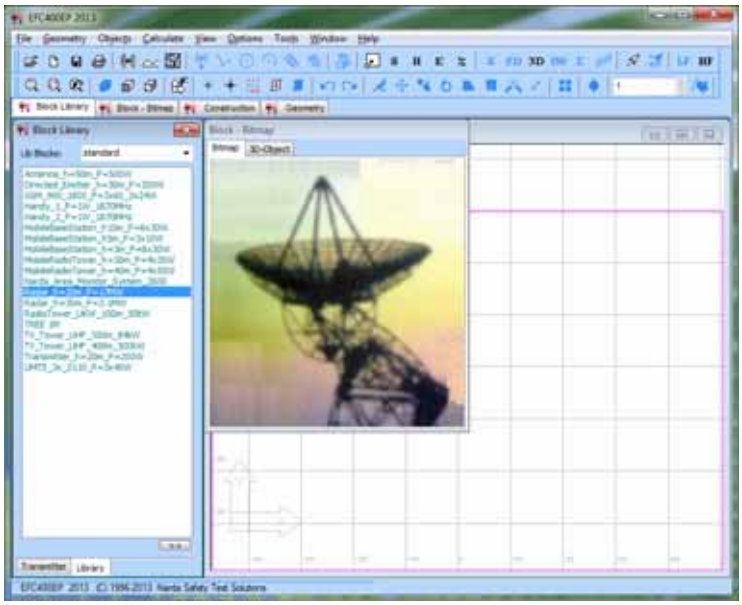


Step 2:

Switch over the **Geometry Window** from the **Transmitter view** to the **Library view**. With the selection box you can choose different libraries with predefined objects.

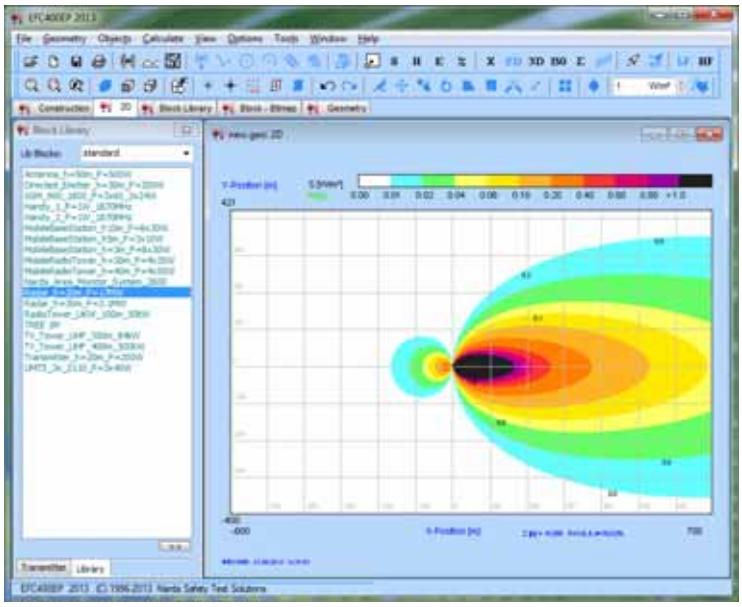
In the **Block-Bitmap** window you see a photo or the 3D-model used in the **Virtual Reality view**. Through double-click you can work on the photo directly. The 3D-model can be swapped if you expand the library view with the >> button. This is of advantage if you want to add designed objects of your own to the libraries.

Now mark the object "**Radar_h=20m_P=17MW**" in the library "**Standard**". Through double-click on the entry insert the block into the construction window. The coordinates are shown on the right below. You drop the block near the coordinate origin (0,0,0) by a click with the left mouse button into the middle of the construction window (right button means abort).



Step 3:

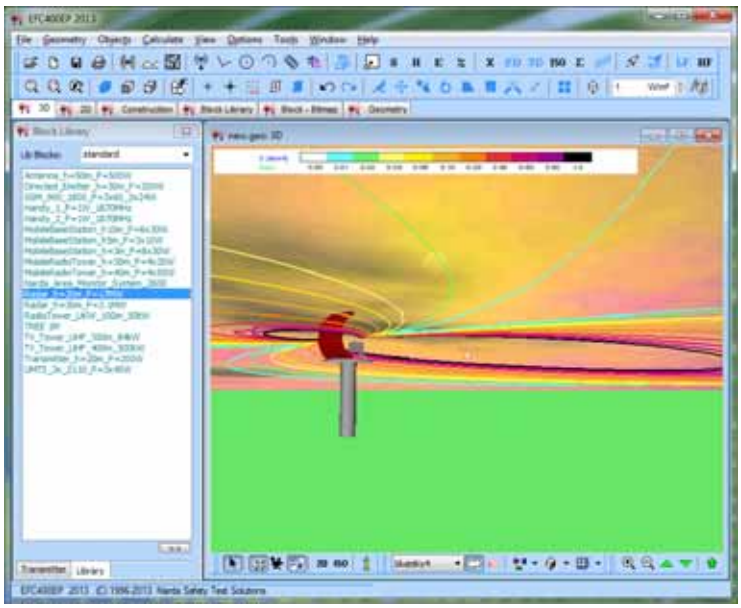
To calculate the **Power Density** click on the S button. You receive the following representation and can adjust colors and ISO-line steps in the **Options menu**.



Step 4:

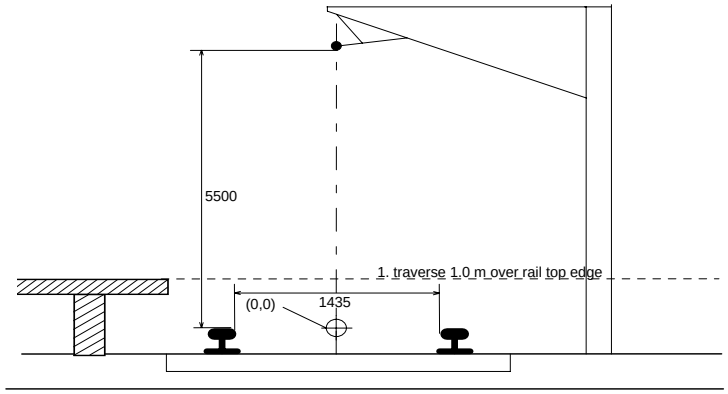
By click on the 3D button you see the construction in the **Virtual Reality view**. Turn on the ISO-lines with the ISO button (from the local toolbar of the 3D-window)

Navigation is done with the local toolbar. In the following graphic through by mouse pull and hold tight the **Ctrl-Key** the ground level was put more deeply.



17.5 Railway Line

In this example we consider a single-track railway line. The geometry is simulated by 3 conductors.



The origin (0,0,0) is set to the center of the track (flush with the rail top edge). The coordinates of the conductors are as follows:

rail on the left	(-0.718, 0, 0) m	I = -250 A
rail on the right	(0.718, 0, 0) m	I = -250 A
overhead wire	(0, 0, 5.5) m	I = 500 A

operating voltage 15 KV, 16 2/3 Hz

The assumed currents represent the maximum load (VDE 0228 T6) and are based on a return current in the rails of 100%.
You can enter the geometry manually (e.g. length set to 1000 m), or load it from the directory EFC-400\ EXAMPLE\BAHN. The following files exist:

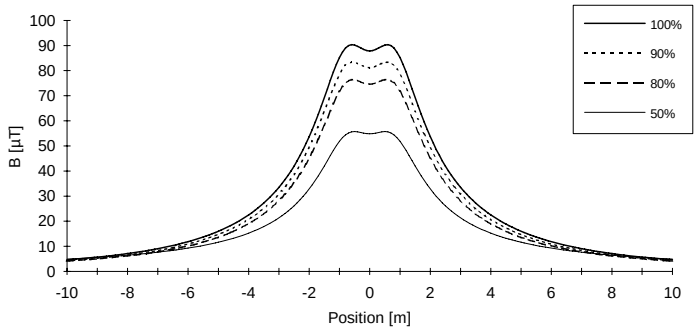
Single-track branch lines

BN100.GEO	100% return current on rail
BN90.GEO	90%
BN80.GEO	80%
BN50.GEO	50%

Note: Suspension, ground and supply wires are not taken into account in these files. In praxis, the ground field strengths (1 m height) can therefore be lower than 50% of the calculated value. If the composition of a route is known in detail, resulting field strengths can be calculated by **EFC-400** exactly.

The currents correspond to the maximum load due to VDE 0228 T6 and represent the worst-case scenario. In praxis, the currents are significantly lower.

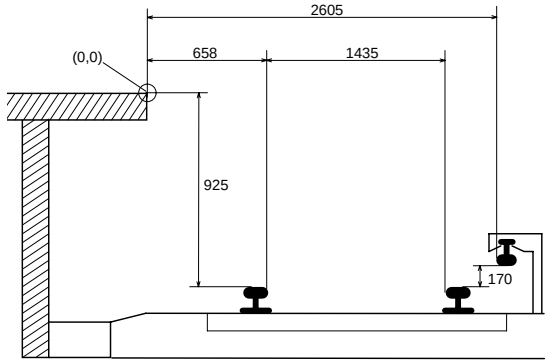
For the computation we start with the CROSSING.GEO file. Adjust the frequency in the **Technical** dialog to 16 2/3 Hz and execute the computation:



The image shows cross-profiles of the magnetic induction at ground clearance of 1 m with different values of the return current.

17.6 Urban Subway

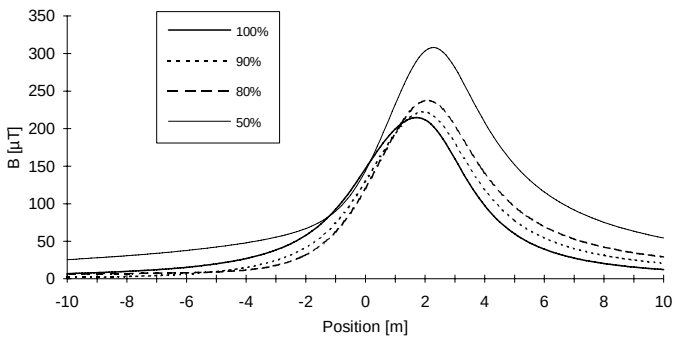
We view a single-track subway line in this example. The geometry is simulated by 3 conductors and corresponds to the *Berliner Großprofil*.



This time we put the origin (0,0,0) on the platform edge. Corresponding geometry data are given in the directory EFC-400\EXAMPLE\U-BAHN:

UG100.GEO	100% return current on rail
UG90.GEO	90%
UG80.GEO	80%
UG50.GEO	50%

The maximum operating current is assumed to be 4 kA (VDE 0228 T6). The operating voltage is 650 V.
Adjust the frequency in the **Technical** dialog to 0 Hz and start the computation:



The figure shows cross-profiles of the magnetic induction at a height of 1 m above the platform at different return current values in the rails.

17.7 Crossing of Railway and Power Line

In this example we consider a crossing between a railway line and a power transmission line. A corresponding geometry file is given in the directory EFC-400\EXAMPLE:

HV-BAHN.GEO
HV-BAHN.CFG

The geometry of the transmission line is the same as in the 380KV.GEO file. The railway line is identical to the line in the example **Route of a Railway Line**.
(The currents are reduced to 1/10.)
Because railway and transmission lines use different frequencies it is necessary to select the mode **Frequency=Free**. A corresponding configuration is in the HV-BAHN.CFG file.

Invoke **EFC-400** and activate the **Automatic Configuration** item. Change to the **Geometry** menu and open the HV-BAHN.GEO file. Execute the computation and select the 2D-view:

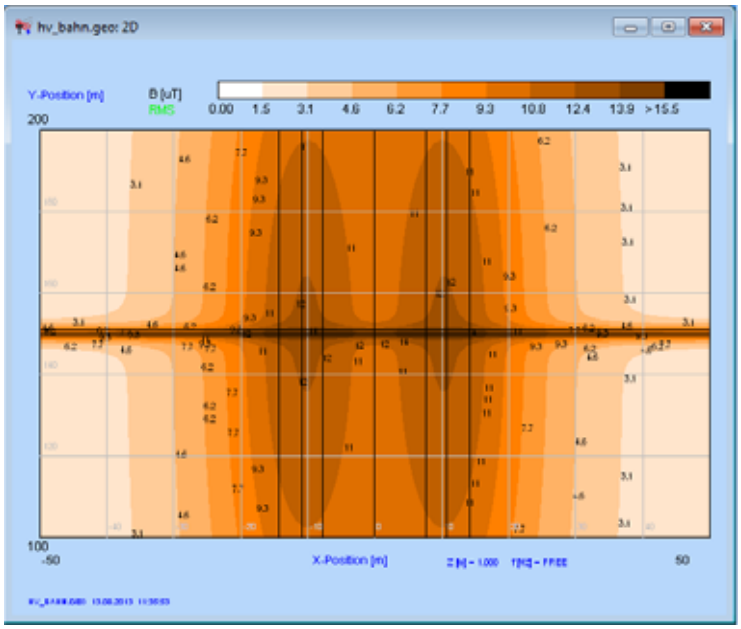


Fig. Magnetic induction, file HV-BAHN.GEO

Attention: The computation time is substantially longer than in the previous examples because mode **Frequency = Free** is selected!

17.8 Power Transmission Line

In this chapter the input of a transmission line is explained by a concrete example.

1) Create a new geometry and open the EXTENDED.GEO file by the **Load Config ...** command from the **Options** menu to set the program into a well-defined initial state. Click on the **EXT** icon of the toolbar if the **Line Editor** is not already activated.

2) Change to the **Calculation Parameters** dialog and enter the following values:

Number of segment	:	1
Startpoint X	:	-200 m
Startpoint Y	:	-100 m
Startpoint Z	:	1 m
Endpoint X	:	500 m
Endpoint Y	:	100 m
Endpoint Z	:	1 m
dx-Size	:	4 m
dy-Size	:	4 m

The other calculation parameters are adjusted automatically.

3) By a double-click on the first transmission line entry in the **Line Editor**, the **Tower Manager** is activated. At first we want to enter a short transmission line consisting of 4 towers with distances of 285 m, 300 m and 240 m, running parallel to the X-axis.

Make sure that the **Standard** library is loaded. If this is not the case, leave the **Tower Manager** with the **OK** button. Change to the **Library Manager**. Press the **Load Lib** button, select the **Standard** library and get back to the **Tower Manager.**

Select now the type *220 kV Einebene*. It suffices in this example to adjust the parameters *Coordinate X* and *Angle* in the parameter-editor of the **Tower Manager.** Change these parameters for the first tower to X= -200 m and an angle of 90° because the girders of the library towers are aligned parallel to the X-axis.
The next tower of the same type is selected in the same way. The X-coordinate is now set to X= 85 m, the angle is 90°. Repeat this procedure with the X-coordinates 385 m and 625 m for the next two towers, and please do not forget to adjust the tower angle to 90°.

4) The transmission line is created now. You can go back to **Line Editor** with the **OK** button. With **B-Field** the calculation is started. Afterwards the 2D-view shows the following picture:

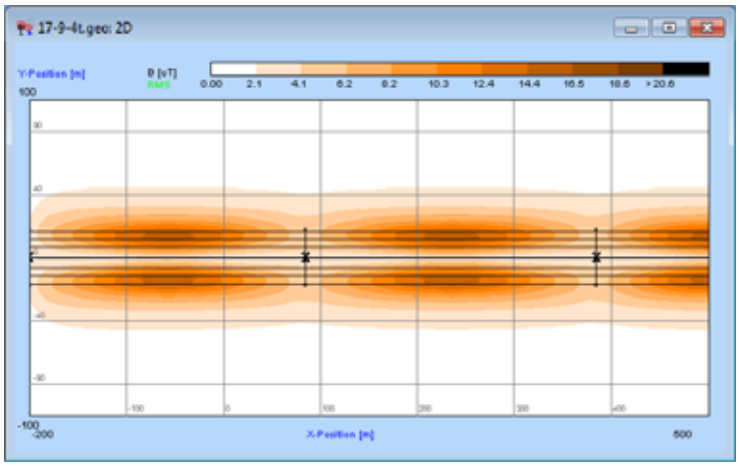


Fig. Example power transmission line with towers, step 4

5) Now we turn and move the complete line in the computation area. Please change to **Line Editor** again and open the **Line Edit** dialog by pressing the **Edit** button. Enable the **All Lines** option and enter the shift values X= -50 m, Y= -50 m and Z= 0 m.
After pressing <ENTER> the movement is carried out and you can view the result in the 2D-view after a renewed calculation.

