CONTROLLING FREQUENCY INFLUENCE ON THE OPERATION OF SERIAL THYRISTOR RLC INVERTERS

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The influence of the controlling frequency on the operation and parameters of the serial thyristor RLC inverters is studied. The autonomous bridge configuration of the serial thyristor RLC inverter without free–wheeling diodes is considered. The semiconductor device can also be a combination of a transistor and a diode connected in series. Two suitable parameters are introduced that are the Q^*–factor of the inverter circuit (frequency independent) and the frequency coefficient n. The meaning of the last is widened for oscillatory, overdamped and critical modes of operation. The relations between this couple of parameters and the load coefficient B, power factor $\cos\varphi$ couple are given. The chart in the (n,Q^*) plane determines the inverter mode of operation. The frequency characteristics namely the output characteristics, the input characteristics, the recovery characteristics, the klirrfactor characteristics and the peak thyristor voltage characteristics are obtained as functions from (n,Q^*) parameters and graphically displayed.

1. INTRODUCTION

In most practical cases the main controlling variable of the autonomous inverters is the controlling (switching) frequency of the semiconductor devices $\omega=2\pi f$ [1]-[5]. The influence of the controlling frequency on the parameters and characteristics of the current-fed inverters is studied in [1], [4]. The controlling frequency characteristics of the serial thyristor inverters for induction heating are obtained in [2]. The frequency characteristics of a transistor inverter operating with a frequency higher than the resonance one are given in [3]. The influence of the controlling frequency at resonance inverters is studied in [5]. On the other hand on the basis in [6] the generalized characteristics of the serial thyristor RLC inverters are obtained in [7] and are confirmed in [8]. They express in an implicit form the influence of the controlling frequency. The name serial thyristor RLC inverters is applied for all the inverters having the structure shown in Fig. 1. Their building device is either a thyristor without a free-wheeling diode connected in anti-parallel or a transistor and a diode connected in series. The influence of the controlling frequency on the operation and characteristics of semiconductor RLC inverters is studied in [9]. It is not known a full study of the influence of the controlling frequency on the parameters of the serial thyristor RLC inverters for different modes of operation including the overdamped and critical character of the circuit to exist.

The objective of the present scientific report is a unified, complete and in an explicit form study of the influence of the controlling frequency on the parameters of

the serial thyristor RLC inverters for different modes of operation to be carried out and the frequency characteristics to be derived.

2. PARAMETERS OF THE INVERTER CIRCUIT

The inverter circuit is of second order and is described by the parameters quality factor Q^* and frequency coefficient n. They can be expressed by the parameters of the inverter (Fig. 1) on one hand and by the load cofficient B and the power factor $cos\varphi$ on the other in the following manner:

(1) $$Q^* = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\sqrt[4]{1-\cos^2\varphi}}{\cos\varphi\sqrt{B}}$$

(2) $$n = \frac{\omega}{\Omega} = \frac{2}{\sqrt{c4B\sin\varphi - c_1B^2\cos^2\varphi}},$$

where Ω is the generalized frequency that for oscillatory character of the circuit $(R < 2\sqrt{\frac{L}{C}})$ is the inherent resonance frequency $\Omega = \omega_0 = \sqrt{\frac{1}{LC} - \delta^2}$, for overdamped character $(R > 2\sqrt{\frac{L}{C}})$ it is the quasi-resonance frequency $\Omega = \sqrt{\delta^2 - \frac{1}{LC}}$ and for critical character $(R = 2\sqrt{\frac{L}{C}})$ it is the damping coefficient $\Omega = \delta = \frac{R}{2L}$. The coefficients c and c_1 have the following values: for oscillatory character $c=c_1=1$, for overdamped character $c=c_1=-1$, for critical character $c=0$ $c_1=-1$. The parameters Q^* and Ω are frequency independent while n expresses directly and explicitly the influence of the controlling frequency. Q^* can be expressed directly by the known coefficient of hesitation k of the resonance inverters but it has a meaning also at overdamped and critical character of the processes. All this shows the convenience of the parameters n and Q^* when studying the influence of the controlling frequency and deriving the frequency characteristics.

