Implementation of new features in ATPDraw version 3

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Abstract – **The paper addresses the new features in the ATPDraw program with focus on the technical aspects of line/cable and transformer modeling. Version 3 of the program supports directly the supporting routines LINE- and CABLE CONSTANTS, CABLE PARAMETERS, and BCTRAN of ATP-EMTP. The paper finally outlines the advanced, multilevel grouping facility and the new support of $Parameter and Pocket Calculator.**

Keywords – Graphical preprocessor, line, cable, and transformer modeling, CAD, ATP-EMTP

I. INTRODUCTION

ATPDraw is a graphical preprocessor to the ATP-EMTP [1, 2] on the MS Windows platform. In the program the user can build up an electric circuit, using the mouse, by selecting predefined components from an extensive palette [3, 4]. Both single phase and 3-phase components are supported. ATPDraw generates the ATP file in the proper format based on "what you see is what you get". ATPDraw takes care of the node naming process. All kinds of circuit editing facilities (copy/paste, grouping, rotate, export/import, undo/redo) are available. Most of ATP's standard components as well as TACS are supported, and in addition the user can create new objects based on MODELS [5] or Data Base Modularization [1]. ATPDraw has a standard Windows layout, supports multiple documents and offers a large Windows help file system.
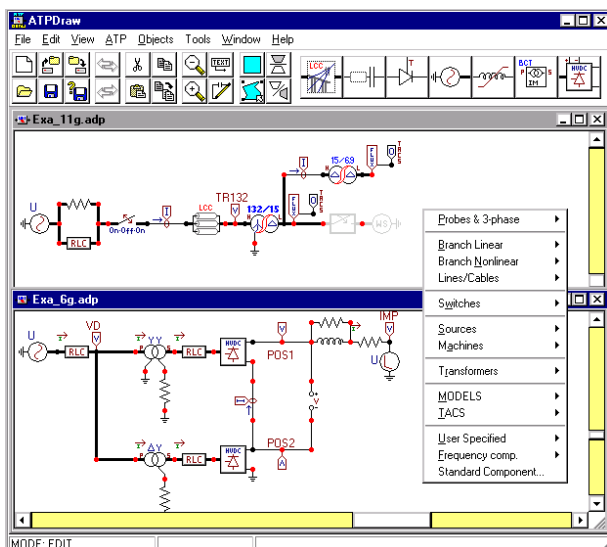

Fig. 1. Layout of ATPDraw's main screen, including the component selection menu
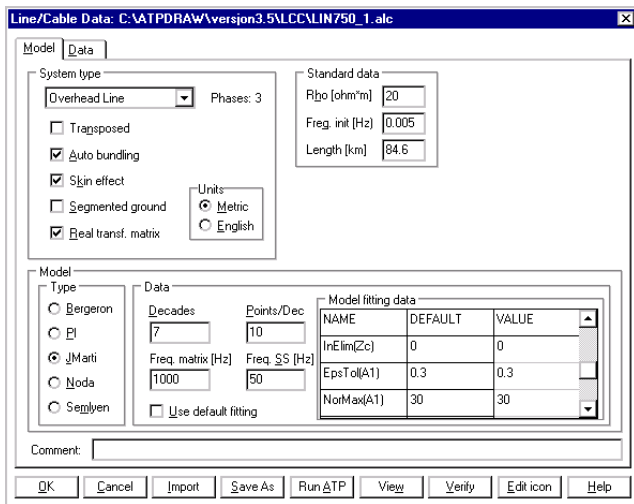
II. NEW COMPONENTS

ATPDraw now directly supports line, cable and transformer modeling via LINE/CABLE CONSTANTS, CABLE PARAMETERS and BCTRAN supporting routines of ATP. The user operates directly with technical data in the circuit. ATP-EMTP is automatically executed to produce the electrical models included in the final data case.