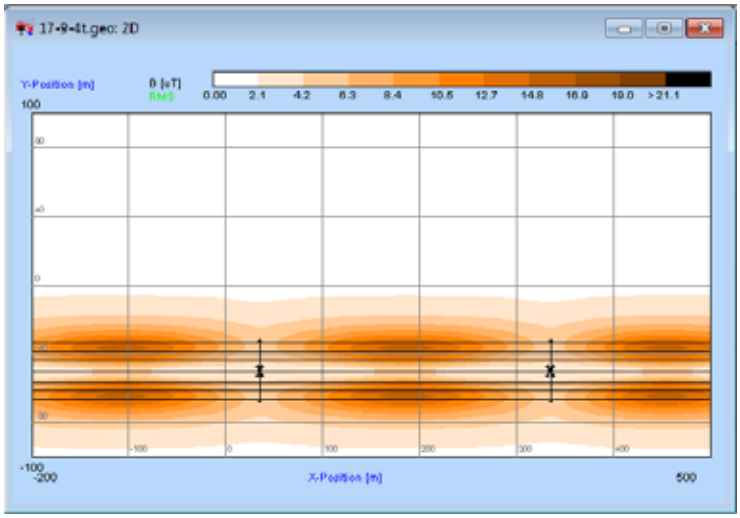


Fig. Example power transmission line with towers, step 5

6) Now the transmission line will be rotated by 5°. To do this, invoke the **Edit** dialog again from the **Line Editor**. Enter the number of the tower around which the complete line is to be rotated; in this case enter **1**. Set the rotation angle to 5° by entering the value **5** in the field **Angle**. After another calculation the following plot is displayed:

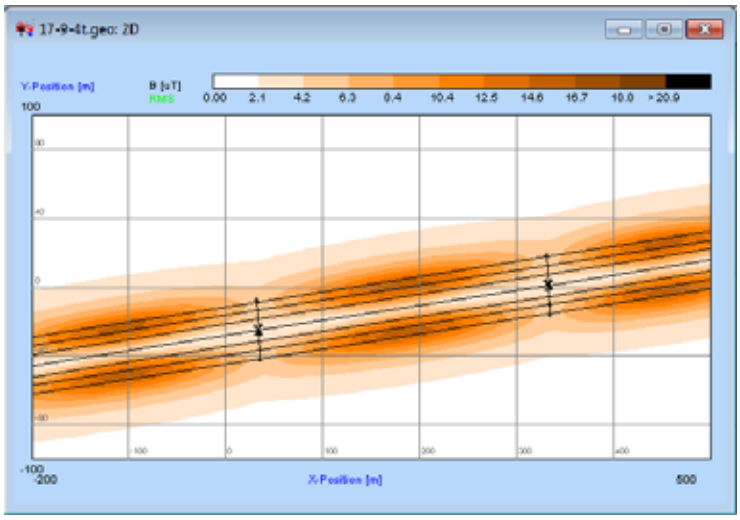


Fig. SAMPLE1.GEO, 2D-view

The geometry just created is available in the EFC-400\EXAMPLE directory (file SAMPLE1.GEO).

17.9 Two Power Transmission Lines

This example uses the 220-KV high-voltage transmission line entered in the previous chapter. A second line, which crosses the first, is added.

1) Before you can follow the step-by-step procedure you have to open the SAMPLE1.GEO file from the EFC-400\EXAMPLE directory.

2) Make sure that the same calculation area is set and the same library is loaded as in the example presented in the previous chapter.

3) By a double-click on the second transmission line entry in the **Line Editor**, a new line is created and the **Tower Manager** turns up.

4) Choose the tower type 380 kV-Donau with the cursor keys. Select four towers of this type with the following coordinates:

Note: In the Tower Manager, the new tower numbers are the sum of all the towers existing in the geometry. Therefore, the new tower has the number 5.

Tower-No.	X-coordinate [m]	Y-coordinate [m]	tower angles [°]
5	-200	50	-90
6	200	50	-90
7	300	-90	-180
8	350	-350	-180

5) The towers 6 and 7 do not possess the correct angle. You can correct this with a **EFC-400** feature especially intended for this purpose:

Select the tower no. 6 and press the **Adjust Angles** button. A dialog box appears in which you can enter the positions of the previous and the following tower. Afterwards the tower is aligned vertically to the connecting line of the two positions. If you have entered the positions correctly, the angle of tower no. 6 is approx. -106°. Repeat this for tower no. 7, (approx. -160°).

Note: You can also execute the event just described with the **Auto Adjust** function in a simpler way. **Auto Adjust** aligns all towers of the transmission line vertical to the connecting lines between their previous and following towers.

6) Because the two entered transmission lines cross, the towers of the second transmission line have to be increased by 10 m. Enter the value of *current tower height + 10 m* (in this case 51,55 m) in the **Tower Manager**. Thereby the complete tower head is moved up by 10 m.
After this the sag of the conductors has to be adjusted according to the changed tower height. This is done by the **SHIFT** function, accessible from the **Conductor Configuration**. After pressing the **Shift** button, select **All**, enter a value of 10 m and confirm with **OK**.

7) The second transmission line is completely configured now and will be displayed in the 2D-view after calculation:

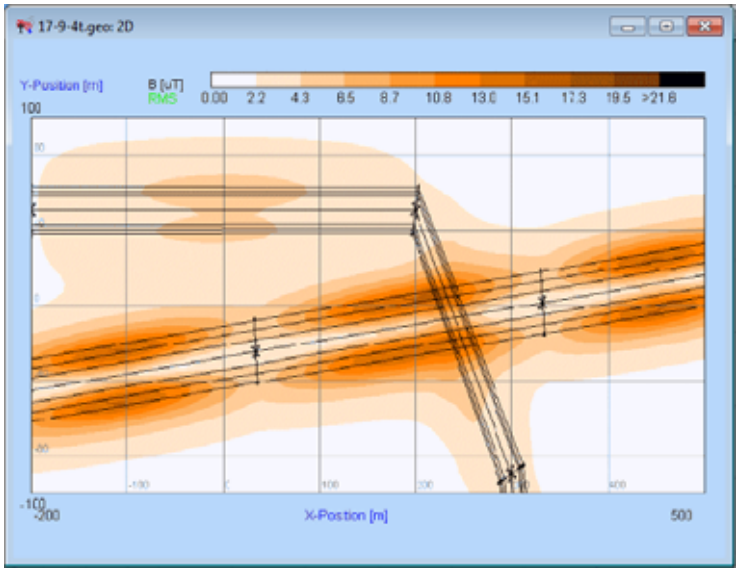


Fig. SAMPLE2.GEO, 2D-view

The example calculated in this chapter can be found in the EFC-400\EXAMPLE directory (file SAMPLE2.GEO).

17.10 Crossing Transmission Lines

In this example a crossing of two transmission lines is viewed. A corresponding geometry file is in the directory EFC-400\EXAMPLE:

CROSSING.GEO
CROSSING.CFG

Invoke **EFC-400** and activate the **Automatic Configuration** item in the **Options** menu. Load the CROSSING.GEO file. Execute the computation and select the 2D-graphic:

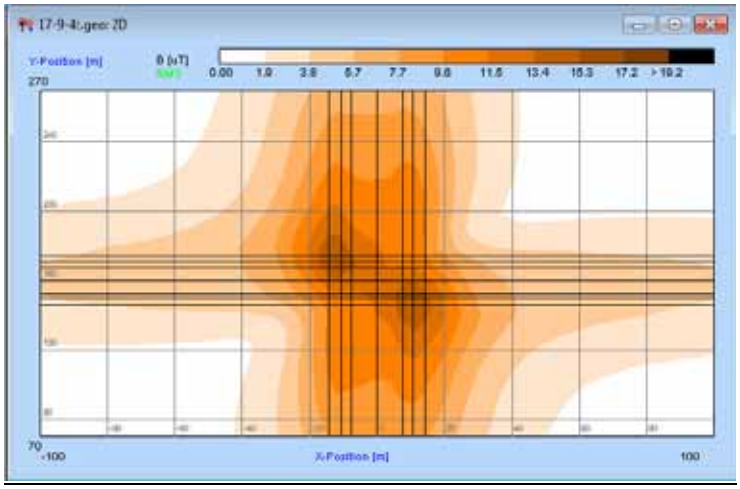


Fig. Magnetic induction, file CROSSING.GEO

Start the computation of the electric field strength with **E-Field**:

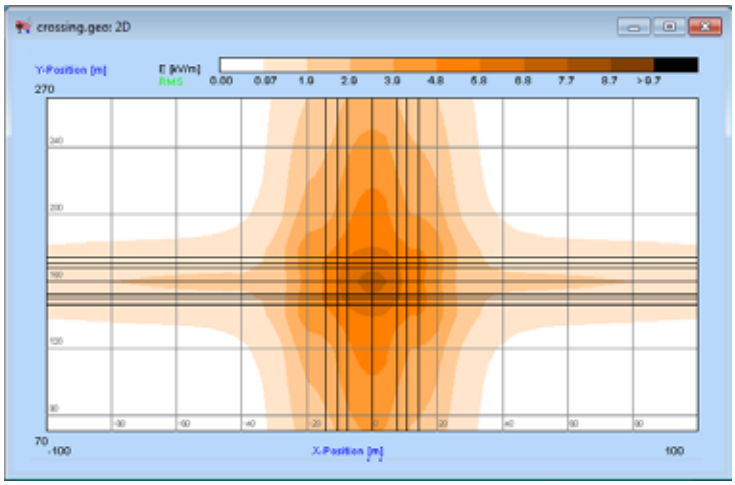


Fig. Electric field strength, file CROSSING.GEO

When opening the geometry, the accompanying configuration is also loaded, which enables the switch **Auto Segments** (dialog **Extended**). **EFC-400** increases the segmentation from 1 to 30 with the message *Conductors too close-> Increase segments to n = 30*.
You can disable this switch and enter the segmentation value manually. Attention: With less than 30 segments errors may occur, caused by the unsatisfactory simulation of the geometry from line charge segments. (see chapter **Computation Parameters**).

17.11 Power Station

Introduction

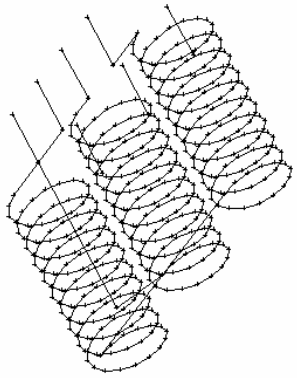


Fig. predefined transformer

Many of the concepts which were introduced with **EFC-400** differ a lot from those of conventional field computing programs and are so revolutionary that they have to be explained in detail.
Basically in **EFC-400** the current-carrying parts of energy plants are modeled as line-type conductors in space. 50000 free definable copies of these conductors are at your disposal. In the simplest case, the construction of a plant is done in three dimensional space, as known from CAD systems. The coordinates can be given locally, e.g. by referring them to a specific point of the plant, or in the global Gauß-Krüger coordinate system. Once constructed parts of a plant can be inserted later in a complete geometry, like single text blocks can be arranged in documents by a word processor.
Beyond this, arbitrary elements designed by the user like towers, bus bars or cables can be summarized as objects. Some predefined objects, e.g. transmission line towers, power station elements or vegetation elements, are already delivered with the software package.

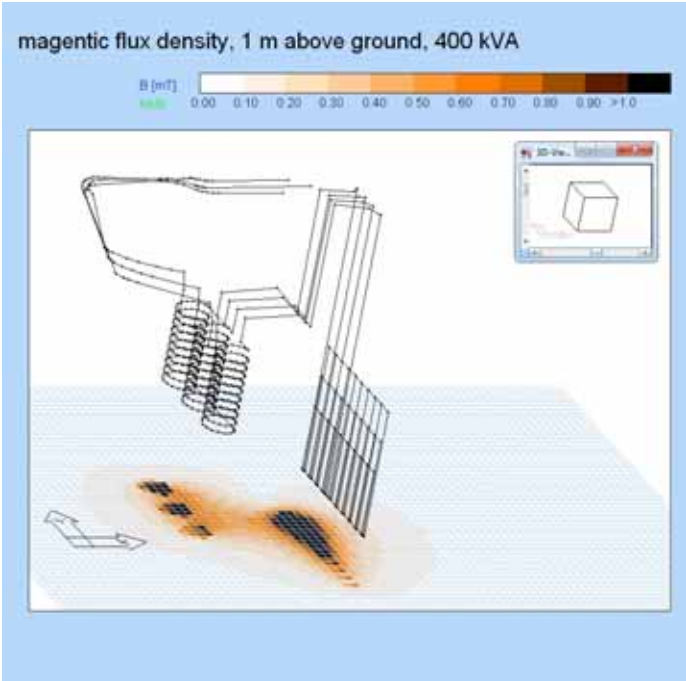


Fig. power station designed with EFC-400

The basic idea of **EFC-400**, however, is to facilitate the definition of own objects for the user, in order to adapt the software to the own requirements without being dependent on further support of the manufacturer.
While constructing installations in three-dimensional space another quality of **EFC-400** is very important. At the beginning of a project the 'empty' space is formatted by topographic

maps in raster or vector format or also construction plans of electric installations. Thus visual construction on already available information is possible. This represents a considerable relief. In addition already existing **CAD**-geometries can be imported in **EFC-400** by means of the **DXF-interface**. Also data can be exported from **EFC-400** to the **CAD-system**.

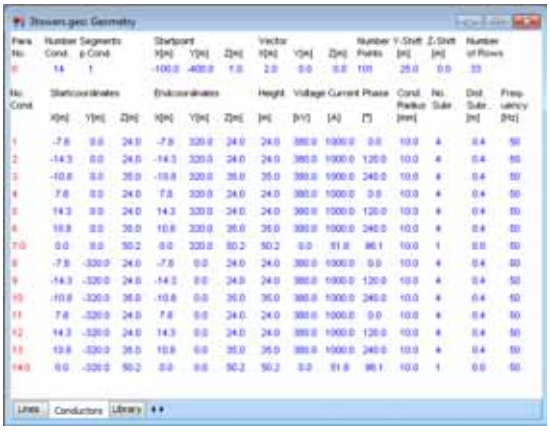


Fig. conductor editor in standard format

EFC-400 provides two models grown historically to work on a geometry which are united under one surface. Every geometry can be modified in the one or in the other model. This is first the original **EFC-400 'standard' format** which is oriented on conductors and blocks. Here single conductors are edited by mouse in a table or a **construction window**. It's possible to look at the **construction window** from every arbitrary view point, i.e. you can edit your geometry in a three-dimensional view, which you can choose freely as known from **CAD-systems**. This format is mainly used for the construction of power stations, terminal stations e.g. The construction is simplified considerably by the possibility of summarizing arbitrary collections of conductors as self-defined blocks, which can be saved in a library for later use.

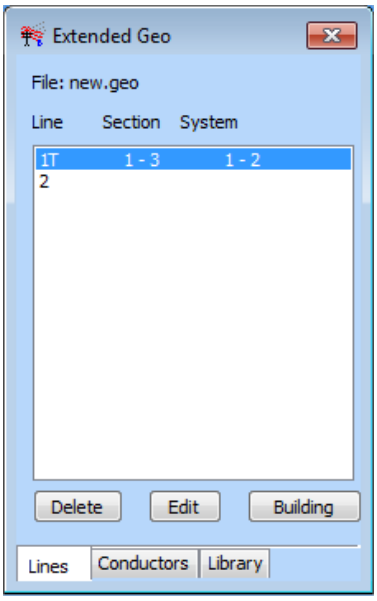


Fig. line editor

The second and more modern model, the so-called **'extended' format**, is line-oriented. Here you first define profiles of transmission line towers, cables or railway lines. Then you only select the locations of the towers by mouse whereupon **EFC-400** generates the complete line for you in a single step. All settings, e.g. currents or phases, affect the whole line. Type and position of single towers or of the complete transmission line can be changed without influencing the electrical parameters of the line. In addition **EFC-400** offers you a phase optimization tool. Altogether the **'extended' format** of **EFC-400** is able to manage up to 1000 towers, 100 transmission lines and 1000 building models. After the generation, all of these objects are addressed via a single couple of coordinates. I.e. the selection of a single cursor position in your topography by mouse enables you to renew the position of any object.
You can work on geometries in both models at any time. To change between the **'standard'** and the **'extended' format** you have to click on the toolbar button named **'EXT'**. When starting **EFC-400** (also as demo version) for the first time, the **'extended' mode** is activated and shows you the line-oriented editor. Simply do a mouse click on the **'EXT'**-button and **EFC-400** shows you a table of the geometry's conductors. The mode activated at the start of **EFC-400** depends on the project and is saved / loaded with the geometry like all other configurations, provided that the option **'automatic configuration'** was activated, as it is default at the start of **EFC-400**.

