

MODELLING AND EMTP SIMULATION OF THE NON-LINEAR AND PARAMETRICAL CIRCUITS TO THE ELECTRICAL POWER QUALITY EVALUATION

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Abstract: It analyses the different non-linear and parametrical elements and circuits models and the possibilities of their simulation using EMTP software. It puts in evidence the characteristics of the simulation in EMTP, for each circuit model analyzed and the possibilities to using the results to the electrical power quality evaluation. In paper applications and numerical results are presented, obtained using the programs realized by the authors.

Keywords: non-linear circuit, power quality, EMTP simulation

1. INTRODUCTION

The study of the non-linear and parametrical elements, together with the study of the circuits containing these elements has a big practical importance, regarding the specified behaviour, in different operating states, of those circuits, and also the qualitative analysis of the power processes which are made in these circuits [2], [4].

The non-linear and parametrical circuit elements stay on the base of some phenomena which intervene in the quality of the power and energy. Through these it finding the harmonic pollution of the power network, with all undesired consequences (supplementary power and energy losses, non-linear and parametrical harmonic resonance, overvoltages and overcurrents, the disturbance of the measuring results etc.). The approach of a non-linear analysis of the power networks behaviour is necessary, because these contain a multitude of non-linear and parametrical circuit elements [1], [3], [5]. The modelling and numerical simulation of their characteristics and of the operating states of the circuits in which these elements are included, represents the power procedures of analysis.

2. NON-LINEAR AND PARAMETRICAL CIRCUIT ELEMENTS MODELLING

The category of the non-linear resistors is very large. This contains all devices with controllable semiconductors or not and the conversion equipment which contain them, at which it adds electric arc phenomena (furnaces with arc, electrical melting, switchgears) and those linked of the corona phenomena. Among the parametrical resistors, it can highlight those overconductors, used on large scale in the construction of the current limiting. The non-linear inductors existing in the electric installations are coils with iron core, their non-linearity coming from the characteristic $B(H)$. The constructive sketch of this inductor, with the principal parts, is shown in Fig.1a. In Fig.1b are graphical represented the non-linear characteristics. The non-linear inductor admits a complex equivalent electrical scheme. The power transformer operating unloaded is a typical examples of non-linear coil in power installations. A special case of non-linear inductor which can operates and into a state of parametrical element, is non-linear inductor controlled.

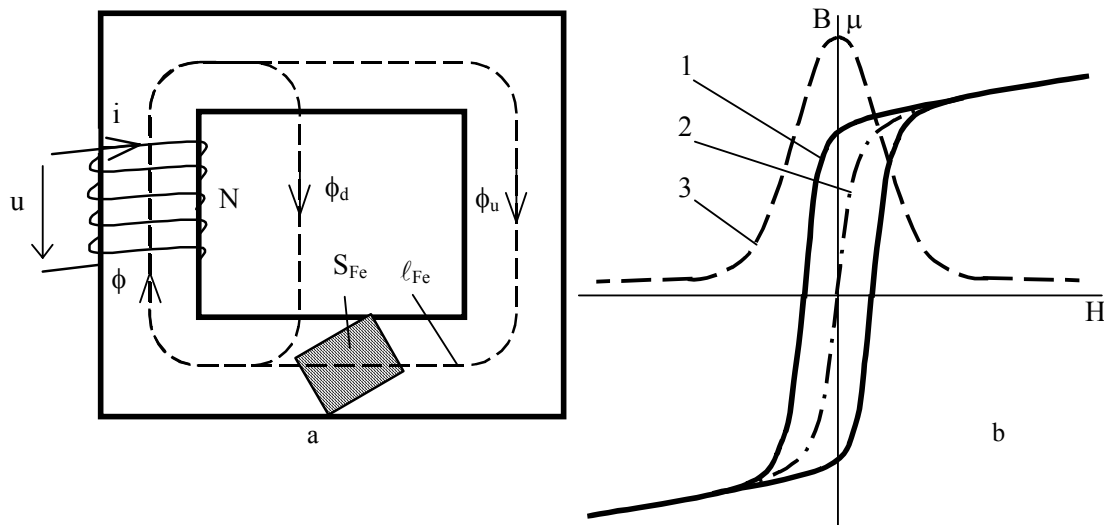


Fig.1. The coil with iron core: a- construction; b- magnetisation characteristics: 1- the hysteresis cycle; 2- the fundamental curve of magnetisation; 3- the magnetic permeability.

