"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2014
Brasov, 22-24 May 2014

ABOUT SINGLE-PHASE VOLTAGE RECTIFIERS OPERATION

Constantin STRIMBU*

*Faculty of Aeronautic Management, "Henri Coanda" Air Force Academy, Brasov, Romania

Abstract: *Some issues regarding the analysis of single-phase voltage rectifier operation will be presented in this paper. The switch is an uncontrolled-type, a diode in this case, which is considered as an ideal one. The expressions of the parameters characterizing the rectifier operation are computed in the paper. Their variations depending on load are also discussed.*

Keywords: *rectifier, diode, single-phase*

1. INTRODUCTION

The schematic of an angle-phase voltage rectifier is presented in figure 1.

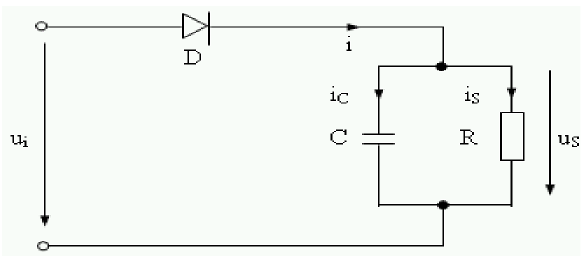

Fig.1. Single-phase voltage rectifier with diode

The steady-state signals expressions are the following [1]:

The diode is "on": $\omega t \in (\alpha_p, \beta)$

$$\begin{cases} i_S = \dfrac{U_M}{R}\sin\omega t = I_M \sin\omega t \\ i_C = \omega C U_M \cos\omega t \\ i = U_M\sqrt{\dfrac{1}{R^2} + (\omega C)^2}\,\sin(\omega t + \xi) = \\ = I_m \sin(\omega t + \xi) \end{cases} \tag{1}$$

The diode is "off": $\omega t \in (\beta, \quad 2\pi + \alpha_p)$

$$\begin{cases} i_S = -i_C = I_{S\beta}\, e^{-(\omega t - \beta)\mathrm{ctg}\,\xi} \\ u_S = R\, i_S = U_M \sin\xi\, e^{-(\omega t - \beta)\mathrm{ctg}\,\xi} \end{cases} \tag{2}$$

where:

$$\begin{cases} \beta = \pi - \xi \\ I_{S\beta} = \dfrac{U_M}{R}\sin\beta = I_M \sin\xi \\ \sin\alpha_p = \sin\xi\, e^{-(\pi + \alpha_p + \xi)\mathrm{ctg}\,\xi} \end{cases} \tag{3}$$

The following notations were used:

$$\begin{aligned} &\mathrm{tg}\,\xi = \omega RC \\ &Z = \frac{R}{\sqrt{1 + (\omega RC)^2}} \\ &I_M = \frac{U_M}{R} \\ &I_m = \frac{U_M}{Z} = \frac{I_M}{\cos\xi} \end{aligned} \tag{4}$$

2. CIRCUIT ANALISIS

2.1 The Voltages and Currents Average Values

According to [2], the expressions of the average values of the circuit signals are the following:

$(U_m)_{\alpha_p}$ - average value of the output voltage:

$$(U_m)_{\alpha_p} = \frac{U_M}{2\pi}\left[\cos\alpha_p + \frac{1}{\cos\xi} * \right. \\ \left. * \left[1 - \sin^2\xi\, e^{-(\alpha_p+\pi+\xi)\mathrm{ctg}\xi}\right]\right] \quad (5)$$

$(U_{def})_{\alpha_p}$ - RMS value of the output voltage:

$$(U_{def})_{\alpha_p} = \frac{U_M}{\sqrt{2\pi}} * \\ * \sqrt{\pi - \xi - \alpha_p + \sin(\alpha_p + \xi)\cos(\alpha_p - \xi) + A} \quad (6)$$

where

$$A = \frac{\sin^3\xi}{\cos\xi}\left[1 - e^{-2(\alpha+\pi+\xi)\mathrm{ctg}\xi}\right]$$

$(I)_{\alpha_p}$ - average value of the current flowing through the diode:

$$(I)_{\alpha_p} = \frac{1}{2\pi}\frac{U_M}{R}\left[\cos(\alpha_p + \xi) + 1\right] \quad (7)$$

$(I_S)_{\alpha_p}$ - average value of the load (R) current:

$$(I_S)_{\alpha_p} = \frac{I_M}{2\pi}\left[\cos\alpha_p + \frac{1}{\cos\xi} * \right. \\ \left. * \left[1 - \sin^2\xi\, e^{-(\alpha_p+\pi+\xi)\mathrm{ctg}\xi}\right]\right] \quad (8)$$

Limit cases:

For pure resistive load, $\omega RC = 0, \xi = 0$ it results:

$$\alpha_p = 0^0\ ,\ \beta = 90^0 \quad (9)$$

$$(U_m)_{\alpha_p} = \frac{U_M}{\pi}$$
$$(U_{def})_{\alpha_p} = \frac{U_M}{2}$$
$$(I)_{\alpha_p} = \frac{1}{\pi}\frac{U_M}{R} = \frac{I_M}{\pi} \quad (10)$$
$$(I_S)_{\alpha_p} = \frac{I_M}{\pi}$$

For pure capacitive load, $\omega RC = \infty, \xi = \frac{\pi}{2}$ it results:

$$\alpha_p \approx 90^0, \beta \approx 180^0 \quad (11)$$

$$(U_m)_{\alpha_p} = U_M$$
$$(U_{def})_{\alpha_p} = U_M$$
$$(I)_{\alpha_p} = 0 \quad (12)$$
$$(I_S)_{\alpha_p} = 0$$

2.2 Rectifier Parameters

According to [2], the following parameters are defined:

The periodicity factor:

$$k_m = \frac{(U_m)_{\alpha_p}}{U_M} = \frac{1}{2\pi}\left[\cos\alpha_p + \frac{1}{\cos\xi} * \right. \\ \left. * \left[1 - \sin^2\xi\, e^{-(\alpha_p+\pi+\xi)\mathrm{ctg}\xi}\right]\right] \quad (13)$$

The k_e factor:

$$k_e = \frac{(U_{def})_{\alpha_p}}{U_M} = \frac{1}{\sqrt{2\pi}} * \\ \sqrt{\pi - \xi - \alpha_p + \sin(\alpha_p + \xi)\cos(\alpha_p - \xi) + A} \quad (14)$$

unde

$$A = \frac{\sin^3\xi}{\cos\xi}\left[1 - e^{-2(\alpha+\pi+\xi)\mathrm{ctg}\xi}\right]$$

The shape factor:

$$k_f = \frac{k_e}{k_m} \quad (15)$$

The wave factor:

$$k_u = \sqrt{k_f^2 - 1} \quad (16)$$

The graphic representations of the four parameters variation as functions of load

$\xi = \mathrm{arctg}(\omega RC)$ are shown in the figures below.

The graphing was performed by using Mathcad.

The periodicity factor, k_m

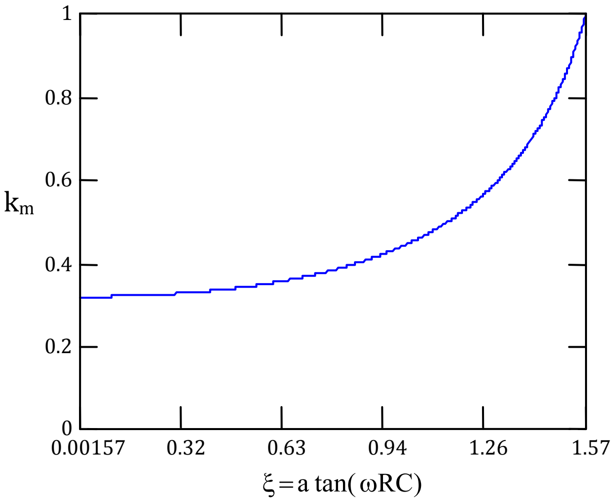

Fig.2 k_m factor variation as function of load, $\xi = \mathrm{arctg}(\omega RC)$

The k_e factor

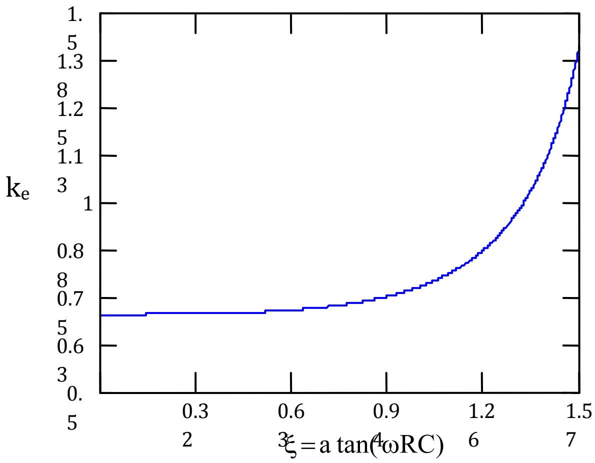

Fig.3. k_e factor variation as function of load, $\xi = \mathrm{arctg}(\omega RC)$

The shape factor, k_f

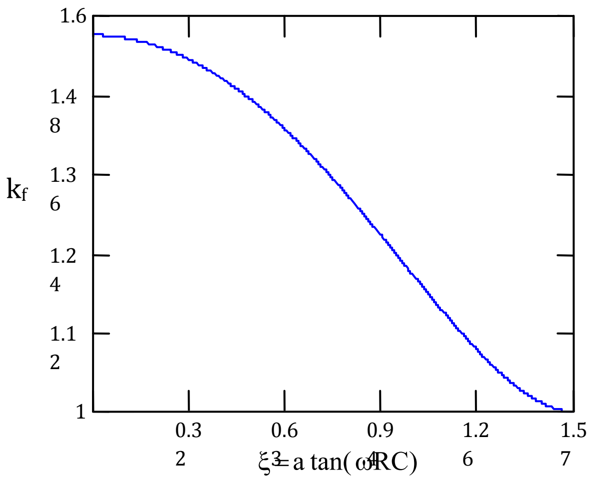

Fig.4 k_f factor variation as function of load, $\xi = \mathrm{arctg}(\omega RC)$

The wave factor, k_u

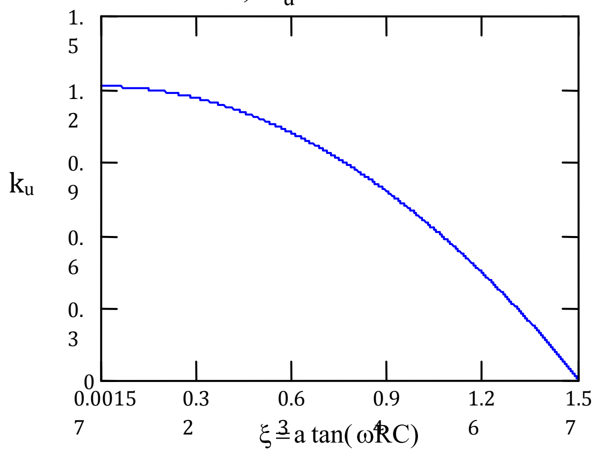

Fig.5 k_u factor variation as function of load, $\xi = \mathrm{arctg}(\omega RC)$

Considering the limit cases, the following values of the rectifier parameters are computed:

For the pure resistive load,

$\omega RC = 0$,

$\alpha_p = 0^0$

it results:

$$
\begin{aligned}
k_m &= 0.318 = \frac{1}{\pi} \\
k_e &= 0.707 = \frac{1}{\sqrt{2}} \\
k_f &= 1.571 \\
k_u &= 1.21
\end{aligned}
\tag{17}
$$

For pure capacitive load,

$\omega RC = \infty$,

$\alpha_p \approx 90^0$,

it results:

$$
\begin{aligned}
k_m &= 1 \\
k_e &= \sqrt{2} \\
k_f &= 1 \\
k_u &\to \infty
\end{aligned}
\tag{18}
$$

3. CONCLUSIONS & ACKNOWLEDGMENT

The following conclusions are deriving from the study of the half-wave voltage rectifiers equipped with uncontrolled electrical valves:

The diode turn-on angle α_p has an increasing variation of load (R);

The diode turn-off angle β has an decreasing variation of load (R);

The periodicity factor k_m is an increasing function of load (R);

The k_e factor is an increasing function of load (R) too;

The shape factor k_f is a decreasing function of load (R);

The wave factor k_u is also a decreasing function of load (R).

REFERENCES

1. Cerbulescu, D. *Convertoare statice de putere: Redresoare* Craiova: Editura Scrisul Românesc (1995).
2. Matlac, I. *Convertoare electroenergetice* Timişoara: Editura Facla (1987).