Construction of a power station

Before starting your first own construction of a power station it's meaningful to have a look at an example of an already constructed station. You can find such an example in your demo version. Start **EFC-400** and select the **'open'** item from **'file'** menu to open a geometry. In the appearing **'file-open-box'** change to directory **'EFC-400\ Example\Tstation'** and select file **'Station1.geo'**.
A window including a table of the geometry's conductors and the construction window are opened. **EFC-400** will initialize the 'empty' space with the stored ground plan of the station automatically by activating 'auto background map' from the **'show background map'** submenu of **'geometry'** main-menu.
You will see the plant's conductors on the digitized ground plan now.

Note: If the construction window should once be closed, you can open it manually with the '**construction**' command from the '**view**' main menu.

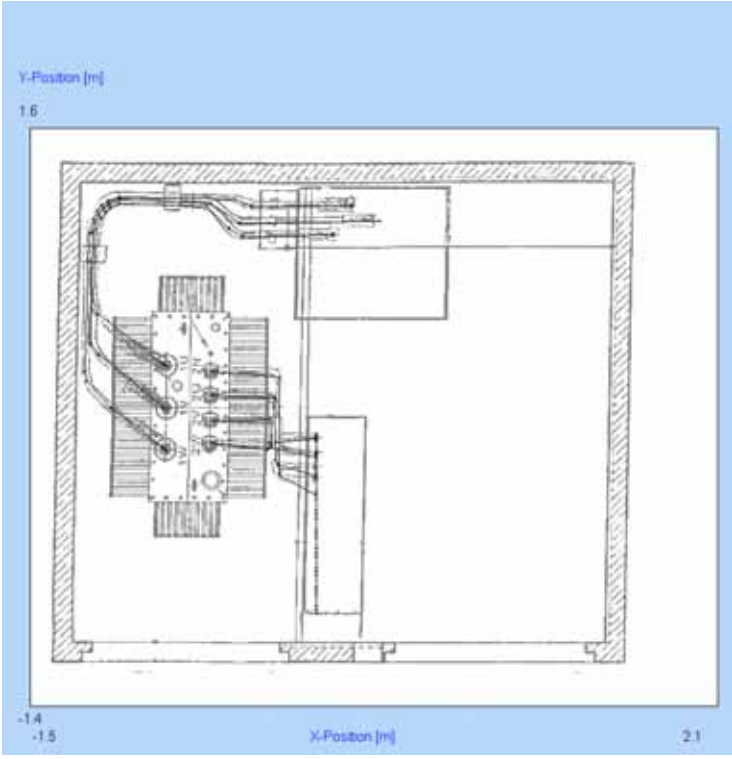


Fig. '**construction window'** with ground plan and conductors

It is a simple station type where no high voltage section was taken into account. For the transformer only the transformer candles were modeled. The plant you are going to construct, however, will include the transformer coils, too.

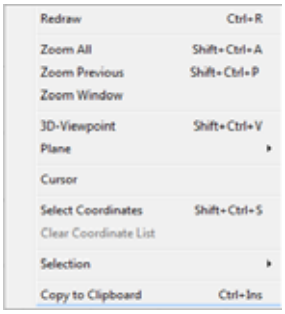


Fig. **context menu**

Note: Don't be confused of the little misfitting of the ground plan, please. This will frequently be the case if you digitize drawings.

To examine the geometry more exactly in 3D-view, click with the right mouse button on the window's white free area and choose the **'3D-viewpoint'** item from the appearing **context menu**. A window appears, which allow you to choose an arbitrary viewpoint of the geometry. Choose a view in which you can see all components. We presuppose that you know the function of the now visible elements.

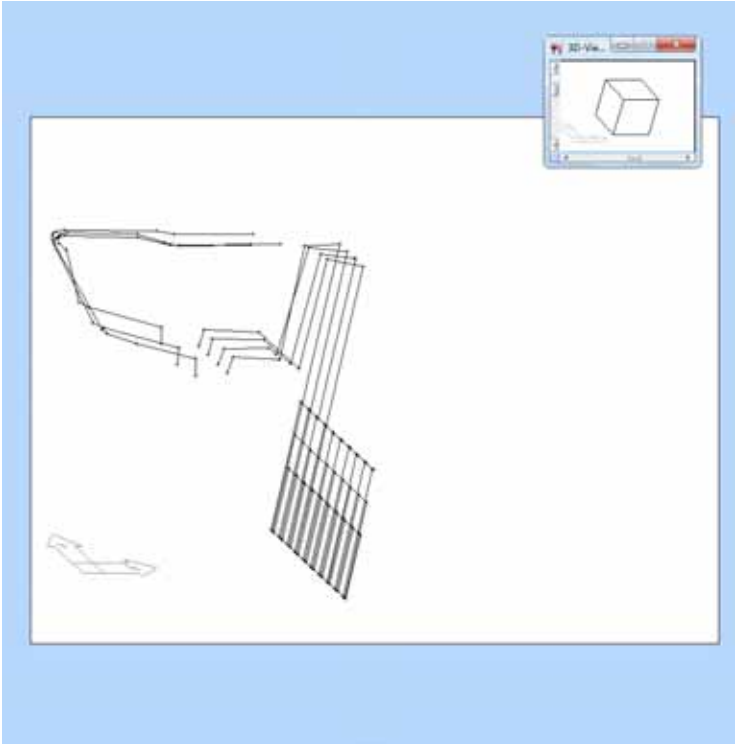


Fig. 3D-view of the conductors with **'3D-viewpoint'** (right top)

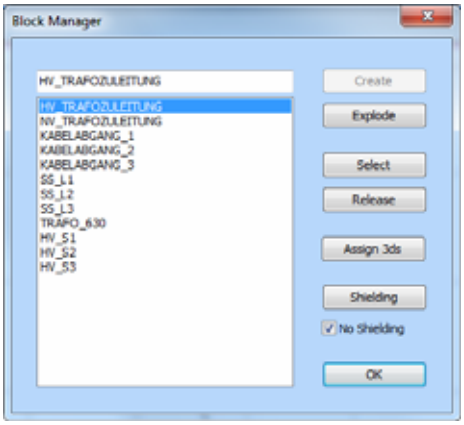


Fig. **block manager**

To explain you the principles of the construction of geometry in detail it's useful to activate the **block manager** in order to clarify the division inside the geometry. Choose the **'blocks'** item from **'geometry'** menu or click on the corresponding toolbar button. You receive information about the function of the toolbar by clicking with the mouse on a toolbar button and reading the text in the status line, before you pull back the mouse pointer and release the mouse button.

Move the **block manager** to a position where the geometry isn't covered anymore. In the **block manager** you see single blocks the geometry consists of. Choose e.g. the **'SS_L1'** entry by mouse, and click on **'select'** in order to mark phase **'L1'** of the low voltage bus bar. There are no difficulties to unite the single blocks **'SS_L1'**, **'SS_L2'**, **'SS_L3'** and **'SS_N'** to the whole bus bar system. To do this it's necessary to select all 4 entries by means of the **'select'** button to enter the new name, e.g. **'SS_GES'** in the upper line and to confirm by

clicking on the **'create'** button. Please note that **EFC-400** supports only one block level, i.e., a block can't contain any sub-blocks. In other words, every conductor can only belong to one block.

Close the **block manager** now by clicking on the **'OK'** button. Another possibility to mark conductors for later editing is to click on them directly with the mouse pointer. In the construction window you can also mark several conductors at one go by pulling up a frame around them with the mouse.
By pressing the 'Ctrl' key while clicking on conductors all connected conductors get marked; complete blocks are marked pressing the 'Shift' key.

Provided that one or several conductors are marked, you can call the **context menu** by clicking on the free area of the **construction window** with the right mouse button, in order to edit the selected conductors. After calculating the magnetic flux density of the geometry by clicking on the 'B' toolbar button, we would like to terminate this example.
When the calculation is finished (see status line) the **'2D'** window opens automatically to get a top view of the magnetic flux density. Also close the 3D-viewpoint control window showing the cube.

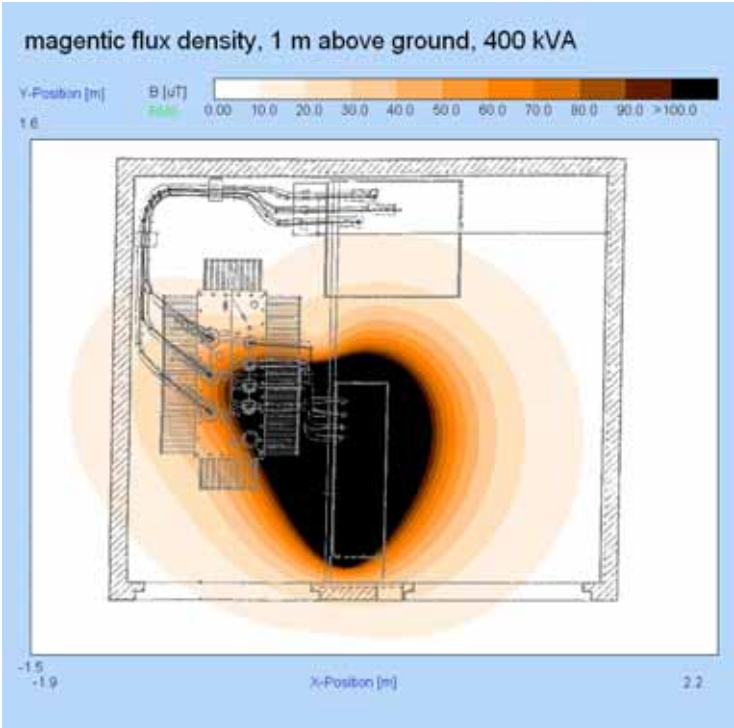


Fig. **'2D-plot'** of the calculated magnetic flux density

In the **2D-view window** of the magnetic flux density you can enlarge (zoom) interesting areas by means of the **context menu** (right mouse button). By selecting the 'cursor' item from

this menu you can also read the value of the magnetic flux density at arbitrary points.
Please close the complete project after this example by clicking on the **'close geo'** item from **'file'** menu.

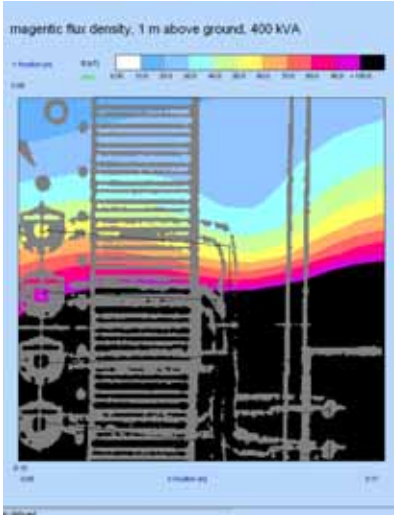


Fig. enlarged detail

In the following we want to show you in detail how this station was constructed. To do this we first divide the construction proceeding in main steps:

A) Digitizing the map to format space

B) Logical division of the construction into single subgroups

C) Construction of the subgroups according to step B) and storing these in the block library for further usage

D) Positioning of the constructed subgroups on the map

E) Connecting the subgroups to the complete power station

F) Checking the geometry

G) Computing the field strengths

Step A): Digitizing the map to format space

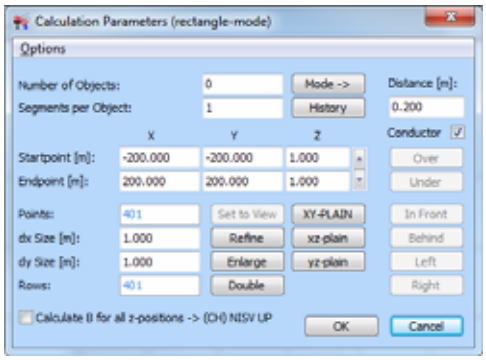


Fig. '**calculation parameters'** dialog

The first step A) can be left out in this example since the digitized map is already included in this example.

After you have closed the project a while ago you first have to create an empty geometry now. You obtain this by selecting the **'new'** item from **'file'** menu. Select the template **'station'**. An empty table of conductors and the construction window appears. The dimensions of this window are defined in the template **'station'**. If no template is selected the dimensions are always identical to those of the construction window of the last opened geometry.
If it is necessary you can change the dimensions of the calculation field by means of the **'calculation parameters'** item from **'calculate'** menu or by clicking on the corresponding toolbar button.

Up to now the space you see in the **construction window** is neutral. For the initialization you have to load the ground plan via the **'Bitmap - 265 colors -> gray'** item from the **'import background map'** submenu of **'geometry'** main-menu. Select file **'Station1.pcx'**.

Note: Alternatively you have the possibility to load a vector topography in DXF-format or graphics in true color, e.g. satellite photos in JPG-format, if available**.**

Fig. '**insert coordinates'** dialog

The appearing **'insert coordinates'** dialog shows you the relation of the raster graphic to space. The corresponding coordinates are already adjusted correctly. For the construction of own plants you must calculate the corresponding information from your digitized plans by hand.
Please confirm with **'OK'** to finish formatting of the space. Indeed we have just got an ideal basis for constructing the geometry directly on the real topography.

To enlarge the view please select '**double'** in the **'calculation parameters'** dialog.

Step B): Logical division of the construction into single subgroups

Next we agree on the subdivision of the plant into the following logical groups:

1. *Low voltage distribution*
2. *Low voltage connection to the transformer*
3. *Transformer model*
4. *High voltage supply of the transformer*

The greatest work while constructing a new plant, just consists in the construction of the different groups.
In anyway this construction is not needed if the group is already contained in the library. Also in many cases it is the easiest way to modify an existing group.
In the following we want to create these groups. Once you have constructed recurring elements like the low voltage distribution we ask you to skip the next step C). The same is valid if you don't want to do the extensive construction in this example.
Otherwise please continue with the construction of the groups.

Step C): Construction of the subgroups according to step B) and storing these in the block library for further usage

C.1 Construction of the low voltage distribution

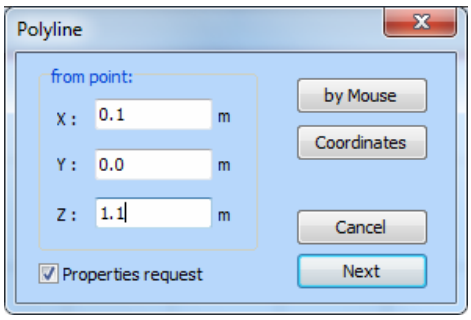


Fig. '**polyline**' dialog

The low voltage distribution of this example has altogether ten outgoing cables. We begin with the construction of the first part of the upper bus bar. Please create a new conductor by selecting the **'polyline'** command from the **'3D-objects'** menu of **'geometry'** main-menu or by clicking on the corresponding toolbar button. Please enter the start coordinates (0.1, 0, 1.1) in the appearing **'from point'** box and confirm with **'OK'**. Another box named **'to point'** appears. Please activate the mode **'relative'** before entering the vector (-0.1, 0, 0) of the first conductor part. Based on this first conductor part you can construct the first phase of the outgoing cable by clicking on **'next'** and entering the relative coordinates (0, 0, -1.1). Close the dialog with **'OK'** then. A final dialog appears, asking for the electrical parameters of the just constructed conductors. In the case of this example you can close the box with 'OK' without any further specifications. To get a better view of the constructed conductors please open the **'calculation parameter'** dialog from **'calculate'** menu and change to the xz-plane.