A. Line/cable modeling

To add a line or cable to the circuit, the user first specifies a 1-9 phase line/cable model. The input dialog box of this circuit element is shown in fig. 2. In this dynamic dialog box the user specifies if the component is a cable (with or without enclosing pipe) or an overhead line. Then the geometrical and material parameters can be entered under *Data*. Under *Standard data* the ground resistivity (only homogenous ground supported), the initial frequency and the line/cable length are specified. Finally the user selects the suitable electrical model under *Model* along with special frequency and fitting data required in each case. It is straightforward to switch between the various electrical models (Pi, Bergeron, JMarti, Semlyen, and Noda) and ATPDraw handles all the formats, apart from special multiple pi-sections. Only those cases that really produce an electrical model are supported. Fig. 2 illustrates a JMarti specification of a 750 kV overhead line given in fig. 3.

In a cable data case the user can easily switch between CABLE CONSTANTS and CABLE PARAMETERS. The first supports a flexible grounding scheme and the Semlyen model, while the second supports additional shunt capacitance/conductance and the Noda model. For each cable in the system the user can specify data for the core, sheath and armor and copy data between cables.

Selecting *View* will display the cross section. This gives a quick overview of the system so obvious errors can be avoided. In the *View* module zooming is supported as well as clipboard support of the graphics. This feature is particularly useful for cable systems as it also shows which conductor is grounded as illustrated in fig. 4.

Fig. 2. Line/Cable dialog box. Upper: Selection of system type (line or cable), standard data (grounding and frequency) and Model data (type of model and frequency). Lower: Specification of conductor data.
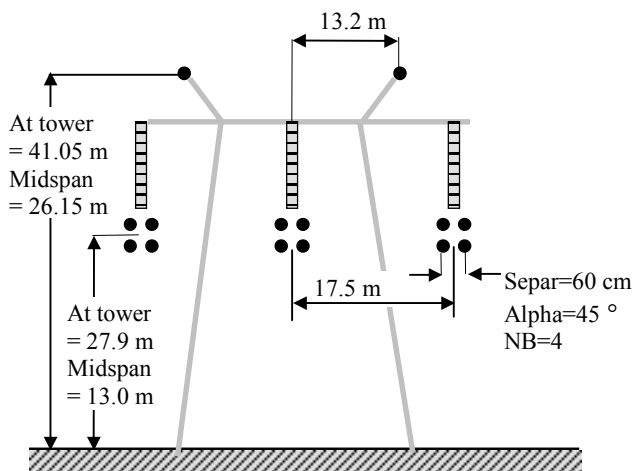

Fig. 3. Cross section of 750 kV overhead line.

An important part is the *Verify* module that supports two method of model verification. The first one is called LINE MODEL FREQUENCY SCAN [1]. This method compares the model with the exact PI-equivalent in the frequency domain. Calculation of impedances in the zero and positive sequence and the mutual sequence impedance between two circuits of 6-phase systems is supported. The user can specify which circuit the conductors belong to and optionally ground conductors. Fig. 5 shows the verification of the model in fig. 2-3. The method can be used to verify if the model is suitable for the typical transients occurring in the study. For the JMarti line verified in fig. 5

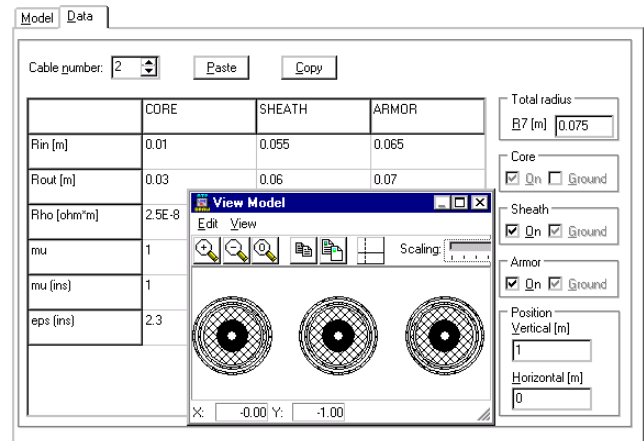corrections could be to change the frequency for which the transformation matrix is calculated at.