Contrariwise, the parameters B and $cos\varphi$ can be expressed by n and Q^*:

(3) $$B = \frac{\sqrt{n^2c[1-\frac{1}{4(Q^*)^2}]+(Q^*)^2}}{n^2c[1-\frac{1}{4(Q^*)^2}]Q^*}$$

(4) $$\cos\varphi = n.\sqrt{\frac{c[1-\frac{1}{4(Q^*)^2}]}{n^2c[1-\frac{1}{4(Q^*)^2}]+(Q^*)^2}}$$

for oscillatory and overdamped character of the circuit, and

(5) $$B = \frac{2\sqrt{n^2 + 0{,}25}}{n^2}$$

(6) $$\cos\varphi = \frac{n}{\sqrt{n^2 + 0{,}25}}$$

for critical character.

3. MODES OF OPERATION CHART

The chart, showing the influence of the parameters B and $cos\varphi$ on the inverter modes of operation is given in [7]. Similar chart, showing the influence of the parameters n and Q^* on the inverter modes of operation is shown in Fig. 2. In principle both charts are equivalent.

4. INVERTER CIRCUIT STUDY

Detailed study and analysis of the serial thyristor RLC inverters is done in [6]. On this basis the generalized characteristics are obtained in [7] and are confirmed in]8]. They express in a hidden form the influence of the controlling frequency on the inverter operation. A computer program is developed that processes the mathematical information, determines the modes of operation and calculates the inverter parameters when changing the controlling frequency (by varying n) at different quality factors Q^* of the circuit.

5. RESULTS. FREQUENCY CHARACTERISTICS

The frequency coefficient n is varied from 0.2 to 2.0 at an interval of 0.2, while the quality factor Q^* assumes the values 0.2; 0.35; 0.5; 1; 2; 4. The following frequency characteristics are obtained and graphically displayed.

Output characteristics (Fig. 3):

(7) $$OCH = \frac{I}{I_d}$$

Input characteristics (Fig. 4):

(8) $$ICH_N = \frac{U_d}{I_d \Omega L}$$

Recovery characteristics (Fig. 5):

(9) $$TQC = \frac{t_{q.c.}}{T}$$

Klirrfactor characteristics (Fig. 6):

(10) $$k_f[\%] = \frac{\sqrt{I^2 - I_{(1)}^2}}{I_{(1)}}$$

Peak thyristor voltage characteristics (Fig. 7):

(11) $$UVSM = U_{VSm} / U_d$$

I, $I_{(1)}$ are the RMS value and the first harmonic RMS value of the inverter current; $t_{q.c}$. is the circuit turn-off time; $T=1/f$ is the period of the controlling pulses; U_{VSm} is the peak thyristor voltage; U_d, I_d are the supplying voltage and current.

6. CONCLUSION

The results from the present study and from the generalized characteristics coincide. The generalized characteristics are experimentally confirmed. Hence, the results from the study of the controlling frequency influence and the controlling characteristics derived are correct. The mathematical information for calculating the frequency controlling characteristics could be applied for organizing an adequate digital control system of the inverter.

7. REFERENCES

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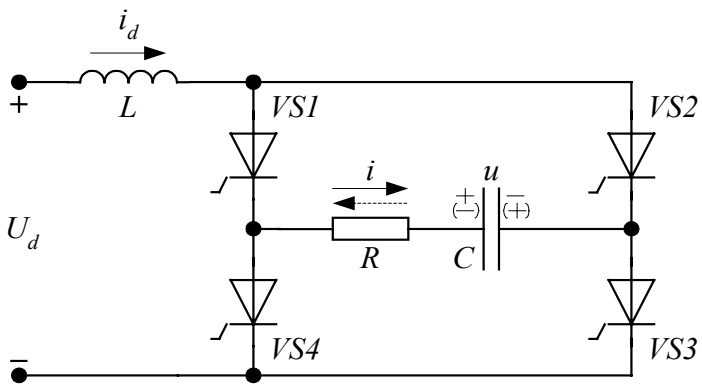

Fig. 1. A serial thyristor RLC inverter without free-wheeling diodes.