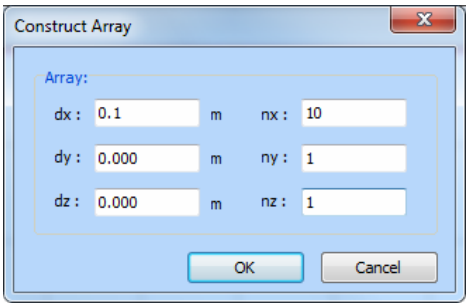


Fig. '**construct array**' dialog

To duplicate the part just designed, you first have to mark both conductors by pulling up a frame around them with the mouse. Next select the **'construct array'** command from the **local menu** (right mouse button). The shift in x-direction must be 0.1 m, the number must be 10.

Now the first bus bar inclusive the outgoing cables is complete. At the end of the bus bar, however, one surplus conductor is left. Delete it by marking it and pressing the **'DEL'** key. Next we construct the current bar to the low voltage distribution. To do this, construct a conductor with the start coordinates (0.7, 0, 2.1) and a length of -1 m in z-direction by using the **'polyline'** command. For this conductor, in contrast to the previous conductors, enter the following electrical parameters: voltage 0.4 kV, current 577 A, phase 0°.

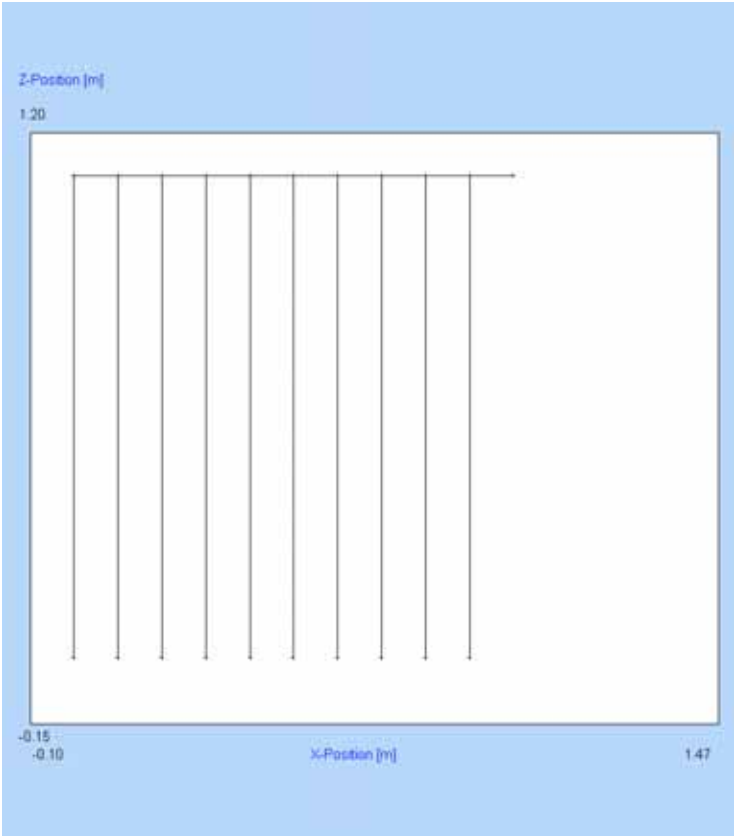


Fig. first bus bar inclusive outgoing cables

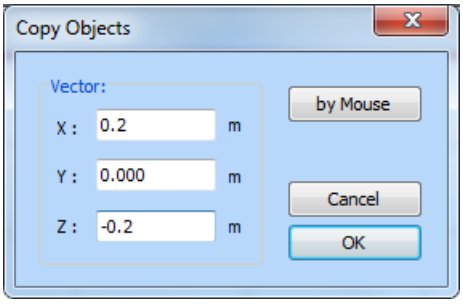


Fig. **'copy'** dialog

To get the conductor groups of the phases L2 and L3, we use the **'copy'** command. Select all conductors by using the **'select all'** command from the local menu. Enter the vector (0.02, 0, -0.2) as shift of the conductors.
For the construction of the third phase select the **'selection/last selection'** item from the **local menu**, in order to mark all conductors of phase L1 once again. Execute the **'copy'** command again, this time with a shift of (0.04, 0, -0.4).

A little correction is necessary, now. The supplying current bars of the phases L2 and L3, which are leading to the low voltage distribution, must be shifted 0.1 m in x-direction (one nodal point) in case of phase L2 and 0.2 m in x-direction (two nodal points) in case of phase L3, respectively. Please do this alone by means of the **'move'** command, which works in a similar way as the **'copy'** command. After you have enlarged the calculation area by selecting the **'double'** you should get a low voltage distribution as shown in the following picture.

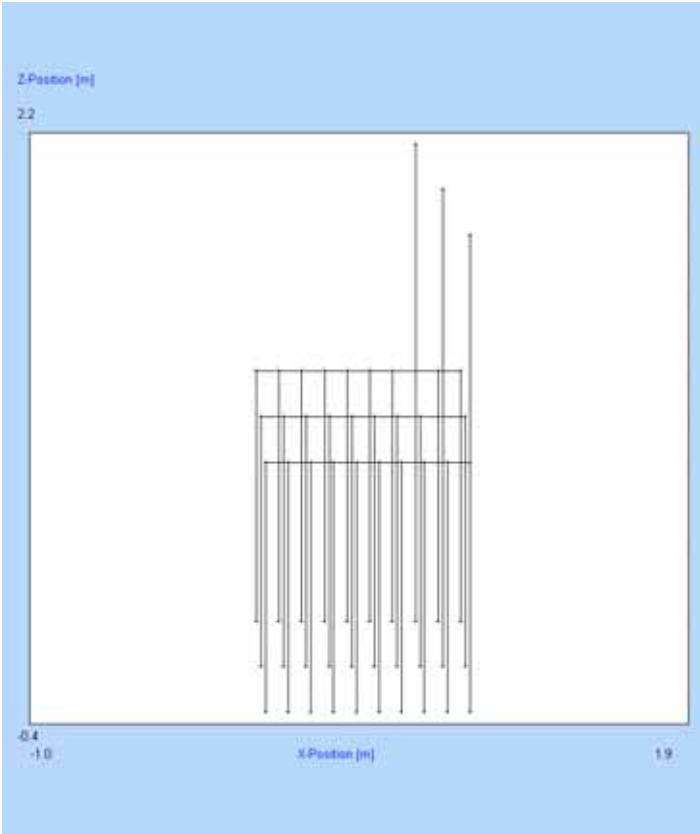


Fig. low voltage distribution with current bars

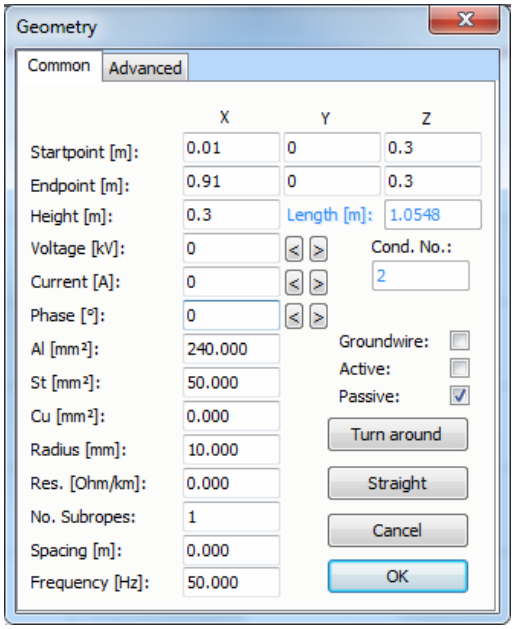


Fig. specification dialog for conductors

Finally we construct the PEN-bar. To this, please create a conductor at the position (0.01, 0, 0.3) with a length of 0.9 m in positive x-direction and a second conductor at the position (0.58, 0, 2.1) with a length of 1.8 m in negative z-direction. In the **specification dialog** for these conductors you enter 0 V, 0 A and a phase of 0°.

In order to obtain that the outgoing cables end at the PEN-bus bar, you have to mark these cables by pulling up a frame around them with the mouse. Unmark the four main bus bars which have been marked unavoidably with the outgoing cables. Select **'edit'** from the **local menu** and enter 0.3 m as z-coordinate for all endpoints.
To remove the sag please select all conductors and execute the **'straighten'** command from the local menu. Alternatively to the **'straighten'** function you can activate the **'auto straighten'** entry from **'tools'** menu. If you do so, only straight conductors are permitted for the construction.

In the same way set the start points of the three supplying current bars and the corresponding PEN-bar to a uniform height of 2.1 m.

If you have not activated the **'auto straighten'** function before, please mark all conductors and execute the **'straighten'** command from the local menu, in order to remove an eventual sag of the conductors.

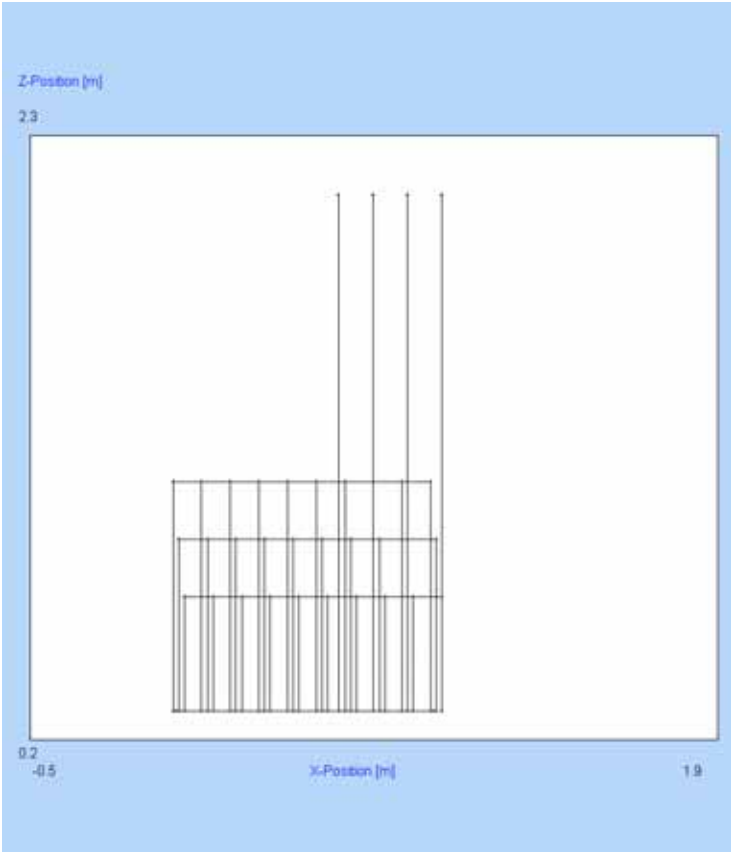


Fig. complete low voltage distribution

Now we have completed the construction of the low voltage distribution. However, the currents of the different conductors haven't been set yet. You can use the **'correct kirchhoff law'** function to let **EFC-400** calculate the currents.

Therefore we first set the currents of the three supplying current bars. Click on the corresponding conductors (vertically going conductors) with the right mouse button and set current and phase of the right current bar to 577 A and 240°, respectively; set current and phase of the second current bar from the right to 577 A and 120°, respectively, and of the third current bar from the right to 577 A and 0°, respectively. To let **EFC-400** calculate the missing currents, mark all conductors and execute the **'correct kirchhoff law'** function from **'calculate'** menu.

When pressing the function key '**F4**' EFC-400 shows the calculated currents of all conductors. Some conductors are shown in red. These conductors are **active**, while the gray ones are **passive**.
All conductors on which the current has been set manually are automatically identified as active conductors. Thus the geometry just contains three active conductors. The function '**correct kirchhoff law**' needs this active conductors to calculate the current distribution on connected conductors.

Because the current entry of the complete power station lies not at the low voltage distribution, these conductors have now to be converted into passive ones, to allow later setting of currents automatically. Therefore mark all conductors and execute the command '**active objects | set passive**' from the '**geometry**' menu.

At the end we construct a case around the low voltage distribution. Therefore call the '**case manager**' with '**geometry | 3d objects | case**' and create a new case by pressing '**new**'. Insert the coordinate (0.5, -0.1, 0) for the case midpoint; for the width 0.3 m; for the height 2.2 m; for the length 1.1 m and for the height at roof 2.2 m.

Now the construction of the low voltage distribution is really finished. In order to be able to use the actual geometry later we will define a new block.

Mark the complete geometry and select the **'blocks'** item from **'geometry'** menu. Enter **'NVT_1'** as name for the block and create the block by clicking on the **'create'** button before you conclude the dialog with **'OK'**.

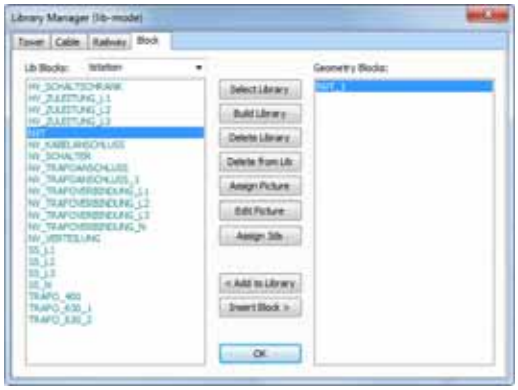


Fig. '**block library**'

To save the block in the library call the **'block library'** item from **'geometry'** menu and select the **library** named **'TSTATION'** by means of **'select library'**. The appearing dialog shows two columns of blocks. On the right side you see the blocks of your geometry, you can find the block **'NVT_1'** here. On the left side you see the blocks of the library **'TSTATION'**. Now please select the block **'NVT_1'** and click on the **'add to library'** button to add the block to the **library**. Later you can load this block from the **library** and insert it in your geometry.

C.2 Construction of the transformer model

The next step is the construction of the transformer model. Therefore close your project first and create a new geometry with **'new'** and select the template **'Station'**. (Let's hope you have saved the low voltage distribution in your **library** already!)
The transformer model consists of three coils, the transformer candles and the connections between coils and candles. We start with the construction of the high voltage transformer candles.
Please construct a **polyline** at the point (-0.125, 0.22, 1.3) with a vertical length of 0.15 m in ground direction and assign the parameters 20 kV, 11.5 A and phase 0° (L1).
Use the **'construct array'** command to construct the two other candles moved by respectively -0.22 m in y-position (dy = -0.22; ny = 3). Correct the phase so that the lowest candle in the xy-view has the phase L3 (240°) and the middle candle the phase L2 (120°).
The low voltage candles will be proceeded similar: the first transformer candle starts at the position (0.1, -0.18, 1.15) and ends 0.15 m vertically up from there. The voltage is 0.4 kV, the current 577 A and the phase 240°.
The other candles are created again with the **'construct array'** command (dy = 0.12, ny = 4), whereas the upper candle in the xy-view represents the connection to the star-point of the transformer and so current, voltage and phase are set to zero. For the other three candles (from bottom to top) the phases 240°, 120° and 0° have to be assigned.

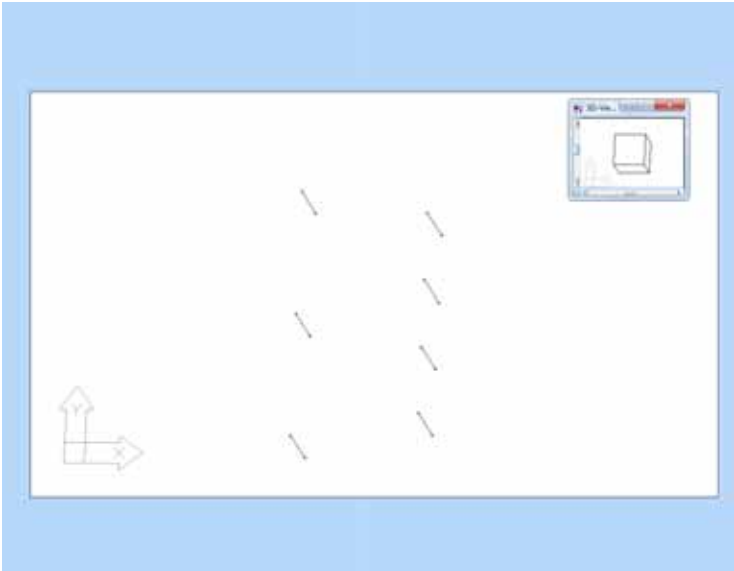


Fig. high and low voltage transformer candles

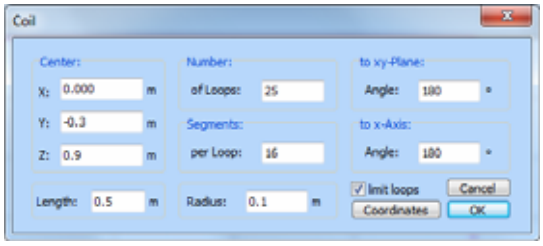


Fig. **'coil'** dialog

Next we start with the construction of the coils of the transformer model. Therefore the **'coil'** function from the **'3D-objects'** submenu of the **'geometry'** menu is used. For the centre of the first coil type in the coordinate (0, -0.3, 0.9); for the length 0.5 m; for the number of windings 25; for the radius 0.1 m and for the two angles **'to xy-plane'** as well as **'to x-axis'** 180°. Confirm with **'OK'** and enter the specifications 0.4 kV, 13.8 A and 240° phase.

The current of 13.8 A results from the transformer model and is calculated as follows:

$$I = I_n * u_k / s$$

With I_n = 577 A , u_k = 6 % and a shielding factor s = 2.5 of the steel encapsulation a current of 13.8 A results.

Note: For saving resources **EFC-400** creates only 10 instead of 25 windings and increases the current by factor 2.5.

The other two coils can now also be created with **'construct array'** (dy = 0.3, ny = 3). For the middle coil please assign 120° and for the upper 0° as phase.

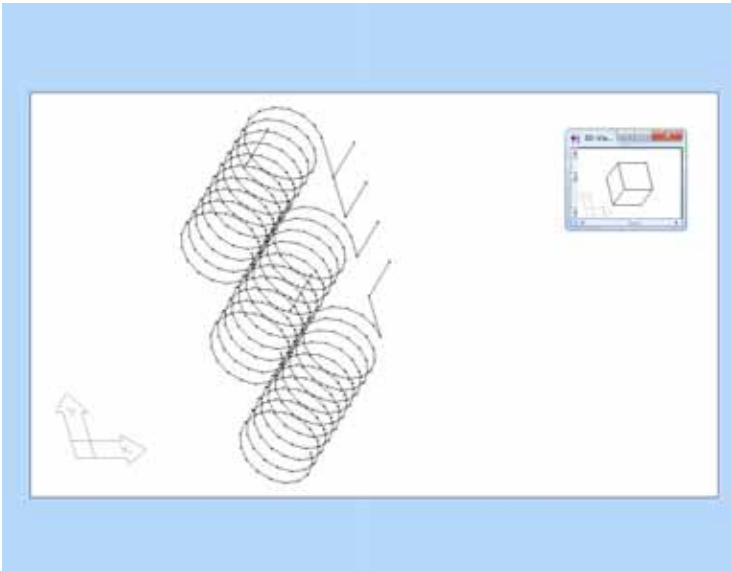


Fig. transformer candles and connected coils

To connect the coils with the low voltage transformer candles the **'connect'** command from the local menu is helpful. Choose a suitable viewpoint with the **'3D-viewpoint'** command and mark the last upper conductor of one of the three coils as well as the accompanying low voltage transformer candle by mouse. Execute the **'connect'** function which gives you the choice between the modification of the existing conductors or the insertion of a new one. Choose **'yes'** to produce a new conductor for the connection between the coil and the candle and proceed then in the same way with the other two coils.

To construct the star-point of the transformer model, please change to a viewpoint in which the three lower connections of the coils are recognizable.

Call the '**polyline**' function and select the button '**by mouse**'. With the cursor in form of a small square you select the end-coordinate of the last conductor at the bottom of the middle coil, which will be quitted acoustically. Next select the end-coordinate of the coil with phase 0° in the same way and finish the polyline by pressing the right mouse button.

Please assign the following specifications to the new created conductor: current = 577 A, voltage = 0.4 kV and phase = 0°.

Construct a conductor from the lower connection of the middle coil to the lower connection of the lower coil in the same way. The specifications should be a voltage of 0.4 kV, a current of 577 A and a phase of 240°.

For an disappearing current sum in the star-point, please set also the last conductor of the middle coil on a current of 577 A and a phase of 120°.

To complete the transformer model only the connection of the star-point with the accompanying transformer candle is missing, which gets the same specifications as the candle. Please construct this conductor by your own!

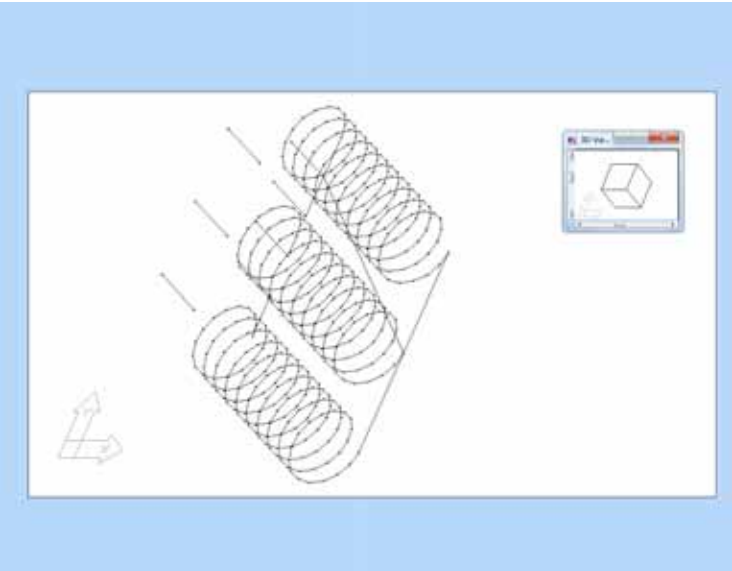


Fig. complete transformer model

With the function key '**F3**' you can take a look at the orientation of the conductors of the transformer model. The conductors of the high voltage transformer candles and the candle of the star-point are oriented from top to bottom, all other conductors show away from the star-point.

If the high voltage transformer candles or the candle of the star-point are oriented from bottom to top, mark all concerned conductors and execute '**rotate | turn around**' from the local menu.
After that all conductors are demarked by double click with the left mouse button. Mark the candle of the star-point and execute '**align direction -> yes**' from the local menu to orientate all other conductors on the candle.

To get the correct currents for the transformer model, those were entered manually for all conductors of the model, what has the consequence that those conductors are **active**. All conductors, except the low voltage transformer candles, therefore must be set **passive**.

Because there is the danger, that by setting the currents automatically, the calculated model currents get changed, all the connections to the coils have to be disconnected. The same holds for the star-point itself.
Therefore mark the three conductors, which connect the low voltage transformer candles with the coils, and the conductor, which connect the star-point with the transformer candle and move these about 0.002 m in x-direction.
In the star-point the conductor with phase 0° gets moved 0.002 m in y-direction, the phase 120° conductor about -0.002 m in y-direction and the phase 240° conductor about -0.002 m in z-direction.

At the end a case around the coils of the transformer is constructed. Call the '**case manager**' and insert for the midpoint of the new case the coordinate (0, 0, 0); for the width 1.2 m; for the height 1.2 m; for the length 0.7 m and for the height at roof 1.2 m.

For later use of the transformer model, select all conductors and create a new block with the title **'transformator'** in the **block manager**.
Call the **'block library'** and save the geometry block **'transformator'** which is visible on the right side in your library **'TSTATION'**.

Step D): Positioning constructed subgroups on the map

Now delete the complete geometry and load the background map if this hasn't happened yet. We start with the insertion of the low voltage distribution and the transformer model in the geometry.
At first we insert the transformer model into the geometry. Therefore please call the **'block library'** and select the **'transformator'** entry in the left list with a double click by mouse. After that the transformer model appears in your geometry it can be moved by mouse to the right position.

Note: Alternatively you have the possibility, to insert the transformer into your geometry with the button **'insert block'**. In the appearing dialog box you have to choose **'by mouse'.**

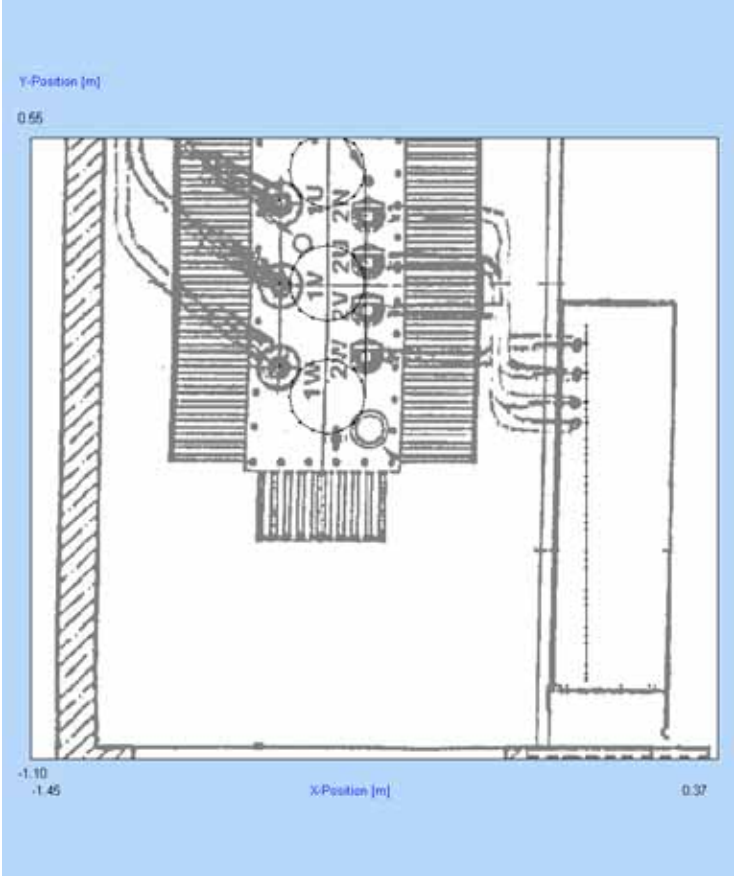


Fig. ground plan with transformer model and LVD

Inserting the low voltage distribution is the same procedure. The only difference is, that the LVD has to be rotated around 90° because the low voltage distribution was constructed in front view. This is done pressing the '<-' key while moving it by mouse.

Note: If you don't insert the LVD by double click, but by the button **'insert block'**, you can enter the rotation angle of 90° directly. If the position of the LVD shouldn't be optimal at the first trial, simply move it. Also additional rotation is possible.

Step E): Connecting the subgroups to the complete power station

E.1 Connection between transformer and low voltage distribution

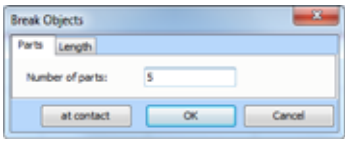


Fig. **'break'** dialog

There are more possible variants for the production of the cable connection between transformer and low voltage distribution, of which we describe a few possible ones in the following.

The single cables get constructed from the starting point at the transformer candle direct to the corresponding connection at the current bar of the low voltage distribution, which can be simplest realized with the **'connect'** function. This is applied for all four conductors; the specifications are overtaken automatically.

After that mark the new four conductors and break them into five parts with the **'break'** function from the **local menu**.

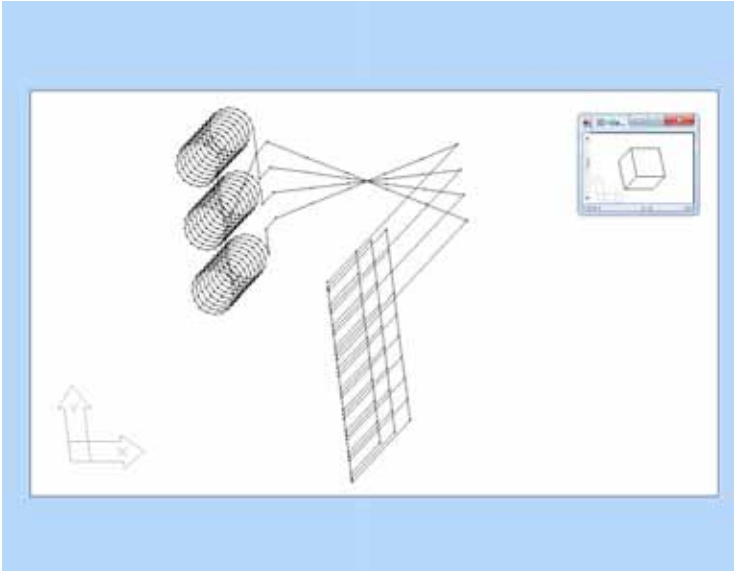


Fig. straight connection between transformer and LVD

With the loaded **'background map'** in xy-view you can now pull the conductors with the **'stretch'** function from the **local menu** by the mouse along the cables drawn in the map.

To do this please mark the first two parts of the PEN-conductor (the two parts near the transformer) by mouse. Call the **'stretch'** function and push the **'by mouse'** button. Instead of the mouse pointer now a cross appears in the **construction window**. With this cross click in the centre of the window and pull the intersection on the first recognizable bend of the cable, before you click once more to finish the command.

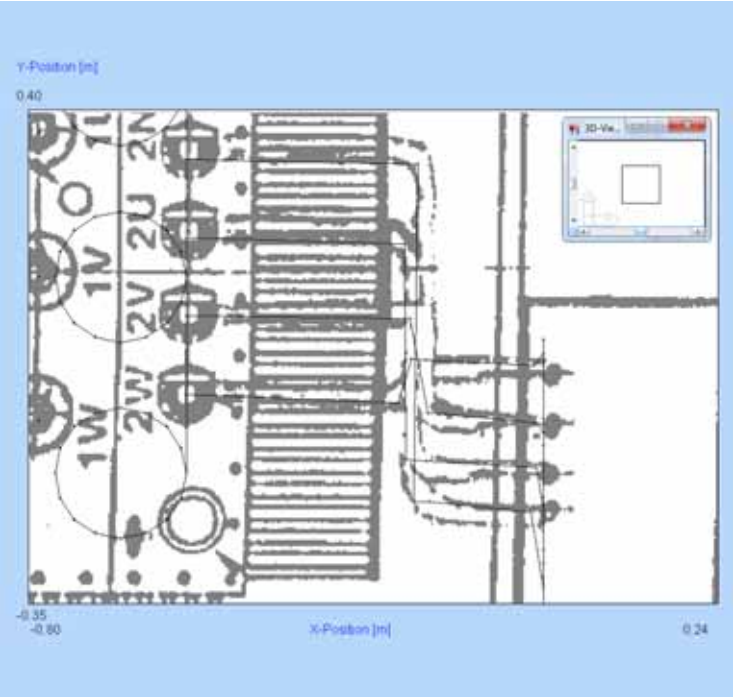


Fig. corrected cable connections

In the same way the second and the third parts are marked and the intersection is pulled on the lowest recognizable bend of the cable. The third nodal point get pulled into the proximity of the second one, since it shall lie more highly later. Slide the fourth intersection into the proximity of the bus bar please.

Deal with the other conductors analog to this example and change the plane to the xz-view afterwards.

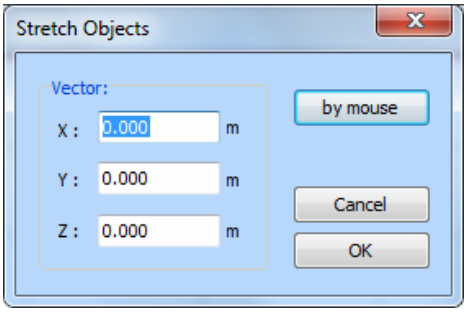


Fig. **'stretch'** dialog

Now please mark the first two conductor parts (the two parts near the transformer) of all four cables together, and pull the intersection far below till the first cabling sections proceed horizontally with the **'stretch'** command. The next intersections get pulled exactly over the just pulled ones **('stretch')**, since the accompanying conductors lay horizontal in y-direction and are not recognizable in this view.

The remaining intersections get also pulled vertical but on the height of the current bar connection to the low voltage distribution.
To complete the construction all new created conductors get summarized as block **'NV_Trafoverbindung'** which is saved afterwards in the **block library**.

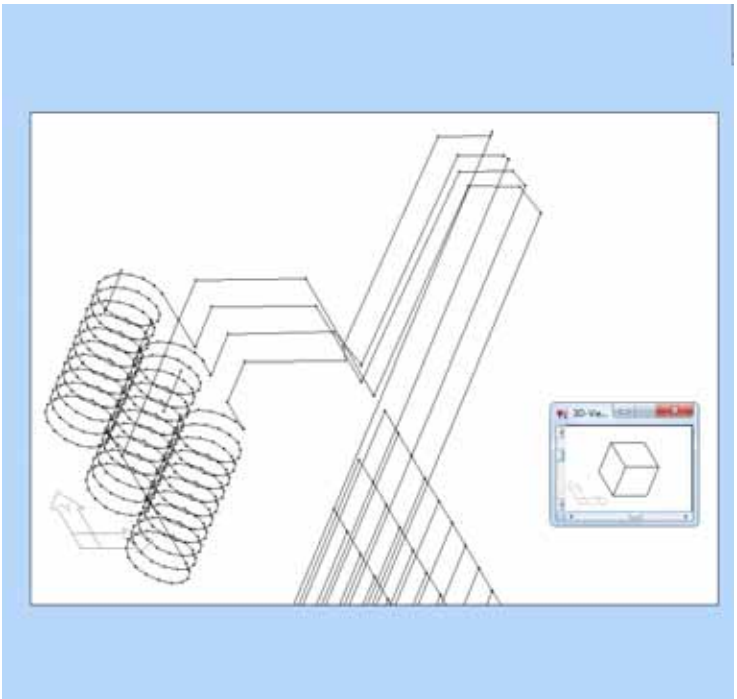


Fig. corrected connections

E.2 High voltage supply to the transformer

You can insert the high voltage supply to the transformer directly as block (**'HV_Zuleitung_L1'** to **'L3'**).
If you want to perform the construction manually there is another interesting possibility where the coordinates get chosen by mouse along the cable drawn in the plan.
Therefore please change into the xy-plane in which the background map and the already inserted transformer model as well as the low voltage distribution are visible.

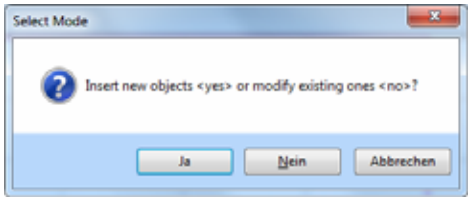


Fig. **'connect'** dialog

After clearing the coordinate list and dismarking of all conductors please choose **'select coordinates'** from the local menu and click with the cross of the mouse along the course of the drawn cable **'L1'** starting from the high voltage section up to the upper transformer candle. After the last selected coordinate the **'select coordinates'** function is ended by the right mouse button. With this coordinates a **polyline** with the specifications of the accompanying transformer candle can be constructed now.

While those conductors till now are on a height of z = 0 m, all conductors up to the bend in the left upper corner of the station get pulled on the height of the high voltage feeding (z = 1.6 m). The remaining conductors get pulled on a height of z = 1.4 m (**'stretch'**) and afterwards straightened with **'straighten'**.

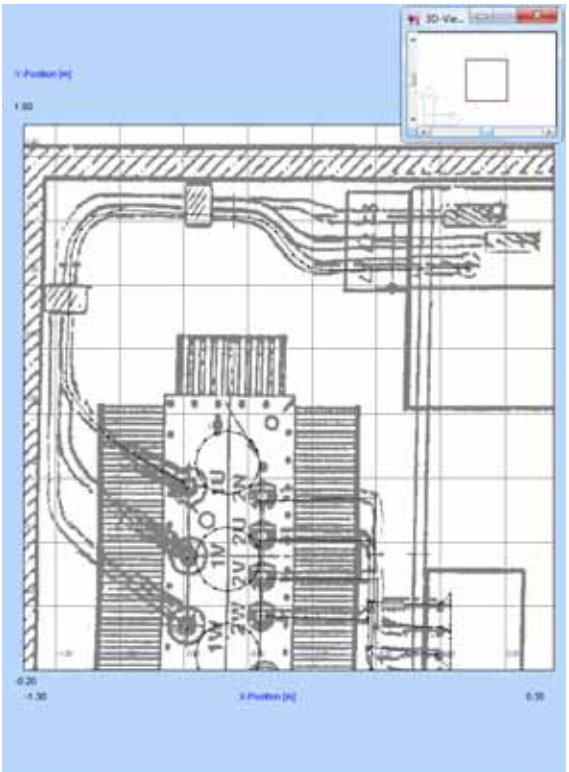


Fig. connection candle - HV-feeding

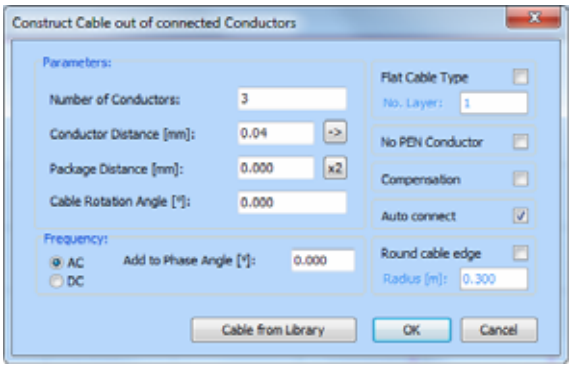


Fig. **'construct cable'** dialog

Note: The call of **'straighten'** is only necessary if the setting **'auto straighten'** is not activated.

To connect this cable with the accompanying transformer candle the missing conductor is completed with **'connect'**.

Please construct the two other cables in the same way. It shall be taken into account that the cable L3 lies 0.04 m below the two other cables in the area in which the cables are transferred as bundle.

Finally summarize all three cables to one block and save it in the block library under the name **'HV_Zuleitung'** for further usage.

Note: You can simplify the procedure performed for the construction of the high voltage feeding to the transformer while you construct merely one phase of this cable and afterwards use the function **'construct cable'** to convert this one phase to a cable consisting of three phases.

Note: Constructing a cable in the **'extended'-format** is another construction possibility of the high voltage feeding to the transformer. Therefore select coordinates along the course of the cable by mouse and generate a cable in the **'tower manager'** whose number of sections corresponds to the number of the selected coordinates minus one. The height position of the new cable is z = 0 m. You can add the actual heights manually while you take those from the planning underlies. For the alignment of the cable at the bends execute the function **'adjust angles / auto adjust'** and take into account that the check box **'allow angle to xy-plans for cables'** is activated. If you change into the **'standard'-format** now you can construct the connections between cable and transformer.

Note: Each of the introduced procedures has advantages and disadvantages. Which of the procedures is most favorably for your respective application case, you may decide after some exercise.
Inside of stations it is most simply to work with the function 'construct cable', which was provided especially for that. For the cable supply of the complete station from outside, the cables from the 'extended' format are more suitable, because these can be quickly positioned inside cable trenches.

Step F): Checking the geometry and setting of currents

After you have added the complete power station out of the single subgroups and the connection lines we prove the correctness of the geometry.

Therefore first change to the top view of the **construction window** (**'xy plane'**). Check once again exactly whether the single groups and all connections are at the right position. Call **'3D-viewpoint'** of the local menu and rotate the viewpoint so that you have a good survey over the geometry. Examine visually the consistency of the construction. If necessary zoom ranges of interest.

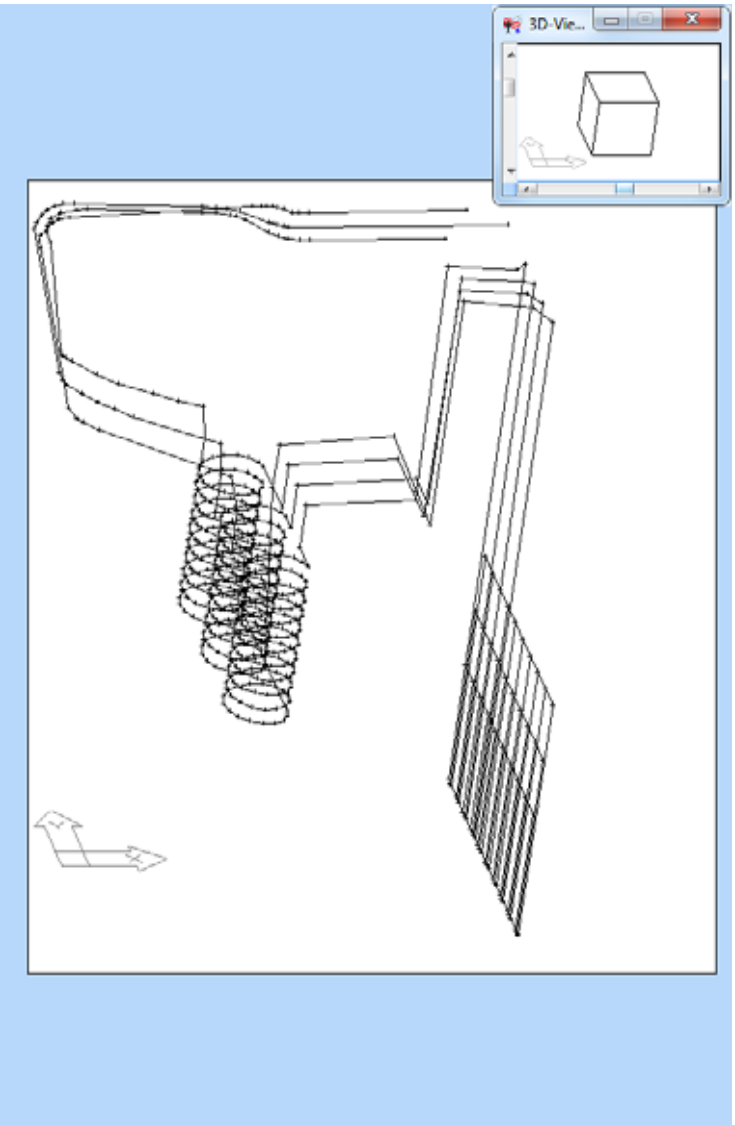


Fig. complete power station in 3D view

Should you have the suspicion that conductors on some positions are not connected you have the possibility to prove

this in the following way: press the ctrl key. If you now select a conductor by mouse. **EFC-400** marks not only this one conductor, but additionally all ones connected with this. If you find spaces between conductors, close these with **'stretch'** or **'connect'**.

To set currents for the complete geometry, only the three conductors of the ingoing HV supply and the low voltage transformer candles have to be active. This can be improved by pressing **'F4'**. This conductors have to carry the right currents and phases, respecting also the conductor direction. All other conductors are corrected to these.
If the geometry contains no errors so far, mark the complete geometry by double click and execute **'correct kirchhoff law'** from the **'calculate'** menu. All currents will be set automatically.
For the computing of field strengths it isn't necessary, that the gaps between all conductors are closed, but only then you can rely on the function **'correct kirchhoff law'** and the test by means of **'check kirchhoff law'** from the **'calculate'** menu, which we want to execute in the following. Now call **'check kirchhoff law'**. **EFC-400** thereupon marks all conductors in which intersection points the kirchhoff law is not fulfilled.
If conductors are marked in your geometry you have to prove the currents on those. This is carried out while you click with the right mouse button on the corresponding conductors and read out the current in the appearing **specification dialog**. Should the currents show no faults so it is possible that eventually the orientation of the connected conductor is incorrect. To prove this you can press **'F3'**.

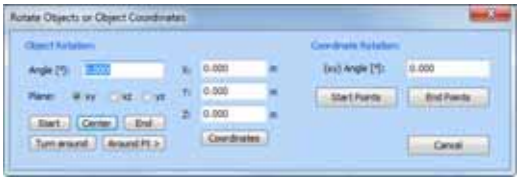


Fig. **'rotate'** dialog

If the orientation of the conductors is correct as well, there is one more possibility that voltage, phase or frequency are different. Therefore if necessary execute once more the **'check kirchhoff law'** function and look at the dialogs which show you the cause of the faults. Eventually repair faults while selecting single or more conductors and change the wrong specifications. In case of incorrect orientation of conductors rotate those if necessary by means of the **'rotate/turn around'** function.

After the corrections it is meaningful to mark once more all conductors and execute the **'straighten'** function with which all conductors are stretched to remove a possible sag.

Note: This is only necessary if the setting **'auto straighten'** is not activated.

Step G): Computing the field strengths

First we compute the field strengths on a plane parallel to the ground in a height of 1 m.
Therefore call the **'calculation parameter'** dialog and press the **'xy plane'** button to align the plane. In every case prove the z-coordinate. Here it must have a value of 1 m. If there is the **'Startpoint'** and **'vector'** lettering shown in your dialog, please change the mode by clicking on the **'mode'** button. After that the lettering **'Startpoint'** and **'endpoint'** should appear in your dialog. In this case specify the calculation plane by declaration of the two opposite corner points of a rectangle. Now check the increments dx and dy which should be 0.05 m. Otherwise adjust these values. Should you wish a finer or rougher calculation grid, you can achieve this with the **'refine'** or **'enlarge'** buttons. Afterwards close the dialog with **'OK'**.

Note: If you want to increase the complete computation area you can achieve this with the **'double'** command.

Before computation it is meaningful to check the computing options once again. Therefore invoke **'options | extended'**. Click on the **'default'** button to choose the standard settings which always lead to correct results. Should the computing speed be too slow, you can increase the number of the interpolation points at a later time if necessary. But then also enable the **'dynamic interpolation'** option to activate the faults control if you still haven't any experience in working with field computations.

Fig. **'technical'** dialog

Next open **'options/ technical'** and click on the **'default'** button again. This makes sure that the frequency gets fixed on 50 Hz and the voltage type is **'system'**. You can start now the computing by clicking on the toolbar button **'B'**. After computation is finished please open the **'2D view'**. The scaling in the **2D view** was carried out on the maximum value. To get a scaling on 100 µT open the **'options | extended'** dialog and insert 100 as **'max data scaling'** and please change the units to µT if necessary. Next open the **'option/ standard'** dialog to activate the title and insert the name 'magnetic flux density, 1 m over the ground, 400 kVA'.

To get another color scheme for printing please invoke the **'colors'** item from the **'options'** menu and choose e.g. the configuration file **'bluepink'** or **'blue'**. Now make an out printing to convince yourself of the quality of the results.

Note: Unfortunately this isn't possible with the demo version.

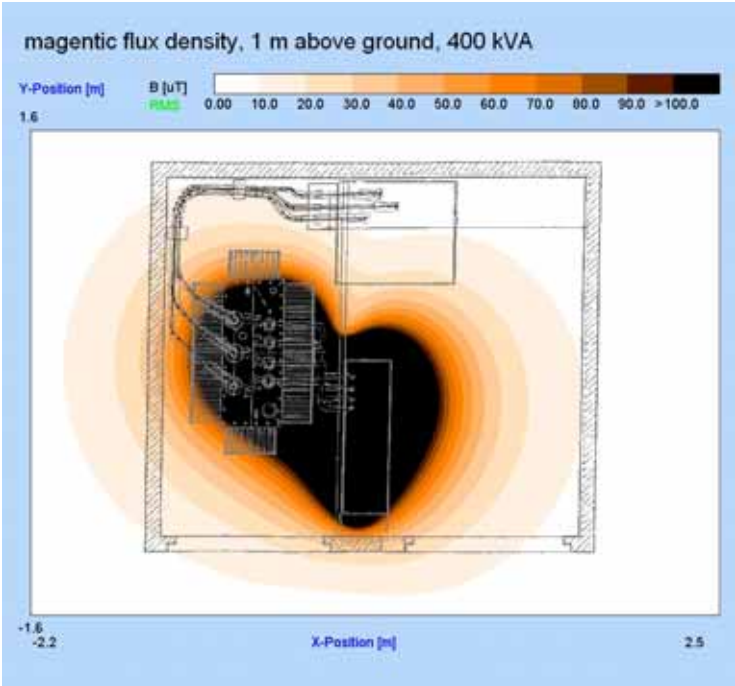


Fig. representation of the computing result in **2D view**

To check the magnetic flux density in a distance of 20 cm from the station wall, like demanded in the "Hinweise zur Durchführung der 26. BImSchV", you can call the cursor function from the **local menu**. While analyzing the coordinates move the cursor into the corresponding distance to read out the flux density in the upper left corner of the window. Of course this value is only valid in the height of 1 m.