Fig. 4. Specification of Cable data under Cable Parameters (grounding is fixed) and View of the cross section. Grounded conductors appear in the background color.
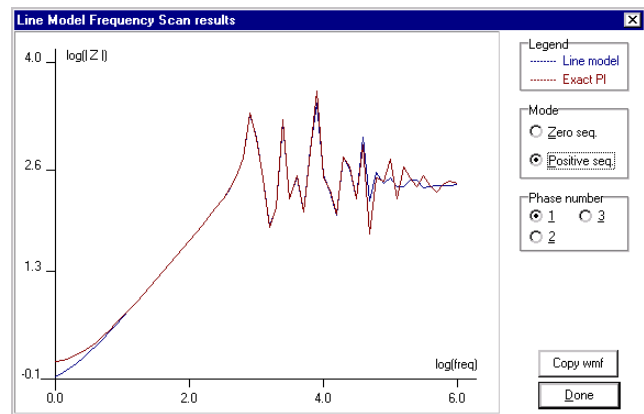

Fig. 5. Verification of the JMarti line in fig. 2, positive sequence. The accuracy is highest around the transformation matrix frequency (Freq. matrix) 1000 Hz.

Fig. 6. Verification of the 750 kV power line in fig. 2-3.

The second method is called POWER FREQUENCY CALCULATION. This method calculates the short circuit impedances and the open circuit reactive power charging in the zero and positive sequence as well as mutual transfer impedance for multi-circuit systems at power frequency. Such values are typically available benchmark data for systems in operation. Fig. 6 shows the verification of the model in fig. 2-3. The method can be used to verify if the

parameters used for the system is correct. Typical problems could be overhead line heights and ground resistivity etc.

When the user clicks on the *Run ATP* or the *OK* button of the Line/Cable dialog box (fig. 2) ATPDraw executes ATP and automatically transforms the punched file into a library file on data base module format ready to be used in the electrical circuit.

B. Transformer modeling

In version 3.5 of ATPDraw, BCTRAN is supported directly in the same way as lines/cables. ATPDraw supports single and 3-phase transformers with up to 3 windings. All types of phase shifts for Δ− and Y-connected windings are supported, and a special handling of auto-transformers is included. Handling of the nonlinear magnetization branch is also incorporated both manually and automatic. In a new *View* module the user can get a picture of the nonlinear characteristic and easily transforms the voltage/current rms-value characteristic into a fluxlinked/peak-current characteristic.

Fig. 7 shows the BCTRAN dialog box with data based on the test report of a 290 MVA transformer shown in table I.

Table I Transformer test report, 290 MVA 50 Hz.

Main data	[kV]	[MVA]	[A]	Coupling
HS	432	290	388	YNj
LS	16	290	10465	d5
Open circuit test	E0 [kV] (%)	[MVA]	I0 [%]	P0 [kW]
LS	12 (75)	290	0.05	83.1
	14 (87.5)	290	0.11	118.8
	15 (93.75)	290	0.17	143.6
	16 (100)	290	0.31	178.6
	17 (106.25)	290	0.67	226.5
Short circuit test	[kV]	[MVA]	ek, er [%]	Pk [kW]
HS/LS	432/16	290	14.6, 0.24	704.4

The reference current in the open circuit case is
$$I_{ref} = 290\,\text{MVA}/(\sqrt{3} \cdot 16\,\text{kV}) = 10.5\,\text{kA}$$

Under *Structure* in fig. 7, the user specifies the number of phases, the number of windings, the type of core (not supported yet, except for single-phase cores, triplex), and the test frequency. The dialog box format adapts the number of windings and phases. The user can also request the inverse *L* matrix as output by checking *AR Output*. *An Auto-add nonlinearities* button appears when an external magnetizing branch is requested as explained below.

Under *Ratings* the nominal line-voltage, rated power, and type of coupling is specified. Connections A (auto-transformer), Y and D are available and all possible phase shifts are supported. The specified line voltage is automatically scaled to get the winding voltage VRAT. If an Auto-transformer is selected for the primary and secondary winding (HV-LV) the impedances are recalculated as shown in section 6.7 in [2]:

$$Z_{H-L}^* = Z_{L-H} \cdot \left(\frac{V_H}{V_H - V_L} \right)^2$$

$$Z_{L-T}^* = Z_{L-T}$$

$$Z_{H-T}^* = \frac{Z_{H-L} \cdot V_H \cdot V_L}{(V_H - V_L)^2} + \frac{Z_{H-T} \cdot V_H}{V_H - V_L} + \frac{Z_{L-T} \cdot V_L}{V_H - V_L}$$

(1)

where Z_{L-H}, Z_{L-T}, and Z_{H-T} are the *Imp. [%]* values from fig. 7 (lower) and Z_{H-L}^*, Z_{L-T}^*, and Z_{H-T}^* are the values written to the BCTRAN file.

Fig. 7. BCTRAN dialog box. Specification of data according to tab. I. Upper: Open circuit data. Lower: Short circuit data

Under *Factory test* the user can choose either the open circuit test or the short circuit test as shown in fig. 7. Under the open circuit test the user can specify where the test was performed and where to connect the excitation branch. Normally the lowest voltage is preferred, but stability problems for delta-connected nonlinear inductances could require the lowest Y-connected winding to be used. The user can choose between the HV and LV, and TV winding for a three-winding transformer. The excitation voltage and current is specified in % and the losses in kW. With reference to the ATP RuleBook [1], the values at 100 % voltage is used directly as IEXPOS=Curr [%] and LEXPOS=Loss [kW]. The user can specify up to 6 point on the magnetizing curve.

C. Nonlinearities

How to handle the nonlinear open circuit characteristic is specified under the *Positive core magnetization* group in fig. 7. Specifying *Linear internal* will result in a linear core representation based on the 100 % voltage values. It is also

possible to handle the saturation. Typically the magnetization inductance can be added externally. To accomplish this the user has to select *External Lm*. The inductive part of the magnetization current at 100 % voltage is then subtracted and the remaining open circuit current becomes equal to the resistive part:

$$IEXPOS[\%] = 100 \cdot (P \cdot 10^{-3}[MVA]/(SPOS[MVA]) \\ = 178.6 /(10 \cdot 290) = 0.0616\% \quad (2)$$

where *SPOS* is equal to the *Power [MVA]* specified under *Ratings* for the winding where the test is performed, and *P* is equal to the open circuit *Loss [kW]* at 100 % voltage. The current in the magnetizing inductance, ref. fig. 8 is then calculated as

$$I_{rms}[A] = \frac{10 \cdot SPOS[MVA]}{3 \cdot V_{ref}[kV]} \sqrt{(Curr[\%])^2 - \left(\frac{Loss[kW]}{10 \cdot SPOS[MVA]}\right)^2} \quad (3)$$

where V_{ref} is actual rated voltage specified under *Ratings*, divided by $\sqrt{3}$ for 3-phase Y- and Auto-connected transformers. *Curr*, *Loss*, and *Volt* are taken directly from the open circuit data. The factor 3 in (3) is used only for the 3-phase case. The U_{rms} values are then calculated as $U_{rms} = \frac{Volt\,[\%]}{100} \cdot V_{ref}\,[kV] \qquad (4)$
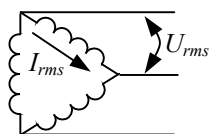

Fig. 8. Definition of the I_{rms}-U_{rms} quantities.

Selecting *Lm-rms* under the *View/Copy* group and then the button *View+* will display the nonlinear characteristic for the positive sequence system as shown in fig. 9.
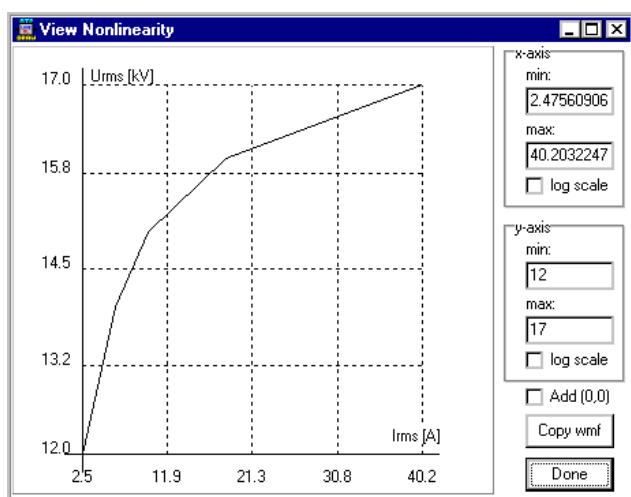

Fig. 9. Viewing the magnetization characteristic.

A similar characteristic can also be calculated for the resistive part. If zero sequence data are available they can be specified in fig. 7 as well.

The calculated I_{rms}-U_{rms} characteristic can be automatically transformed to an *i-λ* (current-fluxlinked) characteristic (by an internal SATURA-like routine [1, 2]). Selecting the *Lm-flux* will allow to display the *i-λ* characteristic similar to fig. 9, and to copy it directly to nonlinear inductances of type 93 and 98.

The user can choose to *Auto-add nonlinearities* under *Structure* and in this case the magnetizing inductance is automatically added to the final ATP-file as a type 98 inductance. ATPDraw connects the inductances in Y or Δ dependent on the selected connection for actual winding for a 3-phase transformer. In this case the user has no control of the initial state of the inductor(s). If more control is needed *Auto-add nonlinearities* should not be checked. The user must then create separate nonlinear inductances and copy the i-λ characteristic.

Fig. 10 shows a simulation of the open circuit excitation current into the low voltage side, applying 16 kV line voltage.
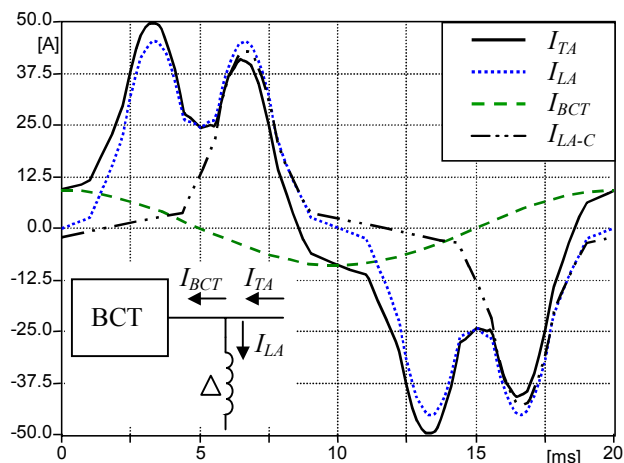

Fig. 10. Open circuit currents at nominal voltage.

Fig. 11 shows the measured no-load current of the at the same transformer. The line-current in phase A is shown together with the phase current A to C. This figure fits qualitively well with fig. 10. The peaks of the line-current are a bit higher, particularly the second peak on the positive part that is produced by the phase current I_{LA-C}.

The current in phase A into the Δ-coupled inductors, I_{LA} shown in fig. 10 consists of two peaks each half period. The first one comes from the current in the inductance in branch A-B (I_{LA-B}) and the second one comes from branch A-C. In (3) it is assumed that the current in each saturation inductor for a Δ-connected winding is equal to the phase current divided by $\sqrt{3}$. This is a doubtful assumption however, since the three involved inductances will go into saturation at different times.

Nonlinear inductances with initial fluxlinked condition are added to ATPDraw. This is straightforward for type 93 inductances while type 96 and 98 require special treatment. A hidden DC voltage source is connected in series with the inductor lasting for one time step and with amplitude of λ(0)/*dt* where λ(0) is the user specified initial fluxlinked

condition. The voltage source (and the required ideal transformer for non-grounded inductances) is hidden in the graphical drawing.
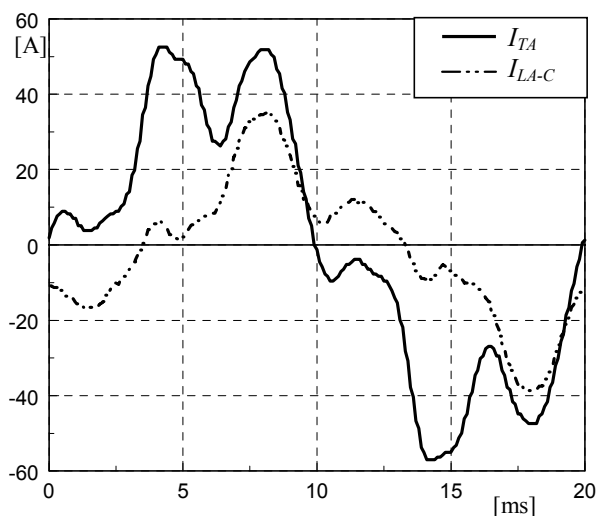

Fig. 11. Measurement of excitation currents at nominal voltage.

In addition these components offer the user to select the fluxlinked output just like any other branch output. To support this ATPDraw adds a TACS branch voltage integrator automatically. Also an extra node will appear where the user can specify the fluxlinked name.

III. NEW EDIT OPTIONS

Two new mayor edit options were added to ATPDraw version 3. These are multilevel grouping and support of text string parameters.

A. Grouping

This option is a powerful tool to increase the readability of the circuit drawings and for reuse of frequent sub-circuits. Typical examples are grouping of TACS blocks into control system units and creation of 3-phase components. A group can be exported and imported making it possible to build up a library of frequent used sub-circuits. ATPDraw supports multilevel grouping.

The grouping process is called *Compress* and the user is free to select which of the data and nodes to be external and accessible from the outside. If two data parameters are given the same name they seen as one from the outside. It is also possible to let a nonlinear characteristic become external.

A simple example is shown in fig. 12 where a 3-phase rms-meter is constructed. The user first selects a group, then *Edit|Compress*. In this dialog box the external data/nodes are specified. Finally, a single default icon (that can be modified) replaces the sub-circuit. The data parameters are the frequency used in the TACS device 66 and the type of input (voltage=90, current=91) to TACS for the three phases. These show up as only two parameters in the final rms-meter object.
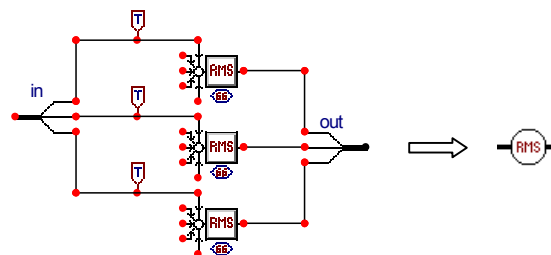

Fig. 12 Compressing a 3-phase rms-meter in TACS.

Fig. 13 shows a more advanced case where a 6-pulse thyristor bridge with TACS control [6] is grouped into a single object with the AC-frequency, the firing delay angle and the RC values of the snubber-circuits as data parameters. This is equal to example Exe_6g.adp in the ATPDraw distribution.
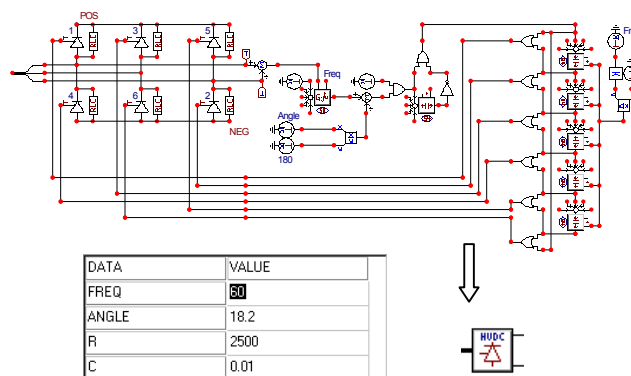

DATA	VALUE
FREQ	60
ANGLE	18.2
R	2500
C	0.01

Fig. 13. 6-pulse Thyristor Bridge grouped into a single object.

B. Parameters

ATPDraw version 3 supports ATP's $Parameters and Pocket Calculator. This implies that the user can specify a 6-character text string for most data parameters and later assign a value to this variable globally. This is particularly useful when a data value is used several times in a circuit. In such a case all equal data parameters could be given the same text string name. The time consuming and risky procedure of clicking up a lot of windows to change the common value can thus be avoided. ATPDraw takes care optimal resolution by adding '_' characters to the text string.

The Pocket Calculator feature allows a data value to be a function of the simulation number in a multiple run. Fig. 14 shows an example where the rms value of the open circuit current for the transformer model in fig. 7 is calculated as a function of the excitation voltage from 12-17 kV. The *External Lm* and the *Auto-add nonlinearities* options are selected.

