# LAWS OF SPACE-TEMPORAL SPECTRAL RELATIONS IN THE FIELD OF MULTIPHASE AC INVERTER DRIVES

Brazhnikov A.V.

*Siberian Federal University, Krasnoyarsk, e-mail: multypha@mail.ru*

The study of AC inverter drives in the case when the number of their phases is more then four allows to find out some basic laws of these systems which does not manifest themselves when the phase number is equal to three or four. Two previously unknown laws of energy efficiency invariance are established in the field of multiphase (i.e. having the number of phases more than four) AC inverter drives. These laws ignoring leads necessarily to the decrease of the multiphase drive system energy efficiency.

**Keywords: laws, space-temporal spectral relations, multiphase, AC inverter drives**

The study of AC inverter drives (ACID) in the case when the number *m* of ACID phases is more than four allows to find out some basic laws of these systems which do not manifest themselves when *m* is equal to three or four. A knowledge of these peculiar laws is of not only scientific (i.e. cognitive), but also great practical importance because these laws ignoring leads necessarily to the decrease of the ACID energy efficiency when $m \geq 5$.

By present time two previously unknown laws of space-temporal spectral relations have been established by the authors of this paper as a result of the corresponding investigations. These laws are true for the case when the motor winding set is symmetric and electromagnetic processes in ACID are steady-state. They are essentially the laws of energy efficiency invariance for the field of multiphase (i.e. having the number of phases more than four) AC inverter drives.

## Law of *m*-invariance

The first of these two laws links the ACID efficiency η, phase number $m \geq 5$ and relative spectra $U^*(c)$ and $B^*(n)$, where $U^*(c)$ is the relative spectrum of the output (phase) voltage $u(t)$ of inverter that is also the AC motor stator phase voltage, *c* is the number of the voltage $u(t)$ harmonic (i.e. the number of a *time* harmonic), $B^*(n)$ is the relative spectrum of the function $b(\gamma)$ which describes the space distribution of the magnetic induction created by each phase winding of the AC motor stator in the machine air gap within the limits of the motor pole pitch, *n* is the number of the function $b(\gamma)$ harmonic (i.e. the number of a *space* harmonic), *t* is a time, and γ is the space coordinate, which is plotting on the space coordinate curved axis Oγ, that runs along entire length of the AC motor air gap ($\gamma \in [0; 2\pi]$).

The above-mentioned relative spectra differ from the corresponding absolute (real) spectra in that the amplitude $A^*(x)$ of some relative spectrum harmonic is equal to $A^*(x) = A(x)/A(1)$, where $A(x)$ is the amplitude of the corresponding (i.e. of the same name) harmonic of the appropriate absolute (real) spectrum and *x* is the number of a harmonic ($x \equiv c$ for $U^*(c)$ and $x \equiv n$ for $B^*(n)$).

The values $U^*(c)$ and $B^*(n)$ for all  and *n* are dimensionless. Therefore both their envelope lines may be constructed on the common two-dimensional subspace (plane) *kOd* (Fig. 1), where the axis *Ok* is horizontal, the axis *Od* is vertical, for $U^*(c)$, and $k \equiv n$ for $B^*(n)$. The values $U^*(c)$ and $B^*(n)$ are plotting on the axis *Od*.

The above-mentioned law is given the title «law of ACID efficiency η invariance to the ACID phase number *m*» (or more simply, «law of *m*-invariance»). It is stated as follows: if $b(\gamma)$ = const when *m* = var, then the envelope line of spectrum $U^*(k)$ must lie not above the envelope line of spectrum $B^*(k)$ on the plane *kOd* to ensure the invariability of the ACID efficiency η when the ACID phase number *m* is changing (Fig. 1, where I is the area, where the law of *m*-invariance is fulfilled, and II is the area, where the law of *m*-invariance is not fulfilled). Besides, the frequency composition of the function $b(\gamma)$ must be identical (at least) to the frequency composition of the voltage $u(t)$ or be wider than it.

The identity $U^*(k) \equiv B^*(k)$ is a particular (the limiting) case of the law of *m*-invariance.

This law is in some contrast with widely known notion of ACID which was obtained as a result of researches only in the field of 3- and 4-phase AC drives. In particular, according to this notion the sinusoidal version of the function $b(\gamma)$ is always considered the optimal version.

## Law of *H*-invariance

The second law concerns the phase-pole controlled multiphase ACID, i.e. when the phase-pole control mode (PPM) is used in ACID [1-3]. This law links the ACID efficiency η, relative spectrum $U^*(c)$, relative spectrum $B^*(n)$ and integer-valued parameter *H* of PPM, where $H \geq 1$ (the value $H = 1$ corresponds to a traditional control mode, and the value $H > 1$ corresponds to PPM).

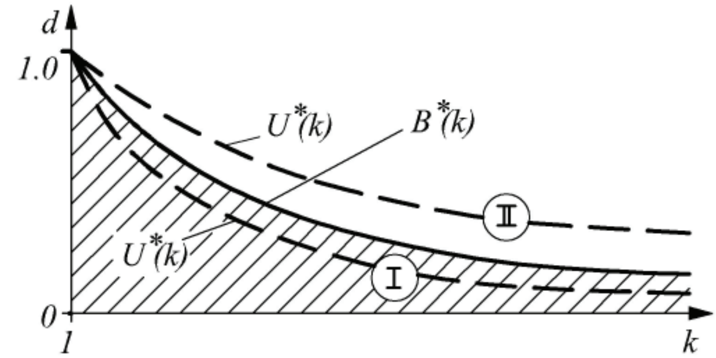


Fig. 1

The essence of the control according to PPM is that in this case the electrical angles between the voltages (or currents) of the nearest phases of inverter increase by a factor of some whole number $H$ without any change of the inverter voltage (or current) amplitude and frequency. During PPM application process, when the parameter $H$ changes, the effect adequate to the synchronous change of the ACID phase number and *number of motor poles* appears.

The above-mentioned second law is given the title «law of ACID efficiency η invariance to the parameter $H$ PPM» (or more simply, «law of $H$-invariance»). It is stated as follows: the identity $B^*(n) \equiv B^*(H{\cdot}n)$ must be provided to ensure the invariability of the ACID efficiency η when the parameter $H$ is changing during PPM application process. Besides, for the mentioned purpose the law of $m$-invariance must also be fulfilled as to spectra $U^*(c)$ and $B^*(n)$ for all values of parameter $H$ (Fig. 2, where the line 1 is the $n$-dependence of $B^*(n)$ for $H = 1$, the line 2 is the $n$-dependence of $B^*(H{\cdot}n)$ for $H = 2$, and the line 3 is the -dependence of $U^*(c)$).

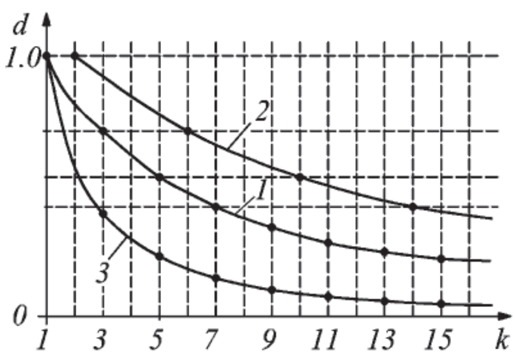


Fig. 2

It is necessary to use some peculiar designs of multiphase AC motors to ensure fulfillment of the $H$-invariance law [2-4].

### Ignoring laws of energy efficiency invariance

If the above-mentioned laws of ACID efficiency invariance are not fulfilled, then the ACID efficiency η decreases and when the ACID phase number $m$ increases more than four and when the going from some traditional control mode to PPM is being attained. For example, $m$-dependence of the ACID efficiency η is presented in Fig. 3 for the case when the function $b(\gamma)$ is sinusoidal and $t$-dependence of the voltage $u(t)$ has form of right-angled meander (in this case the law of $m$-invariance is not fulfilled).

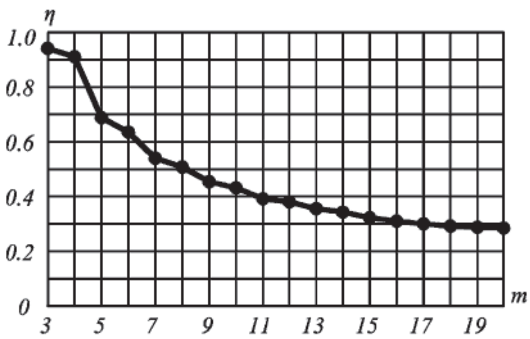


Fig. 3

In support of the $H$-invariance law the mechanical characteristics (i.e. $\omega - M$ characteristics) of some multiphase phase-pole controlled induction motor with $m \geq 6$ are presented in Fig. 4 for the cases when $H = 1$ (line 1) and $H = 2$ (lines 2 and 3), where the line 2 is the mechanical characteristic if the law of $H$-invariance is fulfilled, line 3 the mechanical characteristic if the law of $H$-invariance is not fulfilled, ω is the speed of rotation, and $M$ is the motor torque.

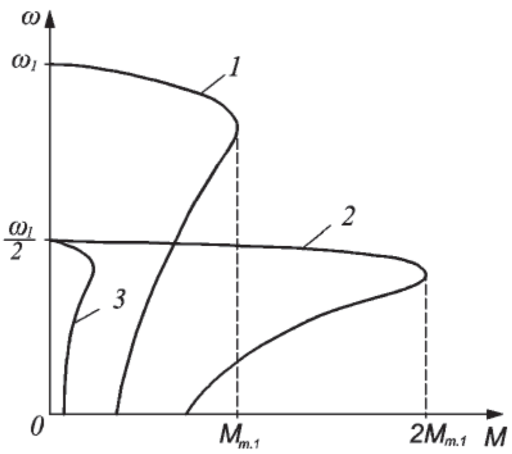


Fig. 4

## Conclusion

The above-mentioned laws of ACID efficiency invariance are particular cases of the fundamental law (or principle), which prevails in the field of multiphase AC drives and may be stated as follows: for the ensuring of maximal energy efficiency of multiphase ACID the laws of space-temporal spectral relations, which acts in the field of these systems, must be necessarily fulfilling during the process of both ACID structural elements design and motor control mode elaboration.

## References

1. Brazhnikov A.V. Additional Resources of Control of Multiphase Inverter Drives // Proceedings of 7th International Conference on Electrical Machines and Drives «ELMA '93». – Varna, Bulgaria, 7-9 October 1993. – P. 325-332.

2. Brazhnikov A.V., Dovzhenko N.N. Control Potentials and Advantages of Multiphase AC Drives // Proceedings of 29th IEEE Power Electronics Specialists Conference «PESC' 98». – Fukuoka, Japan, 17-22 May 1998. – Vol. 2. – P. 2108-2114.

3. Brazhnikov A.V., Panteleev V.I., