A Real Converter of “Boucherot” Type with Ferromagnetic Core Reactor for Applications in Lighting Technology

Kamelia Nikolova, Nikola Trifonov, Angel Pachamanov, Elisaveta Gadjeva,
Technical University of Sofia

Abstract

It is represented a real converter of “Boucherot” type for applications in the lighting technology with non-variant alternating current supply of a group of light sources connected in series to the output terminal of the converter. It is preset a regime of the light sources, for work with similar current, independent of their number, with non-variant alternating voltage supply. The required inductance and capacitance of the converter are chosen under ideal conditions. A laboratory constructed model is researched and the received output properties are defined with registering of the resistance of the circuits and the non-linearity of the reactors, realized with ferromagnetic core. The external errors of constant current source are read with the real model.

Keywords: “Boucherot” converter; non-variant alternating current; series circuit; light sources.

Introduction

The ideal converter formally is with characteristics of a converter without mistakes, independent of the connected varying load.

A real converter usually is constructed with capacitors and ferromagnetic core reactors. The presence of active resistance and non-linearity of the reactors defines some changes in the characteristics, in which appear systematical errors.

In the present paper the errors are researched and it is defined the possible ways for the relative decrease with suitable concordances of the parameters and the characteristics of the capacitors and the reactors. In this way it is possible to construct converters with acceptable errors of the characteristics for a discrete scope of load change.

The research is made at three stages:

1. An ideal converter parameters are calculated at given initial conditions.
2. A real capacitor and reactor are chosen and the characteristics are given with the received errors.
3. The elements of the scheme are modeled in digital space and the results are compared by experiment.

The present paper is assigned to a single phase converter for alternating current and a load of linear resistance with “Boucherot” scheme type “T”.

For the specific case the following initial conditions are given:

- effective source voltage voltage 220V at frequency f = 50 Hz;
- effective current 0,52 A;
- range of varying of load resistance $50\Omega < R_0 < 450\ \Omega$.

Expose

The discussed converters of alternating voltage source in non-variant current source is applicable for types of lighting sources demanding flowing of non-variant current independent of the number of the connected lighting sources.

1. An Ideal converter

The scheme is shown on fig.1. The discussed converter is with coefficient of magnetic connection m=1. All electromagnetic properties change in sinusoidal form with sinusoidal source voltage. Using the method with complex values [1], they are:

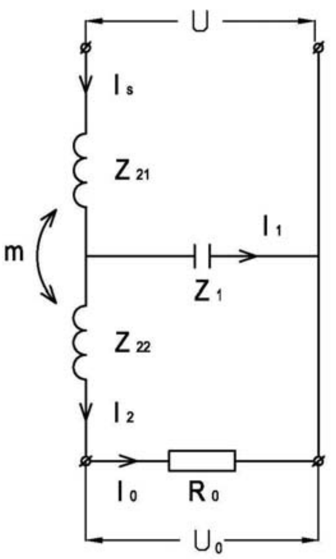


Fig.1

(1)
$$\dot{I}_S = \dot{U}\frac{-jx_1 + jx_{22} + R_0}{-(x_{21}+M)(-x_1-M)+j(x_{21}-x_1)(jx_{22}+jM+R_0)};$$
$$\dot{I}_1 = \dot{U}\frac{jx_{22} + jM + R_л}{-(x_{21}+M)(-x_1-M)+j(x_{21}-x_1)(jx_{21}+jM+R_0)};$$
$$\dot{I}_0 = \dot{U}\frac{-jx_1 - jM}{-(x_{21}+M)(-x_1-M)+j(x_{21}-x_1)(jx_{21}+jM+R_0)}.$$

as the mutual inductance of the reactors is shown with the equivalent impedance $jM = j\sqrt{x_{21}x_{22}}$.

The condition for mode of current source connected to the load R_0 is:

(2) $$x_{21} - x_1 = 0; \quad x_{21} = x_1 = x; \quad C = \frac{1}{\omega x} .$$

The corresponding elements, taking part in the scheme in conditions for current source mode are assessed as the following values:

(3) $$x_{21} = x_1 = x = \frac{U}{(m+1)I_0} = 211.5\Omega;$$

$$L = \frac{x}{\omega} = 673mH; \qquad C = \frac{1}{\omega x} = 15\mu F .$$

The out-going characteristic is shown on fig.2.