The controlled inductor can operate in the state of longitudinal control (Fig.2), if between excitation and control circuits respective, the magnetic coupling is maximum. In addition to the excitation and control coils, the inductor with longitudinal control is equipped with reaction and polarisation coils. Through the polarisation currents having directions and different values, the characteristics of the inductor longitudinal controlled can be translated, as in Fig.3a.

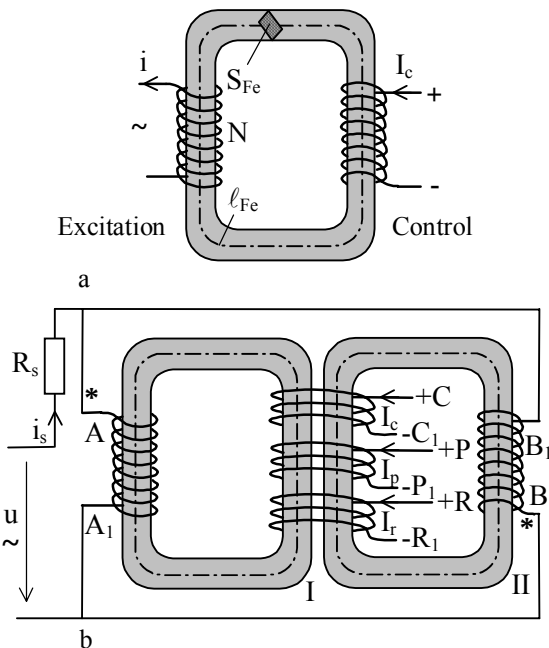


Fig.2. Non-linear inductor with longitudinal control: a- the constructive sketch; b- the magnetic amplifier.

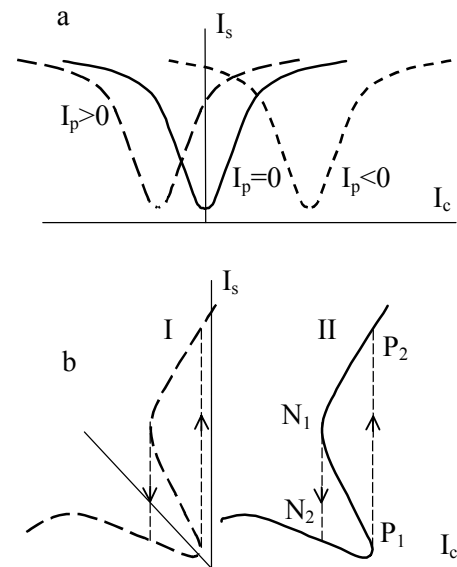


Fig.3. The non-linear inductor with longitudinal control: a-polarisation effect; b- static magnetic relay.

The behaviour with the overunity reaction factor (coefficient) allows to obtain some characteristics of relay type (Fig.3b). If the control direction is perpendicular oriented on the excitation direction, the magnetic coupling between both coils being in this way eliminated, the inductor operates in the state of orthogonal control (Fig.4). The analytical approximation of the characteristics of the non-linear inductors it can do theoretically with any type of functions, but usually is a polynomial approximation extended till the degree 5...7:

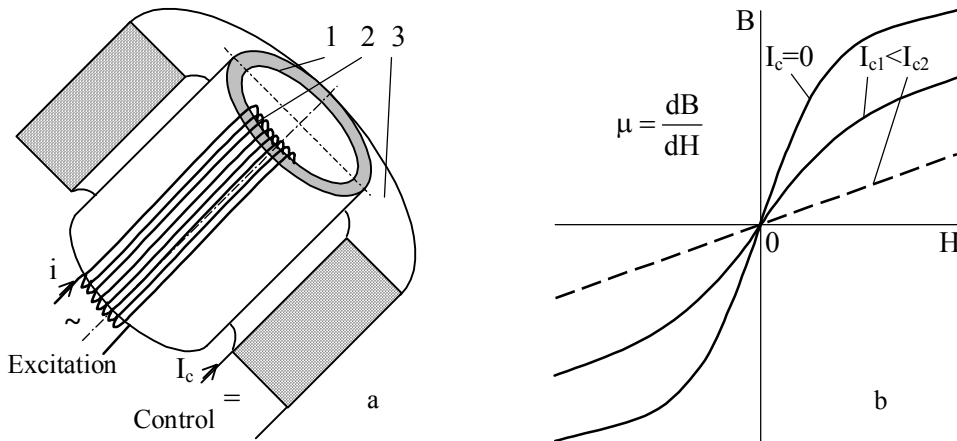


Fig.4. Non-linear inductor with orthogonal control: a- the constructive sketch; 1-ferromagnetic core; 2-excitation coil; 3-control coil; b-operating characteristics.

$$i = a_1 \psi + a_3 \psi^3 + \dots + a_7 \psi^7, \quad (1)$$

i , ψ being the current, respective the magnetic flux, but $a_1, a_3, \dots, a_7$ -constants that can be experimental founded. For the inductor with orthogonal control, the approximation functions of the shape:

$$\left. \begin{aligned} i &= b_1 \psi + b_{12} \psi \psi_c^2 + b_3 \psi^3, \\ i_c &= b_{1c} \psi_c + b_{12c} \psi_c \psi^2 + b_{3c} \psi_c^3, \end{aligned} \right\} \quad (2)$$

i , i_c , ψ , ψ_c being the currents and the magnetic fluxes after the directions of excitation, respective control, but $b_1, b_{12}, \dots, b_{3c}$ -constants, [4].

3. EMTP SIMULATION

The simulation consists in the following steps:

- realisation, in *ATPDRAW*, of the file with the *.adp* extension, which contains the scheme of the electrical model, the inputs, required outputs and general settings;
- the generating of the calculus file, with the *.atp* extension;
- the program compilation and the realisation of the output file, having the *.pl4* extension;
- the visualisation and evaluation of the outputs, using *PlotXY* graphic interface.

For simulation it uses non-linear branch of type 96 (in which it considers the magnetisation characteristic with hysteresis), and also of type 93, where the magnetisation characteristic is approximated through the fundamental of magnetisation. The program schemes contain integrators, which allows the calculus of the magnetic flux through the ferromagnetic core of the inductor.

In Fig.5, Fig.6 are presented the complex scheme of a non-linear inductor, realised in *ATPDRAW* and which allows to simulates the forced operating state, with excitation signal of type sinusoidal magnetic flux (Fig.5), or sinusoidal current (Fig.6).

4. NUMERICAL RESULTS

The voltage and the current successively used as input signals have been chosen with values which to leads at the saturation behaviour of the non-linear inductor studied.

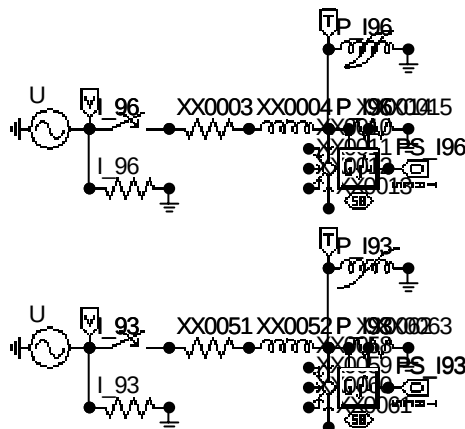


Fig.5. ATPDRAW network simulating the non-linear inductor exciting in sinusoidal magnetic flux:
a-type 96; b-type 93.

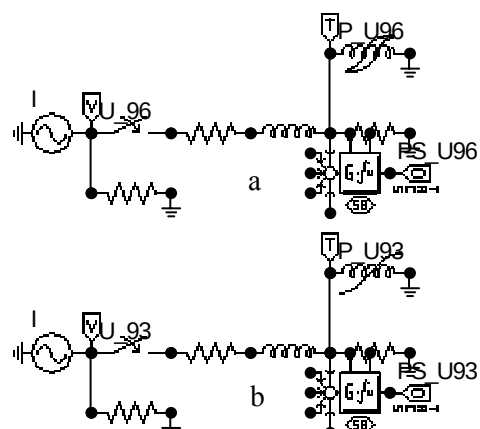


Fig.6. ATPDRAW network simulating the non-linear inductor exciting in sinusoidal current:
a-type 96; b-type 93.

