Quick designing methods for power current inverters with electrotechnology application

*Assoc. prof. PhD. Rumen D.Karov[1], eng. Radoslav I. Trendafilov[2],

Abstract. **Comfortable equations are derived from this work, because of the starting conditions' optimization in the parallel current inverter curcuit, and they are used for different current inverter designing (series-parallel, parallel-series), which have electrotechnology application.**

Unificated methods are obtained for a variety of different curcuits, based on the parallel and series substitution inverter curcuit.

Formula unification and optimization give possibility for quick current power inverter designing with electrotechnology application. The given examples and simulations show the design methods' application ability.

Keywords: **Current inverter, analysis, simulation**

Introduction

Quick method for power current inverters calculation with electrotechnology application is shown in the paper and method comparison is made to the simulation data. The result of the comparison helps to method accuracy evaluation having in mind the simple methodology. Because of the equations complexity, describing the current inverter processes, some assumptions for close to real regimes are made, which are optimal towards maximal voltage, commutation conditions, defasing angle β between output current and output voltage. The paper includes practical equations, results and example calculations at active-inductance load work, characterized with small $\cos\varphi_т$ in electrotechnology applications (as induction metal melting).

Analysis

A coefficients choice for current inverter analysis is recommended [2] by the well know methodologies, which puts indeterminacy in the calculations and slows the procedure.

*TU - Sofia, branch Plovdiv, Electrotechniques and Electronics, tel. 032/659713, e-mail: [1]r_karov@mail.bg, [2]radoslav_t@abv.bg

Because of the made workouts for current equation [1,3] of

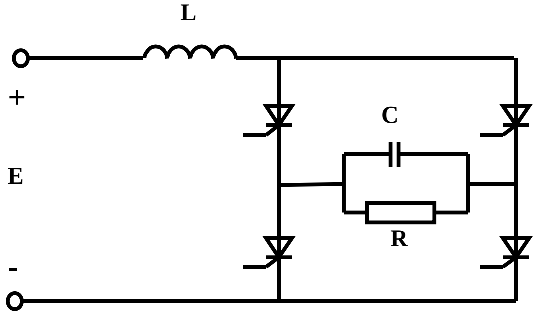

Fig.1

parallel inverter (fig.1), we have:

$$i(t)=\frac{E}{R}+\left(\frac{E+U_{C0}}{\omega L}-\frac{\delta}{\omega}.\frac{E}{R}+\frac{\delta}{\omega}.I(0)\right)e^{-\delta t}\sin\omega t+ \\ +\left(I(0)-\frac{E}{R}\right)e^{-\delta t}\cos\omega t \tag{1}$$

Parallel current inverter modeling methodology is based on the conduction:

$$I(0)=\frac{E}{R} \tag{2}$$

If we substitute $I(0)=\frac{E}{R}$ (2) into current equation i(t) (1), which is obtained for close to optimal regimes, angle $\beta\approx30^0$ and limit regime, where:

$$\sqrt{\frac{L}{C}}=2R \tag{3}$$

then for current in (1) we have:

$$i(t)=\frac{E}{R}\left(1+e^{-\delta t}\sin\omega t\right) \tag{4}$$

For maximal thyristor voltages and power supply voltage, following equations are obtained:

$$E=\frac{U_{изх}}{\sqrt{1.64\eta}},\ U_m=\sqrt{2}U_{изх} \tag{5}$$

The output current phase shifting to voltage and thyristor recovery time can be determined from:

$$\beta=\arccos\frac{\pi}{2\sqrt{2}\sqrt{1.64\eta}},\ t_q=\frac{\beta}{\omega} \tag{6}$$

The equivalent active resistance value in respect to inverter output and currents offer processing is:

$$R=\frac{U_{изх}^{2}}{P_{изх}},\ I_0=\frac{1.64E}{\eta R}\ \text{and}\ I_{AV}=\frac{I_0}{2} \quad (7)$$

The connection between equivalent and active load resistance is:

$$R_{т}=R\cos^{2}\varphi_{т} \quad (8)$$

For load inductance we have:

$$L_{т}=\frac{R_{т}tg\varphi_{т}}{\omega} \quad (9)$$

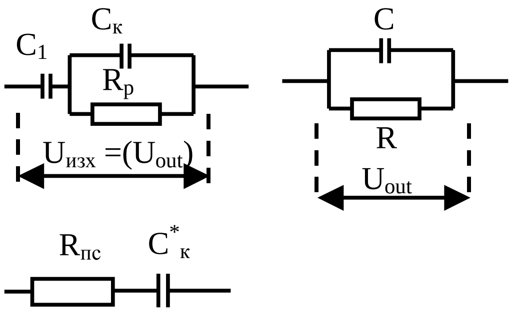

Fig.2

When the output circuit is substituted by series equivalent circuit (fig. 2), the active resistance value is:

$$R_{пс}=R\cos^{2}\beta \quad (10)$$

Minimal required input inductance and parallel capacity values are:

$$L=4R^{2}C \quad (11)$$

$$C_{т}=\frac{L_{т}}{RR_{т}} \quad (12)$$

The same theoretical base can be used for series – parallel current inverter the necessary circuit processing (fig.2).

The parallel capacitor is divided into two components – inductive character compensating one ($C_т$) and compensating one ($C_к$).

The series parallel inverter circuit is shown on fig.3 and its elements can be expressed simply by the substituting circuit as it is shown on fig.2.

As (1) is used and assumption (2), is made, which is applicable for the case, for necessary supplying voltage we have (5).

Thyristor recovery time by the use of β is (6).

Output inverter active resistance and current are (7).

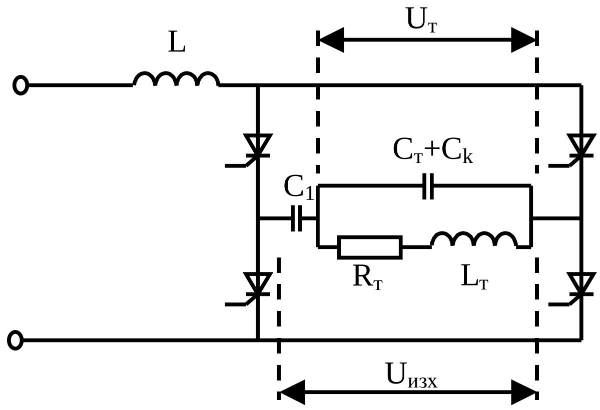

Fig.3

R_p value (fig.2) is:

$$R_{p}=\frac{U_{т}^{2}}{P_{изх}} \quad (13)$$

$U_{изх}$ and $U_т$ ratio is determined by angles γ and β:

$$\frac{U_{изх}}{U_{т}}=\sqrt{\frac{R}{R_{p}}}=\frac{\cos\gamma}{\cos\beta},\ \cos\gamma=\frac{U_{изх}}{U_{т}}\cos\beta \quad (14)$$

As output circuit processing is used, capacitor values can be determined by equations after equivalent capacity towards inverter output is calculated:

$$\omega CR=tg\beta,\ C=\frac{tg\beta}{\omega R} \quad (15)$$

The necessary commutating capacitor, giving enough recovery time is:

$$\omega C_{k}R_{p}=tg\gamma,\ C_{k}=\frac{tg\gamma}{\omega R_{p}},\ C=\frac{tg\beta}{\omega R} \quad (16)$$

Then for series capacitor we have:

$$C_{1}=\frac{1}{\frac{1}{C}\sin^{2}\beta-\frac{1}{C_{k}}\sin^{2}\gamma} \quad (17)$$

and active load component:

$$R_{т}=R_{p}\cos^{2}\varphi_{т} \quad (18)$$

Here – similar to parallel inverter, when output circuit is substituted by series equivalent circuit, active resistance and load inductance values are:

$$R_{пс}=R_{p}\cos^{2}\gamma=R\cos^{2}\beta,\ L_{т}=\frac{R_{т}tg\varphi_{т}}{\omega} \quad (19)$$

