GENERALIZED CHARACTERISTICS OF SEMICONDUCTOR R L C INVERTERS

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Abstract

The new unified approach towards the steady-state analysis of semiconductor RLC inverters is applied and their generalized characteristics are obtained, avoiding the simplifying assumption concerning the shape of the inverter output current (or voltage). The analysis and the expressions for the main parameters of the transistor RLC inverter with free-wheeling diodes for various modes of operation and their validity for the dual thyristor current-fed inverter are utilized. The whole mathematical information is processed by a computer under the control of a specially designed FORTRAN program. At the end the following generalized characteristics are obtained: the output characteristic OCH, characterizing the RMS value of the inverter output current (or voltage); the input characteristic ICH, characterizing the inverter input voltage (or current); the turn-off (recovery) characteristic, characterizing the thyristor turn-off (recovery) time for the thyristor inverters and additionally the klirrfactor kf[%], characterizing the difference between the sinusoidal shape and the real shape of the output current (or voltage). These generalized characteristics of the semiconductor RLC inverters are given as functions from the load coefficient B and the load power factor $\cos\varphi$ *. They are proved in several different ways. They show more accurately the influence of B and* $\cos\varphi$ *on the inverter operation.*

The new unified approach towards the steady - state analysis of semiconductor RLC inverters, proposed in [1], makes possible to obtain their generalized characteristics without a simplifying assumption concerning the shape of the inverter output current (or voltage). This approach is based on the duality equivalence between the transistor RLC inverter with free - wheeling diodes and the thyristor parallel current - fed inverter. The transistor voltage - fed inverter can be considered as a partial case of the transistor RLC inverter with free - wheeling diodes, working in aperiodical mode when $C=\infty$.

The expressions for the analysis of the transistor inverter working in resonant mode with capacitive reaction of its diagonal serial RLC circuit and continuous inverter current (Fig.1) are taken from [2] and [3]. In this case the dual counterpart namely the thyristor parallel current - fed inverter is not fit for operation due to the lack of thyristor turn - off time. When the transistor inverter current becomes discontinuous the expressions for the variables are changed in such a manner in order the discontinuity of the inverter current and its influence on the other parameters to be taken into account.

When the transistor inverter works in resonant mode with inductive reaction of its diagonal serial RLC circuit and the shape of the of the inverter current looks like that shown in Fig.2, the expressions for the analysis taken from [2] and [3] are only slightly changed to take into account the opposite sign of the initial inverter current which leads to an opposite sign in the expression for the "a" coefficient and influences the average currents through the devices and that drawn from the supplying source. In this case the dual counterpart of the transistor inverter namely the thyristor parallel current - fed inverter has a capacitive reaction of its diagonal circuit and is in principle fit for operation depending on the other inverter parameters.

The expressions for the analysis of the transistor inverter working in critically - aperiodical or aperiodical mode are given in [4] and [5] respectively.

The generalized characteristics are obtained in the following manner. The main parameters of the inverter circuit namely the load coefficient B and the load power factor $\cos\varphi$ are varied in practical limits, for instance $B=0.05$ - 8.0 and $\cos\varphi=0.05;$ $0.2;$ $0.35;$ $0.5;$ $0.8;$ $1.0.$

The load coefficient of the transistor RLC inverter with free - wheeling diodes is

(1a) $$B=\frac{\sqrt{1+\omega^2C^2R^2}}{\omega^2LC}$$

and the load power factor is

(2a) $$\cos\varphi=\frac{\omega CR}{\sqrt{1+\omega^2C^2R^2}}$$

The load coefficient of the thyristor parallel current - fed inverter (the transistor inverter dual counterpart) is

(1b) $$B=\frac{1}{\omega C\sqrt{R^2+\omega^2L^2}}$$

and the load power factor is

(2b) $$\cos\varphi=\frac{R}{\sqrt{R^2+\omega^2L^2}}$$

where R, L and C are the parameters of its diagonal parallel circuit.

Ten for different modes of operation of the inverter circuit its main parameters are calculated applying the already stated methods of analysis [2], [3], [4], [5]. The whole mathematical information is processed by a computer under the control of a specially designed FORTRAN computer program. At the end the following generalized characteristics of the inverter circuits are determined.