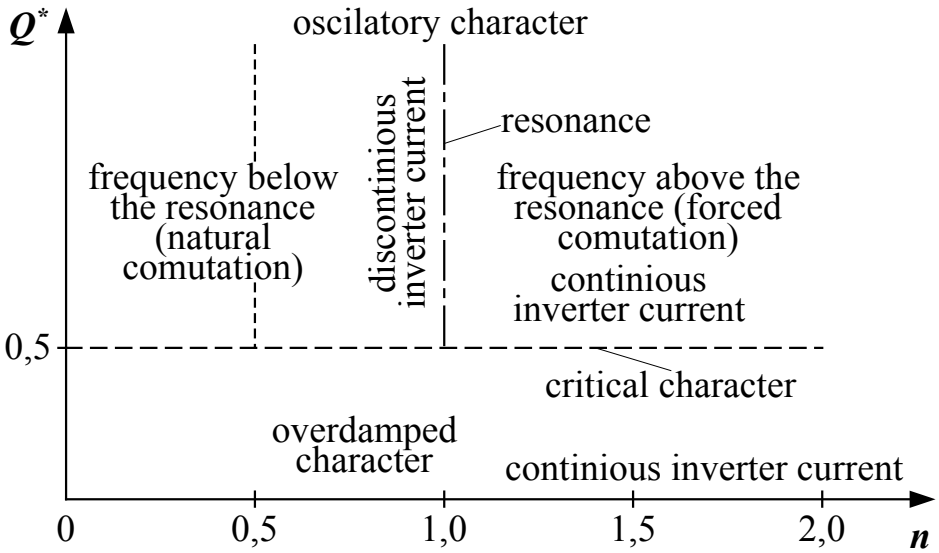

Fig. 2. Modes of operation chart.

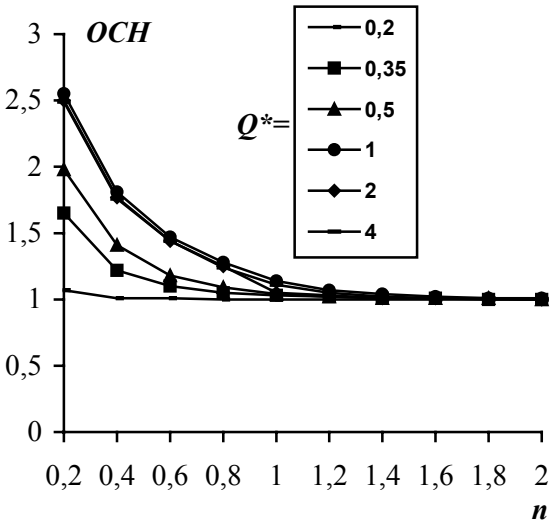

Fig. 3. Output characteristics.

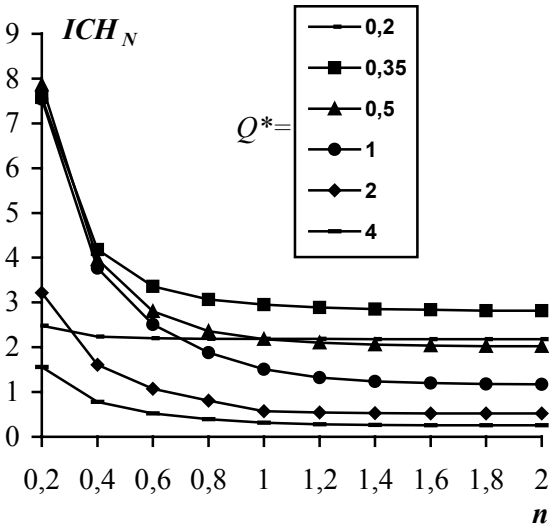

Fig. 4. Input characteristics.