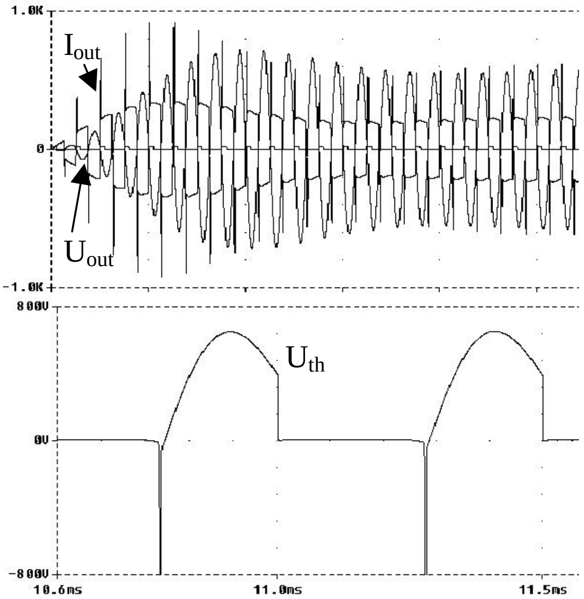

Fig.6

Minimal input inductance is (11), but necessary input inductance reactor is:

$$L = \frac{R_{пс}}{R_T} L_T \qquad (20)$$

Compensating load inductance component is:

$$C_T = \frac{L_T}{R_p R_T} \qquad (21)$$

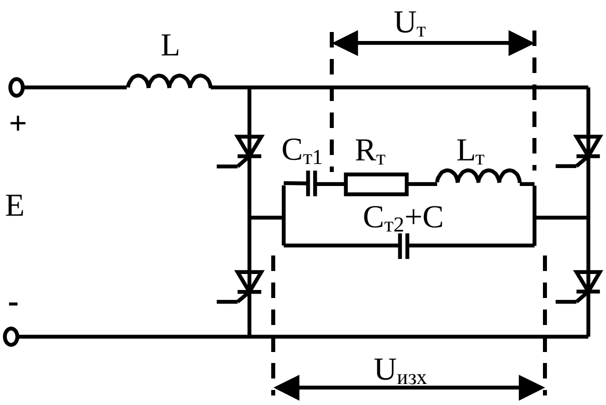

Fig.4

For parallel-series current inverter (fig.4) modeling also begins with the help of (5), (6), (7) and $U_{изх}/U_т$ ratio is determined by angles φ_e and $\varphi_т$:

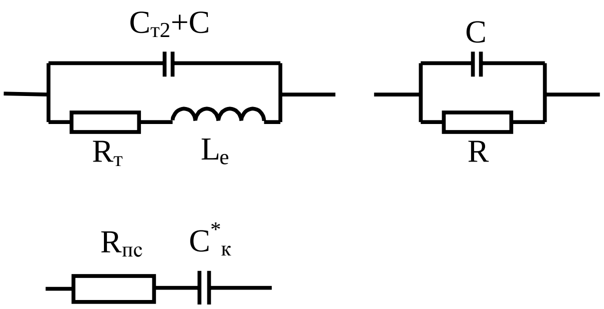

Fig.5

$$\frac{U_T}{U_{изх}} = \frac{\cos\varphi_e}{\cos\varphi_T},\ \cos\varphi_e = \frac{U_T}{U_{изх}}\cos\varphi_T,\ R_T = R\cos^2\varphi_e,$$

$$L_T = \frac{R_T \mathrm{tg}\varphi_T}{\omega} \qquad (22)$$

from where equivalent inductance L_e (fig.5), $C_{т1}$ and $C_{т2}$ are determined.

$$L_e = \frac{R_T}{\omega}\mathrm{tg}\varphi_e,\ C_{T1} = \frac{1}{\omega^2(L_T - L_e)},\ C_{T2} = \frac{L_e}{RR_T} \qquad (23)$$

C and L values are determined from (15) and (20).

Calculations and simulation results.

Calculations and simulation of series-parallel current inverter for electrotechnology application are made according to the following output data: $\cos\varphi=0,1$; $U_{изх}=500V$; f=2kHz; $\eta=0,95$; $U_т=450V$. Data comparison is made on Table 1.

Table 1. Results

	E	$U_{th\ max}$	I_0	t_q	β	γ
Calculated values	400V	700V	250A	38μS	27°	9°
Simulation values	400V	650V	230A	33μS	24°	7°

	C_1	$C_т+C_k$	$R_т$	$L_т$	L
Calculated values	93μF	376μF	0,02Ω	15μH	1,48mH
Simulation values	100μF	400μF	0,02Ω	15μH	1,5mH

Inverter curcuit simulation graphics is shown on fig.6.

Conclusions: By the use of the shown calculations a current inverter for electroechnology applications can be modeled with quick methodology at different ratio of inverter circuit and input inductance parameters. Used switching elements type can also be determined the base of maximal work current and voltage.

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