□ Output characteristic OCH, shown in Fig.3 (see [2] for comparison), which for the transistor RLC inverter with free - wheeling diodes is

(3a) $$OCH=\frac{I}{I_d}$$

where I is the RMS value of the inverter current and I_d is the average value of the current drawn from the supplying source, and which for the thyristor current - fed inverter is

(3b) $$OCH = \frac{U}{U_d}$$

where U is the RMS value of the output voltage and U_d is the supplying voltage.

- Input characteristic ICH, shown in Fig.4 (see [2] for comparison), which for the transistor inverter is

(4a) $$ICH = \frac{U_d}{I_d \omega L}$$

while for the thyristor inverter it is

(4b) $$ICH = \frac{I_d}{U_d \omega C}$$

- Recovery (turn - off) characteristic TQC, shown in Fig.5 (see [2] for comparison), which has physical sense for the thyristor inverters namely

- for the thyristor resonant inverters with free - wheeling diodes with capacitive reaction of the diagonal serial RLC circuit

(5a) $$TQC = \frac{t_{q.c.}}{T} = \frac{(\theta_2 - \theta_1)[rad]}{\omega_0 T}$$

where $t_{q.c.}$ is the circuit recovery (turn - off) time and $T = \frac{2\pi}{\omega}$ is the period, corresponding to the controlling frequency.

- for the thyristor parallel current - fed inverter with capacitive reaction of its diagonal parallel RLC circuit, whose dual counterpart is the transistor resonant inverter with inductive reaction of the RLC circuit

(5b) $$TQC = \frac{t_{q.c.}}{T} = \frac{\theta_1}{\omega_0 T}$$

- for the thyristor parallel current - fed inverter whose dual counterpart is the transistor RLC inverter, working in critically - aperiodical mode [4]

(5c) $$TQC = \frac{t_{q.c.}}{T} = \frac{\theta_1}{\delta T}$$

- for the thyristor parallel current - fed inverter, whose dual counterpart is the transistor RLC inverter working in periodical mode [5]

(5d) $$TQC = \frac{t_{q.c.}}{T} = \frac{\theta_1}{\Omega T}$$

An additional characteristic giving the klirrfactor of the inverter current for the transistor RLC inverter with free - wheeling diodes

(6a) $$kf\,[\%] = \frac{\sqrt{I^2 - I_{(1)}^2}}{I_{(1)}}.100$$

where $I_{(1)}$ is the fundamental harmonic of the inverter current, and the klirrfactor of the output voltage for the thyristor parallel current - fed inverter

(6b) $$kf\,[\%] = \frac{\sqrt{U^2 - U_{(1)}^2}}{U_{(1)}}.100$$

where $U_{(1)}$ is the RMS value of the fundamental harmonic of the output voltage, as a function from B and $\cos\varphi$, is shown in Fig.6. The klirrfactor *kf*[%] actually shows the difference between the sinusoidal and the real shape of the output inverter current (or voltage). This parameter shows also the applicability (and indirectly the accuracy) of the methods for analysis of inverters, based on the assumption that the output current (or voltage) is purely sinusoidal.

It can be seen from the generalized characteristics *OCH(B,* $\cos\varphi$*)* (Fig.3), *ICH(B,* $\cos\varphi$*)* (Fig.4), *TQC(B,* $\cos\varphi$*)* (Fig.5), that some of their parts are drawn with a normal continuous line and some of their parts are drawn with a dashed line. For the parts of the characteristics drawn with a normal continuous line the values of B and $\cos\varphi$ are such that the thyristor parallel current - fed inverter is in principle fit for operation. For the parts of the characteristics drawn with a dashed line the values of B and $\cos\varphi$ are such that the thyristor parallel current fed inverter is not fit for operation due to the inductive reaction of its diagonal parallel RLC circuit, while its dual counterpart the transistor resonant RLC inverter with free- wheeling diodes works with capacitive reaction of its diagonal serial RLC circuit. The "x" sign, which can be seen on some of the characteristics especially those for $\cos\varphi$=0.05; 0.2; 0.35 in Fig.3, Fig.4, Fig.5 (sharp change of the slope), corresponds to the transition from continuous inverter current (lower values of B) to the discontinuous inverter current (higher values of B) for the transistor resonant RLC inverter with free - wheeling diodes.