For a complete documentation you can continue as described with other heights (e.g. 0 m and 2 m) for the computing plane and make once more an out printing. If persons can stay on the station you should also take into account a height of 20 cm over the roof. But because even with this method the maximum in 20 cm distance from the building wall can be disregarded, it is meaningful to calculate additionally at least one vertical cut in 20 cm distance of the building wall. In the top view of the station in a height of 1 m you can recognize that the maximum is in front of the lower building wall.

To adjust a corresponding calculation plane measure the y-position of the building wall with the cursor. This is about -1.20 m. The plane must therefore cut the y-axis at y = -1.4 m. Call the dialog for adjusting the calculation parameters and click on **'xz-plane'**. Enter -1.40 m for the start point of the y-coordinate and execute the calculation again. By measuring with the cursor you can simply see that the maximum is in a height of 1.20 m over the ground and the magnetic flux density is about 10 µT.

Note: Another possibility to position the calculation plane on a place in front of the wall is offered by the previous choice of the coordinates of a point, around which the calculation plane has to be rotated. In this example select the coordinates of a point with the cursor, which lies 20 cm in y-direction in front of the building wall. This point lies at y=-1.4 m. Call the dialog for setting of the calculation parameters and click on '**xz-plane**'. Now the plane will be automatically rotated around the selected coordinate.

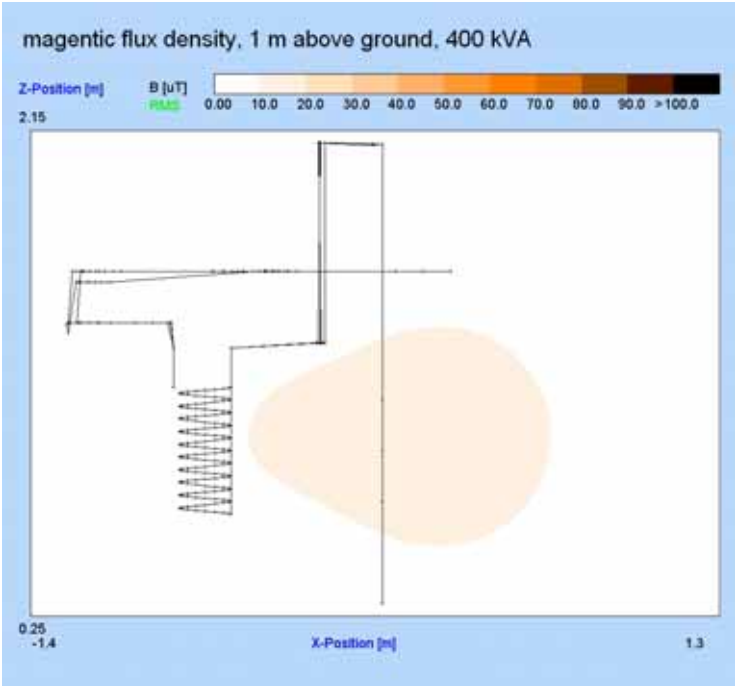


Fig. vertical plane in 20 cm distance in front of the building wall

If you calculate the other three planes in front of the building walls in this way your documentation of the power station is fully concluded.

18. Special Functions

18.1 Coordinate selection by Mouse

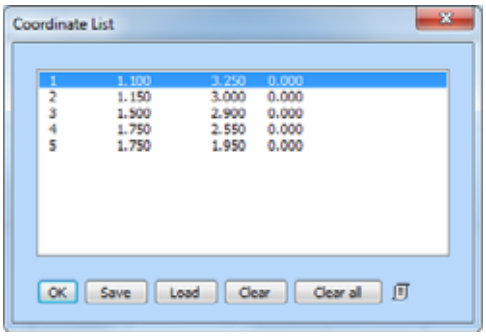


Fig. Coordinate List

EFC-400 allows handling of a list of coordinates, in order to use them for the creation of objects. These coordinates can be inserted into the list by mouse click.
The following selection modes exist:

free mouse position
mouse position with grid-snap
selection start/end coordinates of objects
direct selection of objects coordinates in 3D

The choice of the selection method is carried out with the **TOOLS | COORDINATES | SNAP** menu item. Coordinates can be selected in the views 2D, Isolines and Construction by executing **TOOLS | COORDINATES | SELECT** or by invoking the pop-up menu in the corresponding window by a click with the right mouse button and choosing **SELECT COORDINATES**. The cursor and the coordinate display appear after that. The coordinate is taken into the list with a left mouse click. At the position of the mouse click red markers keep staying until the next redraw.

If the selection of object start/end points is predefined, the described method remains available as long as no object is highlighted. If objects are marked, the start/end coordinates are chosen directly with **SELECT COORDINATES** and no cursor appears.
By setting a snap-grid, the positions selected by cursor are rounded to the next available grid position. Start/end points of objects remain untouched by this.

Note: You can also select coordinates in the 3D view of the construction window. Since free selection of coordinates is not possible from a 3D-viewpoint, selection of object start or end points is well defined. Thus the cursor shows a tiny square executing **Select Coordinates** in 3D view. This procedure is in many cases more comfortable than the old one (selection of object start/end points).

The list of coordinates can be used for the production of the following objects:

transmitter, conductor and tower
drawing of polylines
insertion of blocks
insertion of geometries
creation of buildings
insertion of measured data

A **COORDINATE** button, which calls the coordinate list, is available in the corresponding dialogs. By marking a list entry and confirmation with **OK** the coordinates are assigned to the desired object. In the case of polylines, **SELECT ALL** takes the complete list. In case of towers, only the numbers of list

entries are assigned, as towers are available behind the currently selected one in the transmission line.

In praxis this offers the following simplification:

Example 1: Create a new geometry**.** Load the background map of the area. Select the coordinates of the towers directly from the map. Create the desired number of towers. Assign the complete coordinate list to the tower positions with **SELECT ALL**.

Example 2: You have already made the collecting track and the conductors during the construction of an installation. All typical components are defined as blocks. Choose the insertion points of the components as start/end points of the already available geometry in the coordinate list and join the components together one by one.

Construction Tools

Helpful are the functions F8 - ortho on/off and F9 - snap grid on/off. The snap grid is available in any 3D-viewpoint, but is only drawn in plane view.

Direct work by Mouse

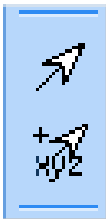


Fig. Direct Mouse Mode

For many functions you have the choice to enter coordinates manually or select coordinates via mouse. With the last 2 speed buttons you can select between direct mouse action or alternative coordinate input.

Note: After construction of power transmission lines, polylines e.g. via the coordinate list, the points remain in the list for later use. Eventually you have to delete the list manual. Activating **Auto Clear** from the **Coordinates** sub menu, clears the list automatically after every construction action.

18.2 Calculator

A compact calculator can be invoked from the **Tools** menu by the **Calculator** item. If you should prefer another calculator, you can enter its name under advanced settings instead of WFCALC.EXE.

18.3 Integrated Editor

A text editor can be started by the **Editor** item from the **Tools** menu, for example for working on batch files. The editor WFEDIT.EXE can be replaced by another editor of your choice.

18.4 DXF Object Filter (DXFilter.exe)

The program DXFilter.exe allows you to remove objects from DXF files below a predefined minimum size. This is useful, if you want to embed scanned DXF files into **EFC-400**. These files can be very large, due to the scanning process. DXFilter.exe removes all objects below the minimum size and reduces the storage space considerably. Moreover, if you select several files, these are connected to one output file!

18.5 WF Paint-Tool

The program **WF Paint-Tool** delivered with **EFC-400** makes the post-processing (e.g. additional marking) of graphs possible. If you call **PAINT** from the **TOOLS** menu (or in the pop-up menu), the active graphic window is selected. Paint-Tool is a simple, yet very fast, program, which uses little resources. It is up to you, as with all **EFC-400** tools, to bind another program of your choice by changing the settings. Provided that your preferred graphic program permits the submission of a bitmap as a command line parameter, it will also open the active **EFC-400** graph automatically.

18.6 Assistant

EFC-400 provides an assistant, which supports your work in many cases: power transmission lines, cables and power stations. The assistant opens automatically at program start of EFC-400 and on creation of new geometries or projects. The assistant contains a brief description of all the construction steps.
Disable **Options | desktop | assistant on new** to turn the Assistant off.

18.7 Undo

EFC-400 supports a maximum of 9999 undo and redo level. The pre-setting is 50 undo/redo level, which should be enough for the most users. If you wish more levels, you can change this in the EFC-400.Ini file.

18.8 Auto Recover

EFC-400 provides a **Auto Recover** function. When the program should crash once during construction, at the next program start the latest construction state will be recovered.

18.9 Menu Language

The main menu is available in two languages: English and German. You can change the language under **Options | Language**.

Note: All language strings are completely loaded out of DLL's. If this is unstable on your platform you can use the internal strings by: a) delete the DLL's with the names lang_us.dll and lang_gr.dll or b) disable the option **Not for Dialogs**, which prevents from loading the DLL's.

18.10 Publish HTML

With this command you can publish your calculation results (pictures) as HTML page. The results can be found in the sub directory **html**.

18.11 Publish CD

Publish CD allows to publish CD's of the kind **Fields in Eastern Berlin V1.0**.
You select the project data you wish on CD and EFC-400 creates the CD-ROM directory EFC-400\temp\cd_rom for you. The contents of this directory needs only to be copied (burned) on CD to get a self running Demo.

18.12 Last Command

Commands can be repeated by F2.

19. Appendix A:

19.1 Data Formats

1) File types

Description of file types

EFC-400.EXE	main program
EFC-400.CFG	standard configuration file
EFC-400. HLP	help file
INSTALL.EXE	installation program
READ.ME	information file
SETTIME.EXE	tool to change the file date
BFC.EXE	run-only command line version

Extensions

*.GEO	geometry data
*.B	calculated B-field data (complete or RMS)
*.BP	calculated B-field data (Peak)
*.E	calculated E-field data (complete or RMS)
*.EP	calculated E-field data (Peak)
*.PRO	ground profile data
*.TMP	temporarily stored computation data
*.REF	reference point of a JPG-, PCX-map
*.PCX	PCX-bitmap
*.JPG	JPEG-bitmap
*.WMF	Windows Metafile format
*.TOW	tower geometry
*.LIB	current library paths
*.ICO	EFC-400 icon
*.DXF	Drawing Exchange Format
*.BAK	backup dataset
*.CFG	configuration files
*.LOG	log-file
*.TAB	tables
*.DOC	documents
*.INI	initialization file
*.BKL	current block library paths
*.XML	XML database
*.MES	array of measured data
*.IFO	project information
*.RPT	report
*.SBK	ToolBook™ files
*.TBK	ToolBook™ files

2) GEO-Format

Geofiles are stored in **ASCII**-format and can be modified by a text editor.
The header contains the definitions of the computation area, of interpolation points, and of the segmentation. Subsequently the geometry elements follow, which are organized in 3 sections:

a) conductors and ground wires
b) tower segments
c) tower parameters

Extract from the 3TOWERS file:

```
calculation startpoint      -100.000  -400.000     1.000          [m]
direction vector               2.000     0.000     0.000          [m]
number of points          101
shift in y-direction           25.000                             [m]
number of rows            33

interpolation points      0
segments per conductor    1


no. of conductors         14

phase conductor no. 1
startcoordinates              -7.750     0.000    23.970          [m]
endcoordinates                -7.750   320.000    23.970          [m]
height at midspan             11.970                             [m]
current, phase                        1000.000     0.000          [A]
voltage                                380.000                   [kV]
number of subropes                 4
rope-radius                   10.000                            [mm]
distance of subropes           0.400                             [m]
al/st, frequency               0.000     0.000     0.000         [Hz]
start, end tower no.               0         0
system no.                         0


no. of tower segments     18

tower segment no.   15
tower no.           1
startcoordinates              -0.250    -0.250    27.700          [m]
endcoordinates                -2.500    -2.500     0.000          [m]


no. of towers             3

tower no.           1     STANDARD\PCX\220EE_G.PCX
type no., name                     5  220 kV - Einebene
coordinates                    0.000     0.000     0.000          [m]
base side length               5.000                             [m]
tower height                  27.700                             [m]
angle                          0.000
tower feet                         4
no. traverse grider                2
grider height, width          19.800   -17.500                    [m]
grider height, width          19.800    17.500                    [m]
```

3) CFG-Format

Configuration files of **EFC-400** contain complete settings, colors etc. The header is similar to the GEO-format. However, settings in a GEO-file have priority. In CFG-files, general settings and options are stored.

Print of the SPECTRAL.CFG file:

```
segments per conductor    1

calculation startpoint       -50. 000   -50. 000     1.000
direction vector               1.000     0.000     0.000
number of points          101
shift in y-direction          20.000
number of rows            21

interpolation points      0

frame on/off              ON
grid  on/off              ON

printer                   DESKJET

StartUpDirectory          D:\BF_LT

colorpalette              SPECTRAL

background color          WHITE
Window color              BLACK
hotkey color              RED
text color                BLACK
data color                BLUE
units color               DARKBLUE

max data scaling                 0.000
show ropes on/off         ON

user plot color 0         0
user plot color 1         1
user plot color 2         2
user plot color 3         3
user plot color 4         4
user plot color 5         5
user plot color 6         11
user plot color 7         12
user plot color 8         13
user plot color 9         15

command delaytime ms      0
print graphics only       OFF
titel on/off              OFF
titel

dynamic interpolation     OFF
auto segments             OFF
sparse matrix inversion   OFF
distance limit            0

frequency                 50
crossection Al/St         OFF
voltage                   SYSTEM
conductiv ground          ON
signed field components   OFF
export 3d data as         4D-PLOT

calculate tower region    OFF
segments per tower        AUTO
extended geometry format  OFF

emission frame            OFF
proportional frame view   OFF
view ground profile       OFF
geometry coordinates      ABSOLUTE
```

4) PRO-Format

PRO-files define ground profiles and consist of an **ASCII-table**, whose format is described in the **Loading Data / Ground Profiles** chapter.

Extract from the PLUS_4M.PRO file:

```
 X\Y[m] 0       20      40      60      80       1000
-200    4       4       4       4       4       4
- 180   4       4       4       4       4       4
- 160   4       4       4       4       4       4
- 140   4       4       4       4       4       4
- 120   4       4       4       4       4       4
- 100   4       4       4       4       4       4
-80     4       4       4       4       4       4
-60     4       4       4       4       4       4
-40     4       4       4       4       4       4
-20     4       4       4       4       4       4
0       4       4       4       4       4       4
20      4       4       4       4       4       4
40      4       4       4       4       4       4
60      4       4       4       4       4       4
80      4       4       4       4       4       4
100     4       4       4       4       4       4
120     4       4       4       4       4       4
140     4       4       4       4       4       4
160     4       4       4       4       4       4
```

5) ASCII Export

Export-files in **ASCII**-format contain a table which can be immediately imported into **MS-EXCEL™.** (Numbers are separated by <TAB>, lines by <Enter>).
If you export the magnetic induction calculated over a grid, **EFC-400** writes an array into the output file. In the case of only a single profile, the file looks as follows:

```
x[m]     B[uT]
 -50.0      1.766
 -48.0      1.920
 -46.0      2.095
 -44.0      2.292
 -42.0      2.517
 -40.0      2.774
 -38.0      3.069
 -36.0      3.408
 -34.0      3.799
 -32.0      4.253
 -30.0      4.780
 -28.0      5.393
 -26.0      6.102
 -24.0      6.916
 -22.0      7.835
 -20.0      8.840
 -18.0      9.883
 -16.0     10.877
 -14.0     11.709
 -12.0     12.260
 -10.0     12.440
  -8.0     12.223
  -6.0     11.685
  -4.0     11.017
  -2.0     10.471
   0.0     10.261
```

6) DXF Export

The export into the **DXF**-format is matched e.g. to **AutoCad™** (> R12.0). A list of the **Isolines**, which defines the polylines, follows after the header. The header is taken from the EFC-400.DXF file. This file contains an empty drawing with predefined layers. The user can replace this file.
The definition of polylines has the following form:

```
SECTION
  2
ENTITIES
0
POLYLINE
8
7
66
1
10
0.0
20
0.0
30
0.0
0
VERTEX
8
7
10
6.040
20
130.000
30
0.0
0
VERTEX
8
7
10
7.000
20
124.676
30
0.0
0
.................................

SEQEND
8
0
0
ENDSEC
0
EOF
```

7) 4D-Color-Array (TXT)

The export file contains 2 arrays. In the first the computation area is stored (coordinates of the calculation points). The second contains the field strength values.