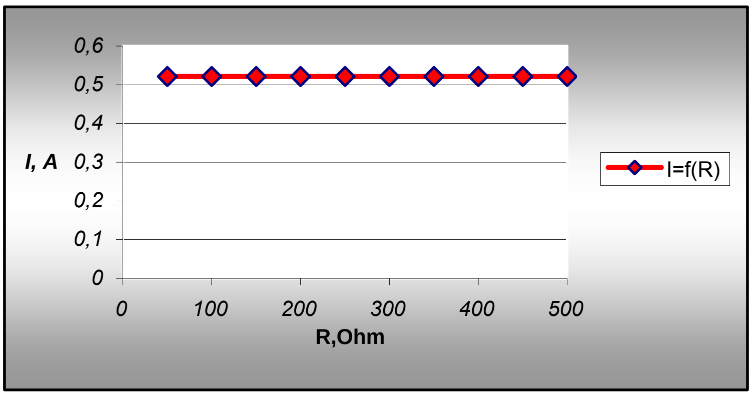


Fig.2

2. A real converter.

The scheme is shown on fig. 3.

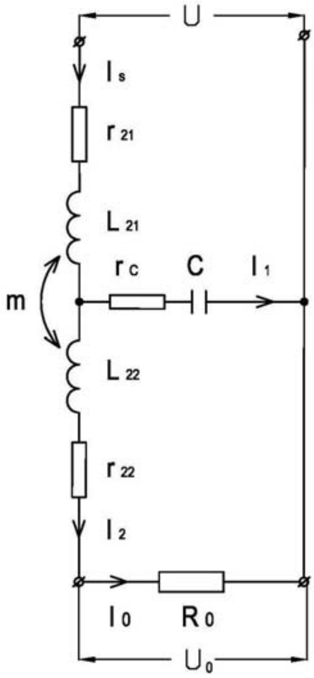


Fig. 3

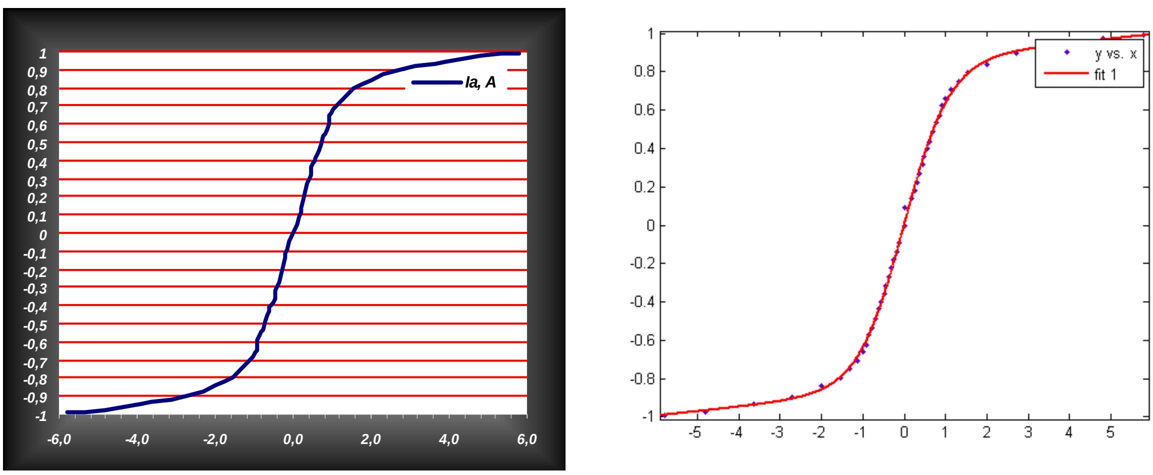
The active resistance r_{L1}, r_{L2} and r_c are defined from catalogues data or projects with data for the reactors and the capacitors.

The non-linear ferromagnetic core reactors change the regimes of electrical quantities, excluding the source voltage. For this purpose the calculations of the quantities and the out-going characteristic have to be made for the corresponding instantaneous values. Basing on them can be calculated the effective values of the currents and the voltages of the load, capacitors and the reactors, as well as the current of supplying source.