The generalized characteristics of semiconductor RLC inverters are proved in several different ways for the various modes of operation, but this information and the computer FORTRAN program for obtaining the characteristics would be subjects of other publications. A simple indirect example of proving the obtained characteristics is their coincidence with the same characteristics for the thyristor current - fed inverter with a parallel RC circuit in its diagonal ($\cos\varphi$ = 1), given in [2]. Especially for this case the characteristics are valid also for transistor voltage - fed inverter with a serial RL load.

The generalized characteristics show more accurately the influence of the load coefficient B and the load power factor $\cos\varphi$ on the inverter behavior.

References

1. Popov E.I. "A new unified approach towards the analysis of semiconductor RLC inverters", Proceedings of the 7th National Scientific Conference with International Participation "Electronic Technique ET'98", 23-25.10.1998., Sozopol, Bulgaria.
2. Natchev N., Maleev G. "Power Electronics", Technika Printing House, Sofia, 1979 (in Bulg.).
3. Karov R.D. "On the general theory of the serial inverters with free - wheeling diodes and without free - wheeling diodes", Proceedings of the Scientific Conference "Radio's Day", vol. III, "Electronic Technique", 7.5.1975. (in Bulg.).
4. Popov E.I. "Investigation of transistor RLC inverters working in critically - aperiodical regime", Proceedings of the Fifth Scientific Conference with International Participation "Electronic Technique - ET'96", 27-29.9.1996. Sozopol, Bulgaria (in Bulg.).
5. Popov E.I. "Investigation of transistor RLC inverters working in aperiodical regime", Proceedings of the Fifth Scientific Conference with International Participation "Electronic Technique - ET'96", 27-29.9.1996. Sozopol, Bulgaria (in Bulg.).