Extract:

```
B[uT]     -50.0    20.0     90.0    160.0    230.0    300.0
 -50.0      1.000    1.000    1.000    1.000    1.000    1.000
 -45.0      1.000    1.000    1.000    1.000    1.000    1.000
 -40.0      1.000    1.000    1.000    1.000    1.000    1.000
 -35.0      1.000    1.000    1.000    1.000    1.000    1.000
 -30.0      1.000    1.000    1.000    1.000    1.000    1.000
 -25.0      1.000    1.000    1.000    1.000    1.000    1.000
 -20.0      1.000    1.000    1.000    1.000    1.000    1.000
 -15.0      1.000    1.000    1.000    1.000    1.000    1.000
 -10.0      1.000    1.000    1.000    1.000    1.000    1.000
  -5.0      1.000    1.000    1.000    1.000    1.000    1.000
  -0.0      1.000    1.000    1.000    1.000    1.000    1.000
   5.0      1.000    1.000    1.000    1.000    1.000    1.000
  10.0      1.000    1.000    1.000    1.000    1.000    1.000
  15.0      1.000    1.000    1.000    1.000    1.000    1.000
  20.0      1.000    1.000    1.000    1.000    1.000    1.000
  25.0      1.000    1.000    1.000    1.000    1.000    1.000
  30.0      1.000    1.000    1.000    1.000    1.000    1.000
  35.0      1.000    1.000    1.000    1.000    1.000    1.000
  40.0      1.000    1.000    1.000    1.000    1.000    1.000
  45.0      1.000    1.000    1.000    1.000    1.000    1.000
  50.0      1.000    1.000    1.000    1.000    1.000    1.000
0        0        0        0        0        0        0
0        0        0        0        0        0        0
0          0.156    1.148    1.676    1.766    1.676    1.148
0          0.158    1.408    2.068    2.191    2.068    1.408
0          0.158    1.747    2.595    2.774    2.595    1.747
0          0.157    2.185    3.313    3.596    3.313    2.185
0          0.153    2.734    4.296    4.780    4.296    2.734
0          0.147    3.378    5.615    6.495    5.615    3.378
0          0.139    4.052    7.230    8.840    7.230    4.052
0          0.130    4.631    8.766   11.321    8.766    4.631
0          0.121    5.001    9.489   12.440    9.489    5.001
0          0.115    5.143    9.118   11.352    9.118    5.143
0          0.112    5.163    8.682   10.261    8.682    5.163
0          0.115    5.143    9.118   11.352    9.118    5.143
0          0.121    5.001    9.489   12.440    9.489    5.001
0          0.130    4.631    8.766   11.321    8.766    4.631
0          0.139    4.052    7.230    8.840    7.230    4.052
0          0.147    3.378    5.615    6.495    5.615    3.378
0          0.153    2.734    4.296    4.780    4.296    2.734
0          0.157    2.185    3.313    3.596    3.313    2.185
0          0.158    1.747    2.595    2.774    2.595    1.747
0          0.158    1.408    2.068    2.191    2.068    1.408
0          0.156    1.148    1.676    1.766    1.676    1.148
```

8) Vector Export (TXT)

The export file contains a table with 6 columns. The first 3 columns contain the coordinates of the calculation points, the last 3 columns the components of the field strength vectors.

Extract:

```
x[m]     y[m]     z[m]     Bx[uT]   By[uT]   Bz[uT]
 -50.0    -50.0     1.0     -0.095    0.000   -0.099
-50.0     -30.0     1.0     -0.155    0.000   -0.192
-50.0     -10.0     1.0     -0.282    0.000   -0.334
-50.0      10.0     1.0     -0.493    0.000   -0.470
-50.0      30.0     1.0     -0.708    0.000   -0.557
-50.0      50.0     1.0     -0.871    0.000   -0.583
-50.0      70.0     1.0     -0.987    0.000   -0.564
-50.0      90.0     1.0     -1.066    0.000   -0.526
```

19.2 Shortcuts

F1	HTML-Help
Shift+F1	Hilfe
F2	Last Command
F3	Show Object direction
F4	Show active Objects
F5	Show colored Phases
F6	Select Coordinates
F7	Show Cases/Buildings
F8	Ortho on/off
F9	Snap Grid on/off
F10	Select All
F11	Release All
F12	Select Last
Ins	New
Del	Delete
Shift+Ins	Copy to Clipboard
Ctrl+O	Open
Ctrl+S	Save Geo
Ctrl+D	Save Data
Ctrl+A	Select all
Ctrl+P	Print
Ctrl+V, Ctrl+X	Move
Ctrl+C	Copy
Ctrl+I	Insert Geometry
Ctrl+G	Ground Profile
Ctrl+M	Import Background Map
Ctrl+L	Library
Ctrl+T	Tower
Ctrl+R	Redraw
Ctrl+N	Calculation Parameter
Ctrl+U, Ctrl+Z	Undo
Ctrl+Y	Redo
Ctrl+B	Calculate B-Field
Ctrl+E	Calculate E-Field
Shift+Ctrl+A	Zoom All
Shift+Ctrl+P	Zoom Previous
Shift+Ctrl+U, Shift+Ctrl+Z	Redo
Shift+Ctrl+V	3D-Viewpoint
Shift+Ctrl+S	Select Coordinates
Shift+Ctrl+C	Clear Coordinate List
Shift+Ctrl+B	Execute External Job B-Field
Shift+Ctrl+E	Execute External Job E-Field
Alt+Shift+Ctrl+M	Mark Connected Objects
Alt+Shift+Ctrl+B	Mark Blocks
Alt+Shift+Ctrl+S	Snap Start Point
Alt+Shift+Ctrl+E	Snap End Point
Alt+Shift+Ctrl+A	Select All
Alt+Shift+Ctrl+R	Release All
Alt+Shift+Ctrl+L	Last Selection
Left Mouse Button	Select Elements
	Select Column
	Select Object
	Select by Window
Ctrl + Left Mouse Button	Select Connected Objects
Shift + Left Mouse Button	Select Blocks
Right Mouse Button	Local Menu
	Object Parameter
Double Click	Select/Release all Objects

19.3 Calculation Errors

The theory of computing low frequency electric and magnetic fields is described in the first chapter of **EFC-400 User's Manual** in detail. The corresponding formulas are the exact analytic solutions for straight conductors of infinite extension (Biot-Savart).

1. Analytic Errors

Implementation of formula inside the software can result in the following errors:

1.a Errors, which arise during computation of the basic elements (straight conductors), through finite numerical resolution of real numbers or software errors (errors in implementation of formula)

Possible differences have been determined by comparing analytic calculations and numeric results of the software in 1 m distance from straight conductors. For conductors of a length of 1 mm up to 10E+6 km the maximum inaccuracy is:

magnetic flux density - 1E-7
electric field strength - 1E-6

Note: The error of 1E-7 is caused by the numeric number format (single with 7-8 significant digits). For computing the electric field strengths the error is about one order of magnitude higher, because the matrix inversion for determination of charge requires many (n^3) operations.

1.b Errors, which result from segmentation of basic elements

According to 1.a, a conductor with a length of 1 km has been divided in segments from 1 to 1000. The maximum error is:

magnetic flux density - 1E-7
electric field strength - 1E-6

1.c Errors through modelling complex geometries out of basic elements

This can be improved for circles and coils for whose magnetic field simple analytic formula are known. Both elements are modelled by EFC-400 through segments of straight conductors.

In the centre of a circle with 1 m radius, under a current of 1 A, the magnetic flux density is 0.6283185 µT. Depending on segmentation the following values have been calculated by EFC-400:

Segments	*B [µT]*	*Error %*
8	*0.663*	*5.23076923*
16	*0.637*	*1.36263736*
32	*0.631*	*0.42472266*
64	*0.629*	*0.10810811*
128	*0.628*	*0.05095541*

In the same way computation for a coil of ten loops with radius and length of 1 m, results in a magnetic flux density of 0.56198517 µT in the centre, while the following values have been calculated by EFC-400:

Segments	*B [µT]*	*Error %*
16	*0.565*	*0.53359823*
32	*0.562*	*0.00263879*
64	*0.56184*	*0.02583832*
128	*0.561835*	*0.02672849*
1024	*0.561997*	*0.00210499*

2. Numerical Errors

Beside the described methodical errors, it is possible that these small errors add on during the multiple calculation process:

2.a Errors, arising while adding the single field portions of many conductors

For verification purposes a single conductor has been replaced by 10000 exact copies with currents of only 1/10000 of the original conductor. The magnetic field has been compared for several length. The maximum error was 1E-7.
Also under additional segmentation of each conductor in up to 1000 parts, (this means addition of 1E+7 values in every point of space), the maximum error is 1E-7.
For the electric field this test is impossible because the conductors can not lie at the same position.

2.b Errors resulting from addition of complex field strengths

The field of two conductors at the same position with opposite current directions and same phases has to vanish. The same is true for two conductors with equal currents and opposite phases, or for three conductors with equal currents and phases shifted by 120° each. For these arrangements the remaining field strength was at maximum 1E-7, for up to 15000 conductors.

3. Errors through the geometric model

Calculation of field strengths requires the construction of a geometric model out of the basic elements provided by EFC-400, which can result in the following errors:

3.a Errors through non circle-like conductor sections

The basic calculation element is a thin line conductor without any expansion in space. However the magnetic field around a conductor with a circle-like section is the same as that of a line conductor by physical law. (Note: This holds not for the electric field!). The expansion only limits the maximum field strength which arises at the conductor surface, because the magnetic flux density inside the conductor decreases to the centre and the electric field strength inside conductors is zero. When the form of the conductor section varies from circle-like, this equivalence is not true anymore near the conductor surface. To consider the field strengths near conductors which are not circle-like, these have been modelled by several line-like conductors. However in praxis this procedure is unnecessary. Comparing for example the magnetic field of 3 bus-bars of section 2x6 cm in a distance 10 cm, with that one of 3 line-like conductors of the same distance, no signification deviation is found already from up to 5 cm distance.
For normal distances in the environment, therefore the form of conductors is not relevant. This also is true for conductor bundles, which get converted into single conductors with substituted radius for computation of electric field strengths automatically. To calculate the exact field strengths at the surface of the conductor bundle, the user receives good results when each conductor of the bundle is constructed separately.

3.b Errors resulting from constructing installations out of basic elements

It has already be shown, that the calculated field strengths of the basic elements agree with the analytic formula. Since this also is a case for complex elements, thus as coils out of several thousand conductors, there is no reason to suppose that this does not hold for any other arrangement of conductors. A coil with 10 loops consisting out of 1000 straight conductors per loop, can in fact be seen as an arrangement of conductors oriented in any way, also the user may see some order.

3.c Errors from neglecting material influence and induction

This matter of fact has already been described in the first chapters of the **EFC-400 User's Manual**. At this place it shall only be supplemented, that the calculation of magnetic flux density without material influence is always the worst case. Also the magnetic flux density can increase direct at the edges of metal parts, this is only a limited local effect.
In praxis normally metal parts always reduce the field in the environment, what is a known reason for the usage of iron for transformers. In the near-field the flux is therefore guided along the desired way to reduce losses. The result is a reduction of the far-field in the environment.
Because of symmetry the form of the far-field is always equal to the field without any material influence. If it is needed to take into account the material influence on the magnetic flux density in the far-field, the influence can therefore be considered as an isotrope shielding factor in first approximation.

3.d Errors through incomplete data

During simulations it is possible that the geometric model consists on wrong assumptions. May be, the user thinks the construction of a special part is not needed because it does not contribute much to the total field.
The mistake herein is that one thinks the increasing in field strengths through the neglected part is low. Because fields are summarised as vectors, just this neglected part can also reduce the field strengths at certain places. Of course agreement with measurements or calculations of other user's can not be achieved in this way.

4. Comparing calculations with measurements

In principal it is not possible to proof the calculation method of EFC-400 by measurements. It can only be compared if the chosen model and the constructed geometry of the user is enough accurate for the desired case.
This is a matter of fact because EFC-400 uses the analytic formula (Biot-Savart) for calculation purposes. On basis of this fundamental physical law the SI-unit A is defined. The calibration of measurement appliance for electric and magnetic fields can never reach the quality of the fundamental physical laws because also the calibration equipment depends on these laws.
However many comparison between measurements and computations have been done in praxis. Also a lot of user's has done own investigations. This holds for power transmission lines, terminal stations, power stations, railway equipment, while in all cases good agreement has been achieved. The most important assumption therefore, is a knowledge of complete parameters to describe the actual working state of energy facilities. For details, the study of the following literature is recommended:

[FGEU 94] **Emissionskataster der elektrischen und magnetischen Feldexposition im Stadtgebiet Berlin - Entwurf** und **Inhaltliche Ergänzung,** Forschungsgesellschaft für Energie und Umwelttechnologie - FGEU mbH, (1994).

[FGEU 95] **O. Frohn, K. Koffke, E. Stenzel, J. Dunker und O. Plotzke,** *Emissionskataster der elektrischen und magnetischen Feldexposition im Stadtgebiet Berlin - Eine vergleichende Pilotstudie in ausgewählten öffentlichen Bereichen*, Teilbericht Berlin-Buch/Karow, Berlin, (1995).

[FGEU 96] **H. Skurk, B. Herold, K. Stoessel und O. Plotzke**, *Emissionskataster der elektrischen und magnetischen Feldexposition im Stadtgebiet Berlin - Eine vergleichende Pilotstudie in ausgewählten öffentlichen Bereichen*, Teilbericht Berlin-Charlottenburg, Berlin, (Mai 1996).

[FRO 94] **O. Frohn, K. Koffke und O. Plotzke,** *Schienengebundene Transportsysteme, Meßberichte für U-Bahn, S-Bahn, Fernbahn und Transrapid,* Forschungsgesellschaft für Energie und Umwelttechnologie - FGEU mbH im Auftrag der BAFAM, Berlin, (1994).

[FRO 94a] **O. Frohn und O. Plotzke,** *Schienengebundene Transportsysteme, Worst Case Berechnungen,* Forschungsgesellschaft für Energie und Umwelttechnologie - FGEU mbH im Auftrag der BAFAM, Berlin, (1994).

[FRO 96] **O. Frohn, K. Koffke, E. Stenzel, J. Dunker und O. Plotzke,** *Rechnergestützte Methoden zur großflächigen Erfassung niederfrequenter elektrischer und magnetischer Felder***,** EMV Kompendium '96, S. 32 (1996).

[KAN 95] **J. Kantz, J. Dunker und O. Frohn,** *Elektrische und magnetische Feldstärken der geplanten 400 kV Freileitung der BEWAG*, Forschungsgesellschaft für Energie und Umwelttechnologie - FGEU mbH im Auftrag der BEWAG, Berlin, (1995).

[KOF 95] **K. Koffke, O. Frohn, E. Stenzel und O. Plotzke,** *Feldexposition im Stadtgebiet Berlin*, EMC Journal 1/95, S 70, (1995).

[PLO 95] **O. Plotzke, K. Koffke und E. Stenzel,** *ICE als Quelle nichtionisierender Strahlung - Magnetisches Feld an der Streckenführung des ICE Berlin,* Strahlenschutzpraktik 3/95, S. 49, (1993).

[STE 96] **E. Stenzel, O. Frohn, K. Koffke, J. Dunker und O. Plotzke,** *Methods of developing an emission cataster for low frequency electric and magnetic fields***,** IRPA9 International Congress on Radiation Protection, Vienna, Proceedings Vol. **3**, S. 589, (1996).

20. Appendix B: Hardlock Documentation