The amplitude of the voltage source is given the text string variable 'AMP'. This variable is then later assign a value under *ATP|Settings* as shown in fig. 15. *The Number of simulations* is set to 6 and this will enable the Pocket Calculator feature. The amplitude is defined as a function of the simulation number KNT. The constant value 816.5 is equal to $1000 \cdot \sqrt{2/3}$.
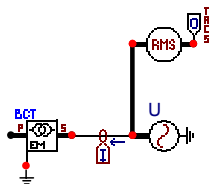
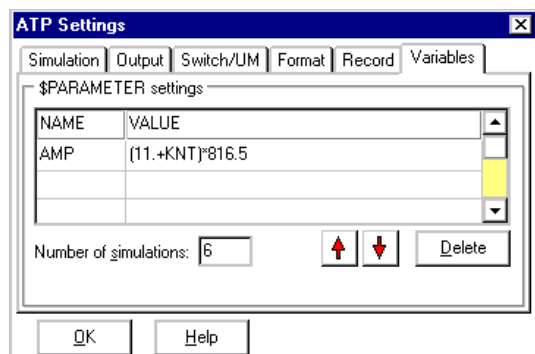Fig. 14. ATPDraw-circuit for calculation of rms-values.

Fig. 15. Assigning a value to the text string 'AMP'.

Fig. 16 compares the measured rms-values of the open circuit currents (from tab. I) with the calculated (from fig. 14). The resistive part of the magnetizing branch is fixed at the 100 % voltage value.
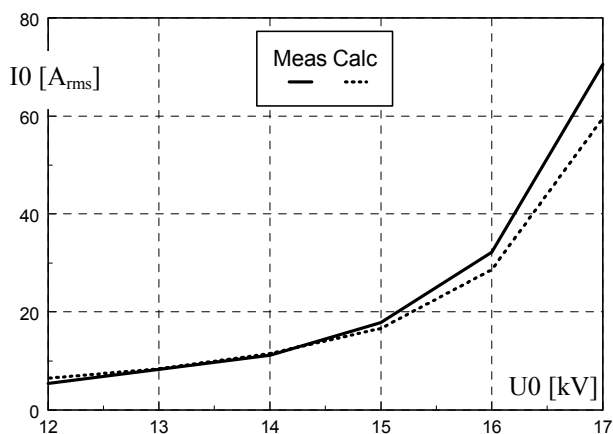

Fig. 16. Comparison of measured and calculated rms-values of open circuit currents.

C. Other options

ATPDraw version 3 also supports some other new features. Among these are
- Rubber-band connections. When this option is selected, connections behave like rubber-bands and follows a moving component/group. This is useful when larger parts of a circuit are moved.
- Automatic lis-file error detection. After the ATP execution the lis-file can be automatically examined for error/warning messages. The user can select 5 different and typical flags.
- Free format ATP-file input. The user now has the option to insert text strings directly into the ATP-file at predefined positions. These text-strings follow the project file. This will enable an indirect support of

special/miscellaneous ATP options like ABSOLUTE U.M. DIMENSIONS etc.
- The file system is substantially changed. The ATPDraw distribution consists of 4 files (along with the examples); The executable program, two help files and the standard component library (ATPDraw.scl) which contains the format of about 200 standard components. The user save his work in a project file, which contains all the files required to edit, run, and distribute the data case.
- A User's Manual [3] that documents ATPDraw version is divided in six parts. Parts 1-3 introduce ATPDraw and explain how to get started with the program. Part 4 is a Reference manual for all menus and components. Part 5 is the Advanced manual that covers the new features presented in this paper, along with how to create new components (Modules or MODELS). Part 6 is an Application manual with several practical examples.

IV. DISCUSSION/CONCLUSION

ATPDraw version 3 covers line, cable, and transformer modeling. The *Verify* part of overhead lines functions well, while problems still exist for cable systems. Verification of Noda models is not supported. The support of BCTRAN still needs improvements and increased knowledge about how to handle 3-legged cores and Δ-connected magnetizing branches, including the nonlinearity in the magnetization losses. Saturation can be automatically added externally to the BCTRAN linear matrix model connected and in Δ- or Y-couplings. Δ-coupled nonlinear inductances can some times cause numerical problems so connecting the magnetization branch at the Y-coupled winding closest to the core is recommended.

The new edit features Grouping and Parameters simplify and open up new possibilities in modular circuit construction.

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