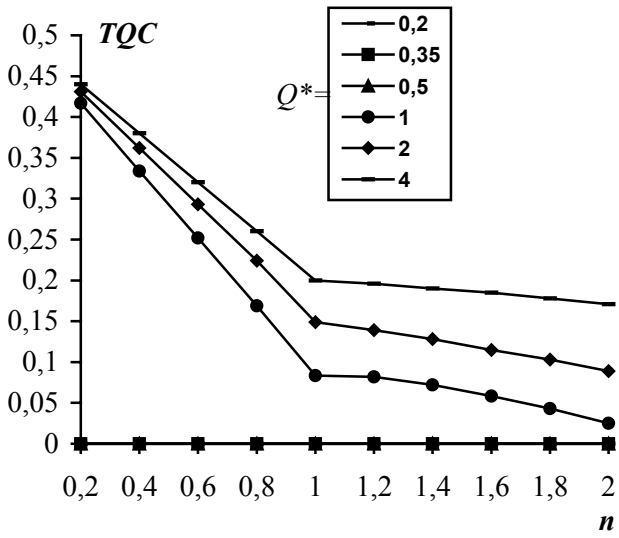

Fig. 5. Recovery characteristics.

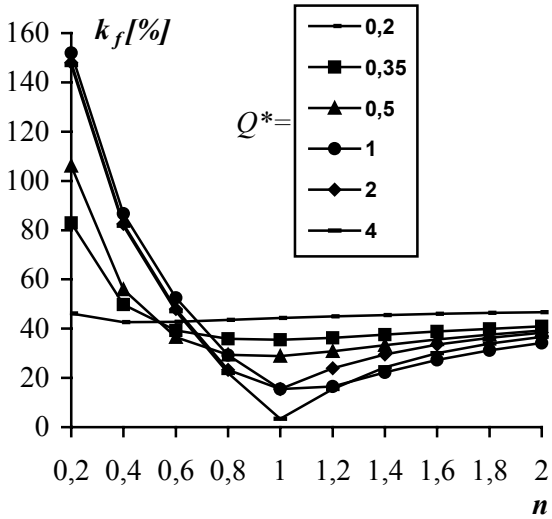

Fig. 6. Klirrfactor characteristics.

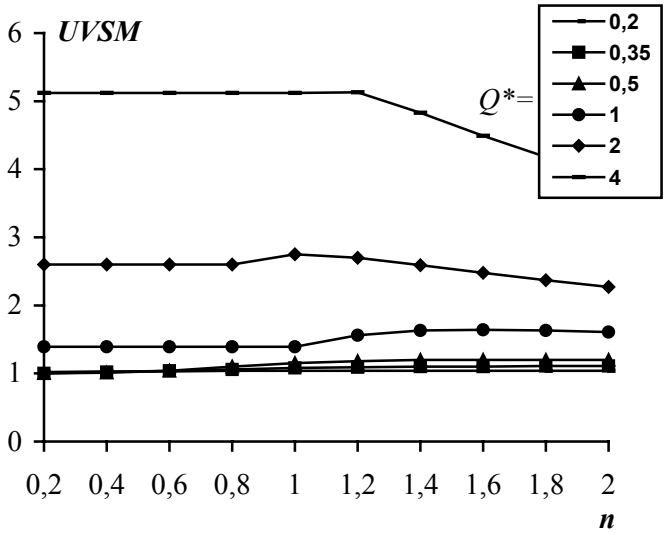

Fig.7. Peak thyristor voltage characteristics.