The calculations can be done with the use of standard programs. To all assigned quantities have to be added the characteristics of the reactors $\Psi_{L21} = f\,(i_{L21})$ and $\Psi_{L22} = f\,(i_{L22})$ for the instantaneous values of Ψ_{L21} и Ψ_{L22}, and the corresponding i_{L21} and i_{L22}.

2.1. Characteristics of the real converter.

The solutions defined with numerical methods in all cases correspond to concrete data for the converter taken into consideration. For the specific case are given the same initial quantities and a ferromagnetic core reactor with experimentally defined characteristic $\Psi_{L21}(i_{L21})$ and $\Psi_{L22}(i_{L22})$, shown on fig. 4.



a) *b)*

Fig.4 a) experimentally received characteristic of the reactor;
b) calculated characteristic, received by mathematical modeling

For correlation of the magnetic induction of the core on fig. 5 is shown it's equivalent characteristic of magnetization $B=f(H_{eq})$ with figuring on the air gap, which is 0,1mm and it's real size.

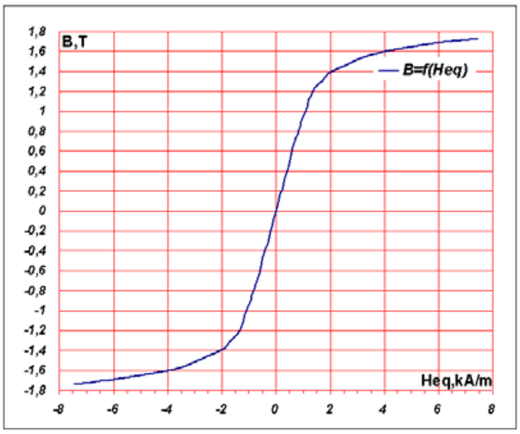


Fig. 5

For the calculation purpose the experimental characteristic for the specific core with air gap and windings of the reactors is represented with curve fitting function. The function is modeled with MATLAB in confidence interval 95% and is represented by the expression:

(4) $\psi_{L1} = \psi_{L2} = f(i_2) =$ *a*tanh((b*x)/a)+c*x=a*tanh((b*i_2)/a)+c*i_2* .

The calculated curve fitting function has:

- Total deviation of the response values from the fit to the response values **SSE = 0.01346**;
- Square of the correlation between the response values and the predicted response values **R-square = 0,9992 at maximum value 1**;
- Residual degrees of freedom **Adjusted R-square: 0.9992 at maximum value 1;**
- Root Mean Squared Error **RMSE: 0.0179.**

These statistics show that the defined curve fitting function represents the character of the flux linkage curve of the reactors dependency on the current i_2 with enough accuracy.

The calculated constants in the confidence interval of 95% are:

(5) a = 0.8553 (0.8162, 0.8944)
b = 0.7716 (0.755, 0.7883)
c = 0.02314 (0.01385, 0.03243)

The active resistances of the elements are with the corresponding values:

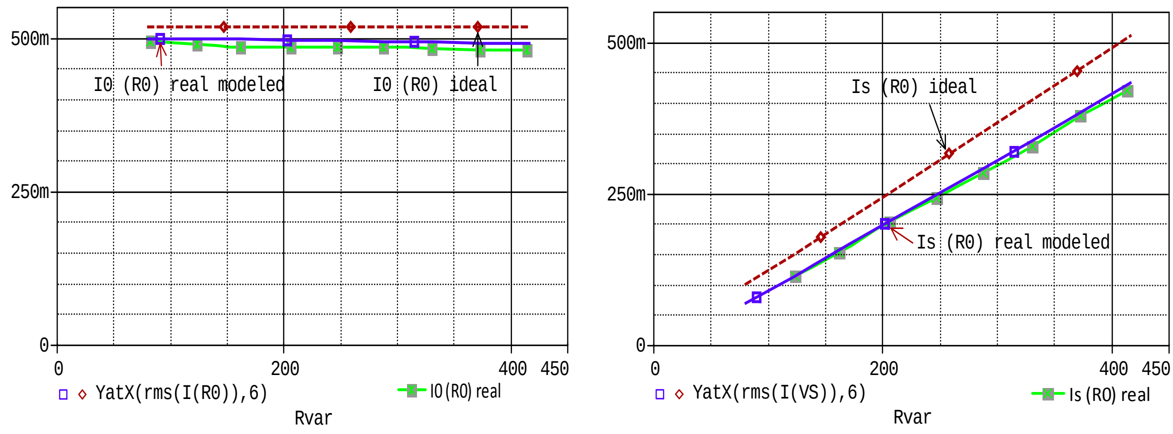
(6) $r_{12}=6\ \Omega$; $r_{22}=7\ \Omega$; $r_c=1.34\ \Omega$.

The conditions for determination of L_{21}, L_{22} and C corresponds to equations (3) for the ideal converter.

The calculations give the results shown on fig. 6 and 7.

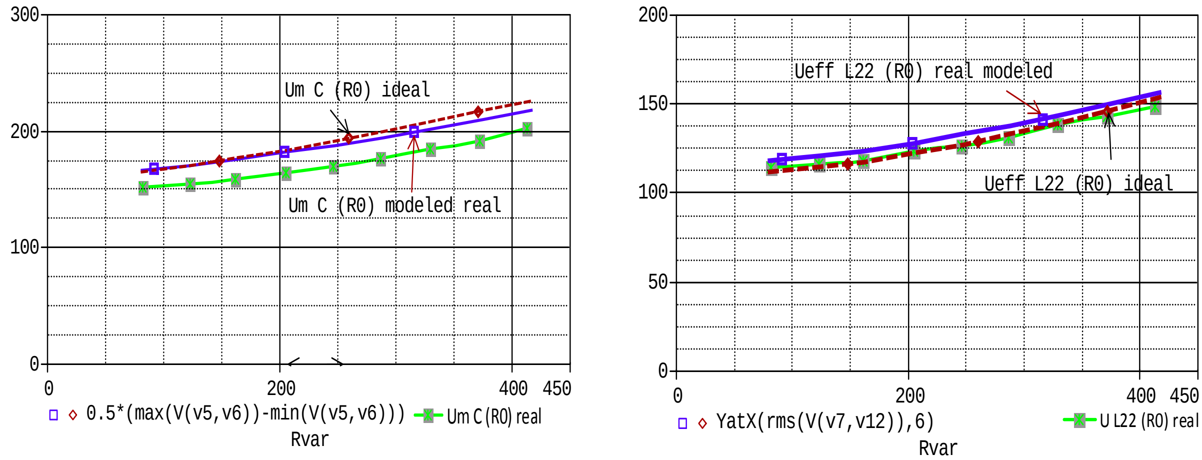
For verification of the correspondence between the theoretical and the measured data a laboratory model is made and the characteristics are shown on the same figures.

All results treat steady-state regime.

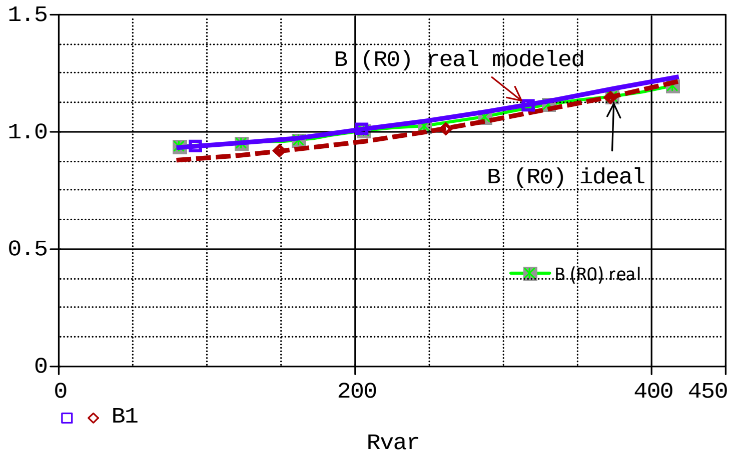


a) b)

Fig. 6 a) Results for I_{0eff}= f (R_0) of ideal, real modeled and real laboratory converter; b) Results for I_{seff}= f (R_0) of ideal, real modeled and real laboratory converter.



a) b)



c)

Fig. 7 a) Results for $U_{m\,C}$ = f (R_0) of ideal, real modeled and real laboratory converter; b) Results for $U_{eff\,L22}$ = f (R_0) of ideal, real modeled and real laboratory converter; c) Results for B = f (R_0) of ideal, real modeled and real laboratory converter

From the results for the out-going characteristics, compared with those of the ideal converter can be observed the errors typical of the real converter:

A) The load current of the modeled real converter is stable with error for the defined range -4% at $R_0 = min$ and -6% at $R_0 = max$

B) The error for the load current of the modeled and laboratory real converter for the observed range is 0% for $R_0 = min$ and +2% for $R_0 = max$. The deviation from the measured values is in the frame of the errors of the measuring process;

B) For load resistance $R_0 > R_{0max}$ the error becomes inadmissibly big. This defines the upper limit for the load range;

C) The differences between the characteristics of $U_{m\,C} = f\,(R_0)$ for ideal, modeled real and laboratory real converter could be explained as with presence of technological manufacturing differences, as with the dependency of the capacitance of the capacitor from it's temperature.

For receiving the given regime of the load from the real laboratory model, as it can be read from the first stage, with the use of given elements with their characteristics it has to be introduced a correction of supplying voltage. In the specific appliance a stable load current with error ±2%, for the discrete range of R_0, could be received with effective voltage of the source 241V, fig.8.

The results define introducing a correction coefficient k_c in calculation of industrial samples in conditions for current source mode:

(7) $$x_{21} = x_1 = x = \frac{U * k_c}{(m+1) I_0},$$

where $k_c = 1.05 - 1.20$, depending on the range of load current stabilization.

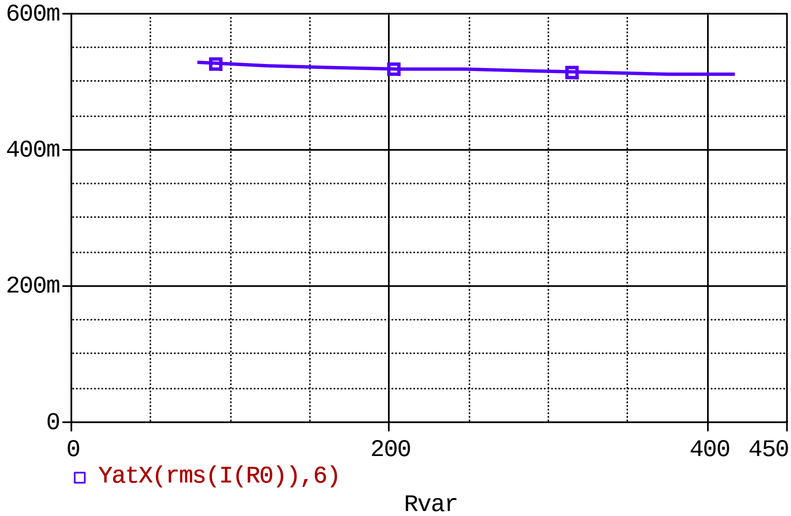


Fig. 8

Conclusion

It is recommended R_{0K} to be in the middle of the R_0 range.

At values of $R_0 > R_{0max}$, the reactor reaches working points of transition to saturation, the primary current sharply increases and the scheme moves out of stable regime.

The comparison shows acceptable concurrence of the real characteristics, received from the mathematical modeling and the measurements from the laboratory model. The reason is the relatively small active resistance of the reactor and the capacitor and for the discrete range the non-linear reactor doesn't reach condition of magnetic saturation of the ferromagnetic core.

The model is suitable for research of the working regimes of the converter.

It is possible to construct and realize an industrial converter of the researched type for application in lighting technology with acceptable stabilization error of the load current.

LITERATURE

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AUTHORS

*[1] **Kamelia Todorova Nikolova** – Eng., assistant in Faculty of Electrical Engineering, Technical University of Sofia, Bulgaria, Cab. 12525, E-mail: knikolova@tu-sofia.bg*

*[2] **Nikola Trifonov Nikolov,** Dr. Eng., Professor in the Faculty of Electrical Engineering, Technical University of Sofia, Bulgaria, Cab. 12227, E-mail: ntrif@tu-sofia.bg*

*[3] **Angel Sarakinov Pachamanov,** Dr. Eng., Professor in department of "ESEOET", Technical University of Sofia , Bulgaria, Cab.12325, E-mail: pach@tu-sofia.bg*

*[4] **Elisaveta Gadjeva,** Dr. Eng., Assistant Professor in department "Electronic Technology", Technical University of Sofia, Bulgaria, E-mail: egadjeva@tu-sofia.bg*