In Fig.7 are presented the characteristics $\psi(i)$ obtained through the simulation, the inductor being excited with sinusoidal signals of voltage type (Fig.7a), respective current type (Fig.7b), in both cases the inductor being simulated, through compression, with non-linear inductor of type 96, and also 93.

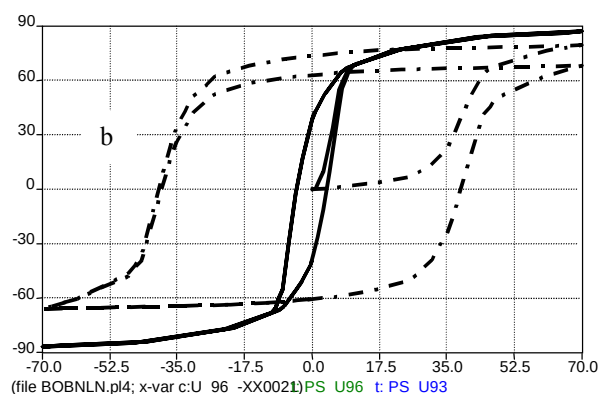
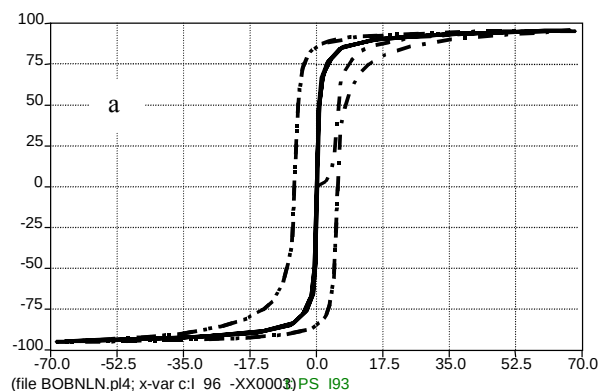


Fig.7. Non-linear $\psi(i)$ simulating characteristics of the inductor exciting in: a-sinusoidal magnetic flux; b-sinusoidal current;

Simulating	93	—————
inductor type:	96	- - - - -

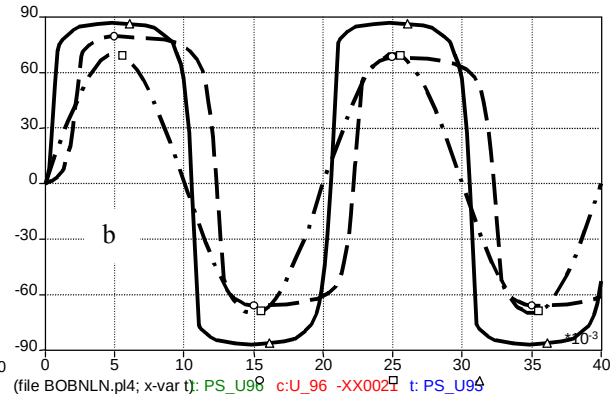
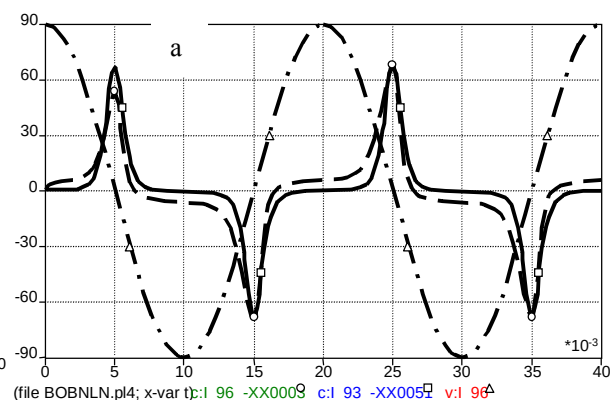


Fig.8. Non-linear inductor exciting in sinusoidal:
a-magnetic flux; b-current;

Input signal:	93	—————
Output, with	93	—————
inductor type:	96	- - - - -

Time variation of the output signals, when the input signals are sinusoidal, is given in Fig.8. It remarks the sharp shape of the output current (in the case of excitation with sinusoidal magnetic flux, Fig.8a), respective plate for output magnetic flux, if the excitation is done with sinusoidal current generator (Fig.8b).