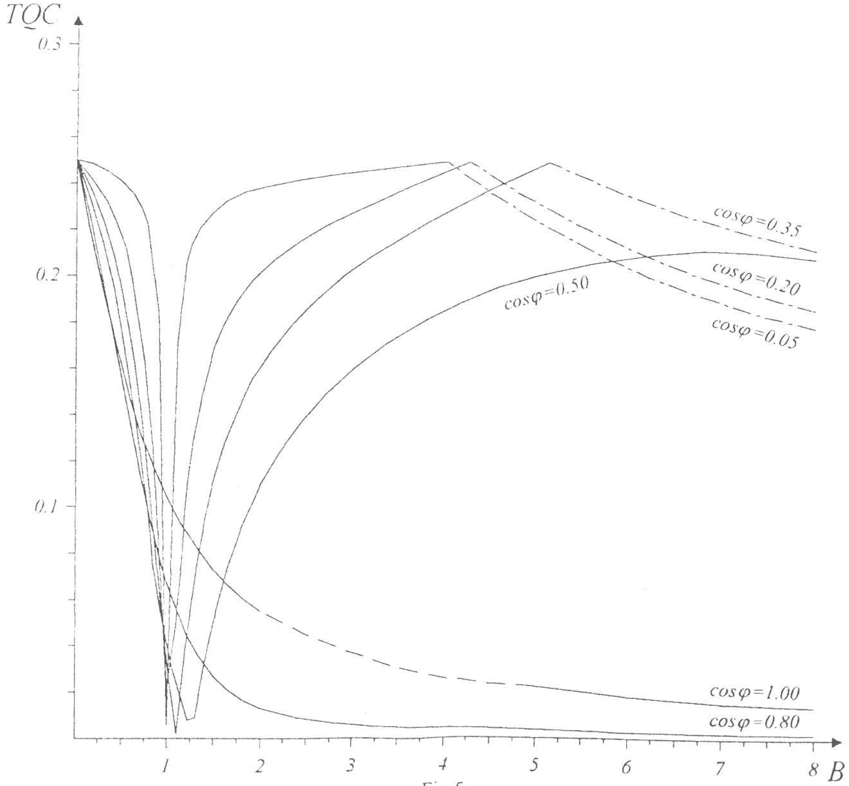


Fig.5

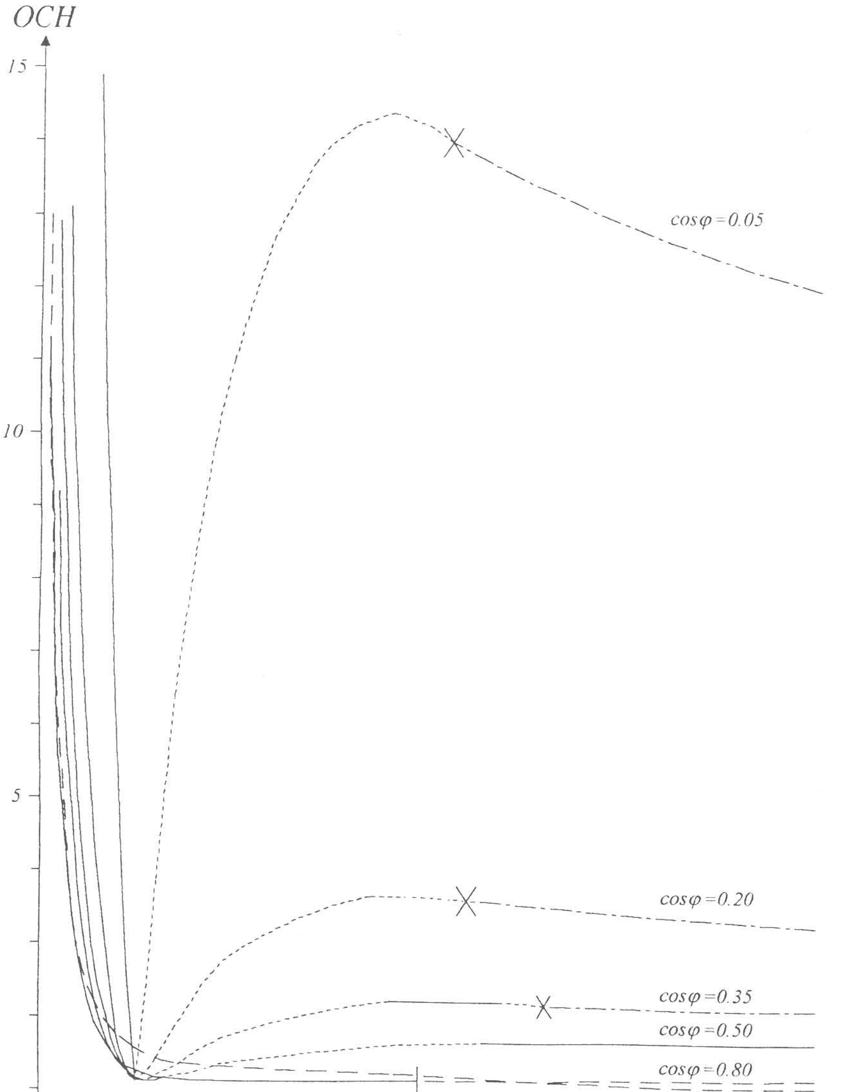
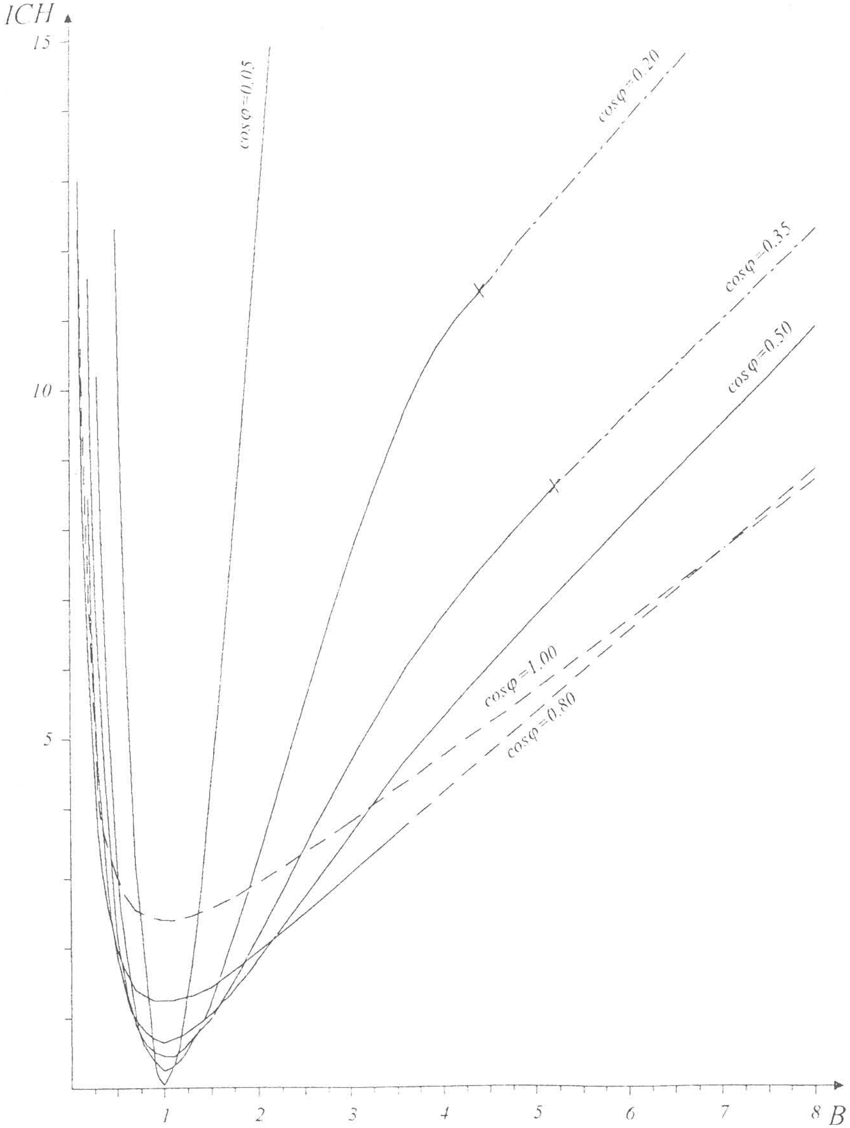

