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# ABOUT POLY-PHASE VOLTAGE RECTIFIERS OPERATION

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***Abstract:*** *Some issues regarding the analysis of poly-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:*** *poly-phase, rectifier, diode,*

## 1. INTRODUCTION

A poly-phase switch, equipped with *m* individual uncontrolled switches (diodes) will be discussed. The input of this device consists in the following poly-phased voltage system:

$$\begin{cases} u_{1,0} = U_M \sin \omega t \\ u_{2,0} = U_M \sin\left(\omega t - \dfrac{2\pi}{m}\right) \\ \dots\dots\dots\dots\dots\dots \\ u_{p,0} = U_M \sin\left[\omega t - (p-1)\dfrac{2\pi}{m}\right] \\ \dots\dots\dots\dots\dots\dots \\ u_{m,0} = U_M \sin\left[\omega t - (m-1)\dfrac{2\pi}{m}\right] \end{cases} \qquad (1)$$

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

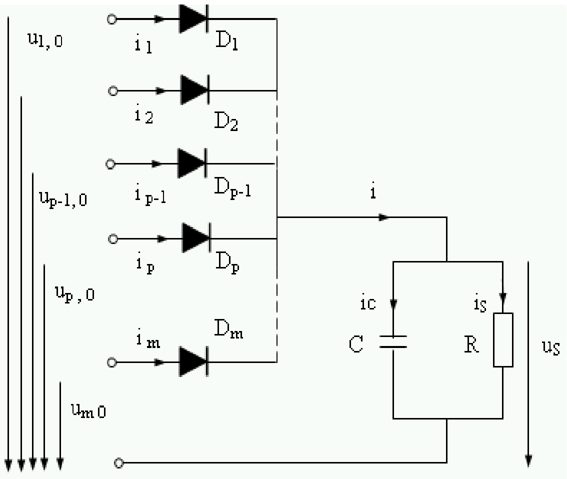


Fig.1. Poly-phase voltage rectifier with diode

The steady-state signals expressions are the following [1,3]:

The diode $D_p$ is "on":

$$\omega t \in \left( (p-1)\frac{2\pi}{m} + \alpha_p , (p-1)\frac{2\pi}{m} + \beta \right)$$

$$
\begin{cases}
u_S = u_p = U_M \sin\left[\omega t - (p-1)\dfrac{2\pi}{m}\right] \\
i_S = I_M \sin\left[\omega t - (p-1)\dfrac{2\pi}{m}\right] \\
u_{D,p} = 0 \\
i_C = \omega C U_M \cos\left[\omega t - (p-1)\dfrac{2\pi}{m}\right] \\
i_{D,p} = I_M \sin\left[\omega t - (p-1)\dfrac{2\pi}{m} + \xi\right]
\end{cases}
\tag{2}
$$

The diode $D_p$ is "off":

$$
\omega t \in \left( (p-1)\frac{2\pi}{m} + \beta \, , p\frac{2\pi}{m} + \alpha_p \right)
$$

$$
\begin{cases}
u_s = U_M \sin\varphi \, e^{-\frac{\left[\omega t - (p-1)\frac{2\pi}{m} - \beta\right]}{\omega R C}} = \\
= U_M \sin\xi \, e^{-\left[\omega t - (p-1)\frac{2\pi}{m} - \beta\right] \mathrm{ctg}\,\xi} \\
i_S = I_M \sin\varphi \, e^{-\frac{\left[\omega t - (p-1)\frac{2\pi}{m} - \beta\right]}{\omega R C}} = \\
= I_M \sin\xi \, e^{-\left[\omega t - (p-1)\frac{2\pi}{m} - \beta\right] \mathrm{ctg}\,\xi}
\end{cases}
\tag{3}
$$

The firing angle is computing by solving the equation:

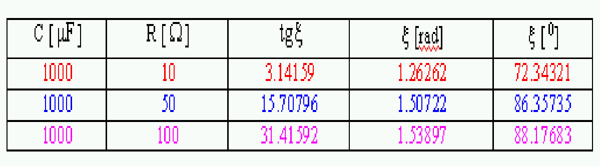
$$
\sin\xi \, e^{-\frac{\left(\frac{2\pi}{m} + \alpha_p - \beta\right)}{\omega R C}} = \sin\alpha_p \tag{4}
$$

The turn-off angle - $\beta$ - expression comes out from the condition: $i_{V,p}\left(\omega t = \beta + (p-1)\dfrac{2\pi}{m}\right) = 0$ resulting:

$$
\beta = \pi - \xi = -\mathrm{arctg}(\omega R C) \tag{5}
$$

The graphic representations of the signals $(u_i, u_s, i_{S,} \, i_C, i)$ as functions of load $\xi = \mathrm{arctg}(\omega RC)$ are shown in the figures below. A three-phase $(m = 3)$ was considered in the above mentioned plots, related to the load values presented in table 1.

Table 1



| C [μF] | R [Ω] | tgξ | ξ [rad] | ξ [⁰] |
|---|---|---|---|---|
| 1000 | 10 | 3.14159 | 1.26262 | 72.34321 |
| 1000 | 50 | 15.70796 | 1.50722 | 86.35735 |
| 1000 | 100 | 31.41592 | 1.53897 | 88.17683 |

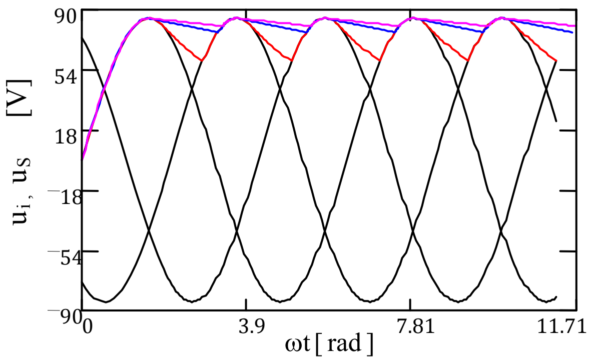


Fig.2 $u_i$ and $u_S$ variation for different load and m=3

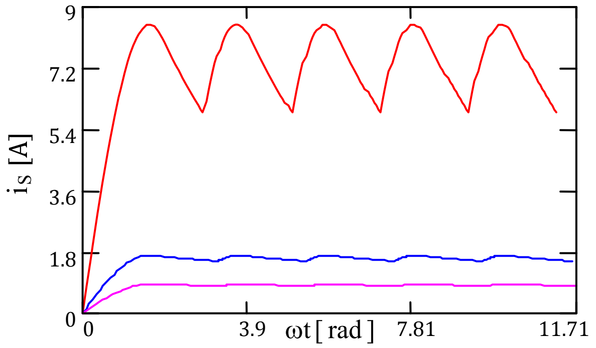


Fig.3 $i_S$ variation for different load and m=3

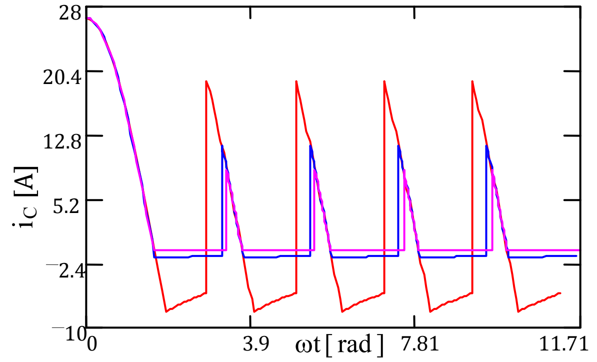


Fig.4 $i_C$ variation for different load and m=3

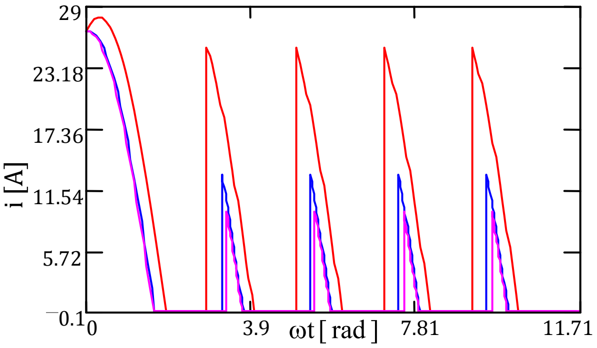


Fig.5 i variation for different load and m=3

## 2. CIRCUIT ANALYSIS

### 2.1 Variations of angles $\alpha_p$ and $\beta$

It results from (5) the following restrictions upon the circuit parameters in order to obtain a interrupted current regime:

$$\begin{aligned} &\xi = \operatorname{arctg}(\omega R C) > \frac{\pi}{2} - \frac{\pi}{m} \\ &m \geq 3 , \xi_{\min} = \frac{\pi}{2} - \frac{\pi}{m} \end{aligned} \tag{6}$$

The non-interrupted current regime is characterized by the fact that a diode turning-off is determined by the turning-on of another one. A necessary condition to be satisfied for the rectifier operation in this working regime is the following:

$$\beta \rangle \frac{\pi}{2} + \frac{\pi}{m} \tag{7}$$

Related to the interrupted current operation, considering a given number of phases – m – of the input voltage system, the capacitive load value is inferior limited by (6). Taking into consideration that $\alpha_p$ has an increasing variation with capacitive load value, it results that a minimum value of this parameter has to exist:

$$\alpha_{p,\min} = \frac{\pi}{2} - \frac{\pi}{m} \tag{8}$$

The variation of turning-on and off angles as function of rectifier parameters $\xi = \operatorname{arc\,tg}(\omega RC)$ and number of phases, m, is plotted in figure 6.

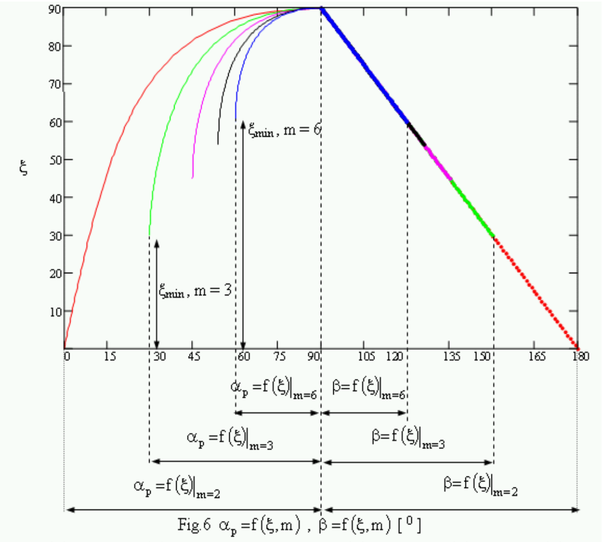


Fig.6 $\alpha_p$ and $\beta$ variation for different load and m=3

### 2.2 The Voltages and Currents Average Values

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

$(U_{d,m})_{\alpha_p}$ - average value of the output voltage:

$$(U_{d,m})_{\alpha_p} = \frac{m U_M}{2\pi} \left[ \cos \alpha_p + \frac{1}{\cos \xi} * \right. \\ \left. * \left[ 1 - \sin^2 \xi \, e^{-\left(\alpha_p + \varphi + \pi \frac{2-m}{m}\right) \operatorname{ctg} \varphi} \right] \right] \tag{9}$$

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

$$\left(U_{def,m}\right)_{\alpha_p}=\frac{U_M\sqrt{m}}{2\sqrt{\pi}}*$$

$$*\sqrt{\pi-\xi-\alpha_p+\sin\left(\alpha_p+\xi\right)\cos\left(\alpha_p-\xi\right)+A}\quad(10)$$

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

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

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

$$=m\left(I\right)_{\alpha_p}$$

(11)

$\left(I_{S,m}\right)_{\alpha_p}$ - average value of the load (R) current:

$$\left(I_{S,m}\right)_{\alpha_p}=\frac{mI_M}{2\pi}\left[\cos\alpha_p+\frac{1}{\cos\xi}*\right.$$

$$\left.*\left[1-\sin^2\varphi\, e^{-\left(\alpha_p+\xi+\pi\frac{2-m}{m}\right)ctg\,\varphi}\right]\right]=\quad(12)$$

$$=\frac{\left(U_{d,m}\right)_{\alpha_p}}{R}$$

## 3. CONCLUSIONS & ACKNOWLEDGMENT

The following conclusions derive from the study of voltage poly-phased rectifiers, provided with non-controlled switches (diodes):

1. The non-interrupt current regime is possible only if the rectifier load respects (6);
2. After the second switch of the diode, the circuit reaches its steady state regime;
3. The diode turn-on angle $\alpha_p$ has an increasing variation of load (R);
4. The diode turn-off angle $\beta$ has an decreasing variation of load (R);

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