EMTP allows to calculus and delivers, as output data, of the power and dissipated energy on the circuit elements from the model. In Fig.9 are graphical represented the calculus results of these sizes, in the case of non-linear inductor analysed, when this is excited in magnetic flux (Fig.9a), respective current (Fig.9b), sinusoidal.

5. POWER QUALITY ANALIZING

The presents of the non-linear elements disturbs the signal shapes, that these are different of sinusoidal shape. The thing has negative effects on quality parameters of the power and energy.

The harmonic analysis of the non-sinusoidal periodical signals allows to specify the frequency spectrum, and also the weight of each oscillation in rapport with the fundamental. In Fig.10 is presented an ATPDRAW network, which makes possible the Fourier analysis of a non-sinusoidal periodic permanent signal. Some numerical results, obtained through the applying of the afferent program in Fourier analysis of the signals which characterises the behaviour of the non-linear inductor in non-sinusoidal forced state, are graphical represented in Fig.11 (type 96), respective Fig.12 (type 93). It evidences the influence of the supply voltage on the content in harmonics of the current, which cross the inductor coils.

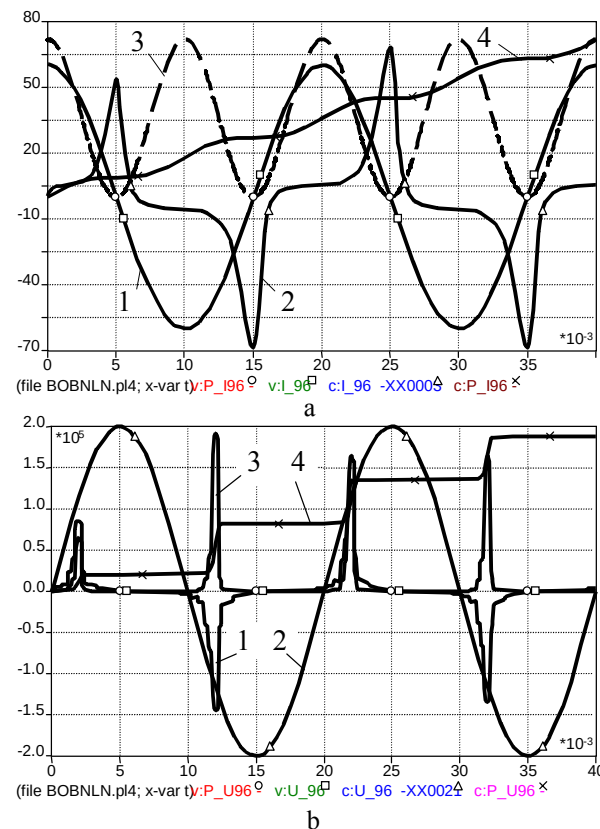


Fig.9. The power and dissipated energy of the non-linear inductor exciting in: a-sinusoidal magnetic flux; b-sinusoidal current; 1-magnetic flux; 2-current; 3-power; 4-energy.

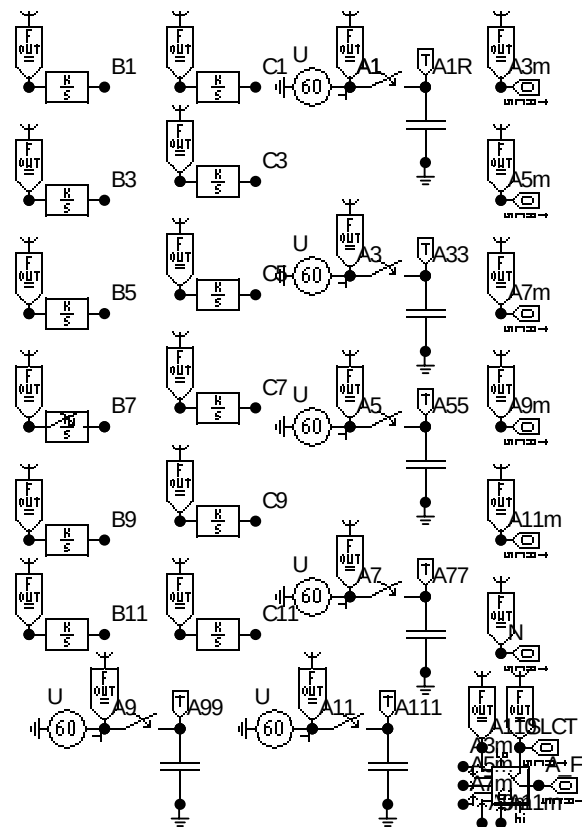


Fig.10. ATPDRAW network Fourier analyse simulating.

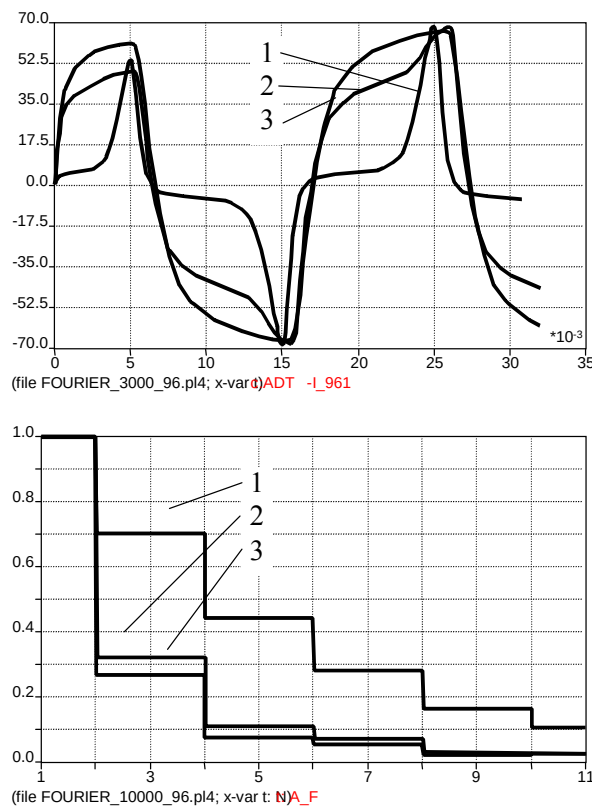


Fig.11. The current and his harmonic spectrum in the case of the non-linear inductor 96 type, exciting in sinusoidal magnetic flux, at different supply voltages: 1-30 kV; 2-20 kV; 3-10 kV.

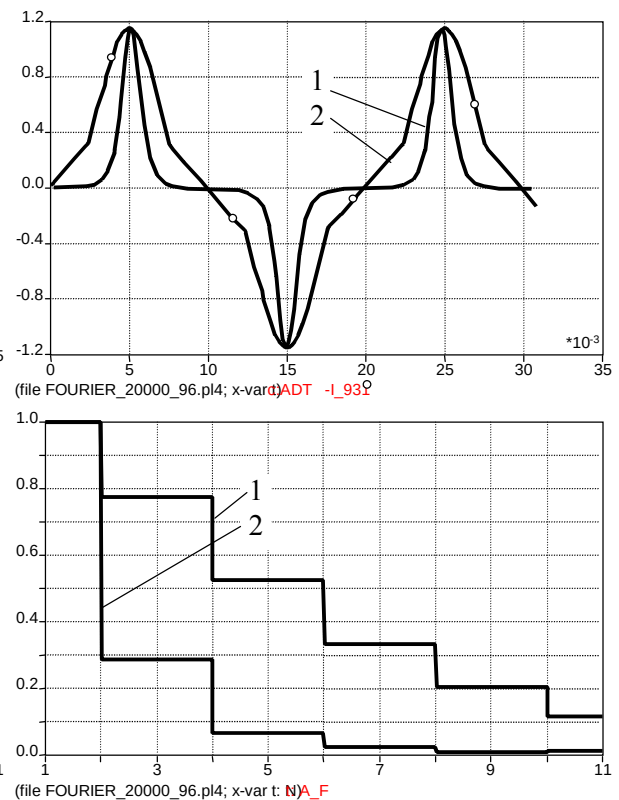


Fig.12. The current and his harmonic spectrum in the case of the non-linear inductor 93 type, exciting in sinusoidal magnetic flux, at different supply voltages: 1-30 kV; 2-20 kV.

6. CONCLUSION

It analysis the calculus possibilities in EMTP of the non-linear electric circuits, with application in the simulation of the non-linear inductor, for which has adopted the model of the complex electrical scheme. It shows the programs and original calculus results, which put in evidence the large possibilities of the EMTP in this domain.

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