OCH
15
10
5
cosφ=0.05
cosφ=0.20
cosφ=0.35
cosφ=0.50
cosφ=0.80
cosφ=1.00
1
2
3
4
5
6
7
8
B

Fig.3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1
2
3
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B
Fig.4

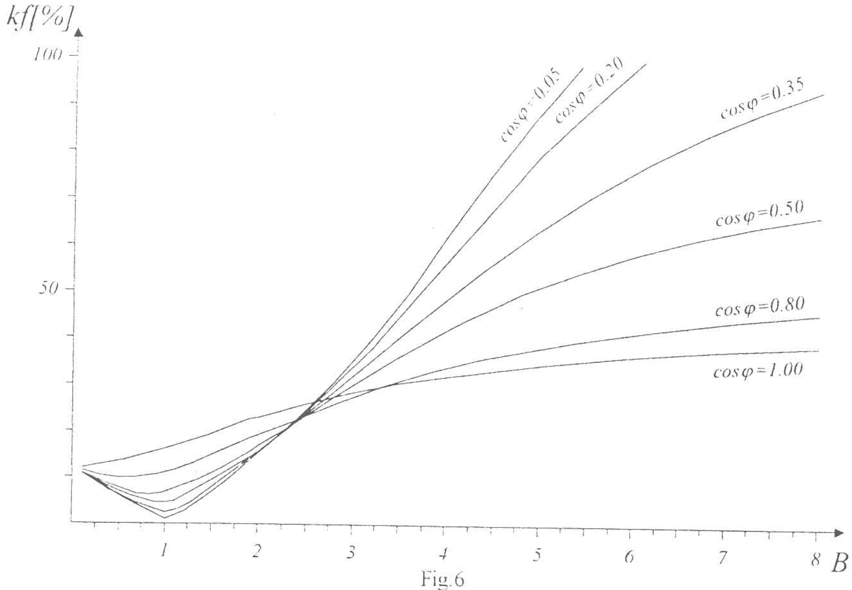

Fig.6

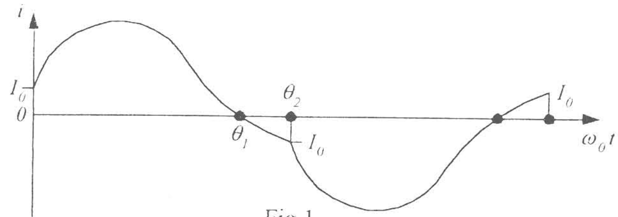

Fig.1

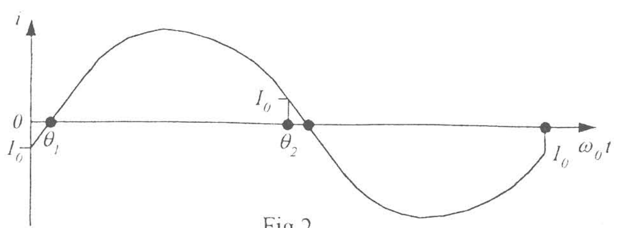

Fig.2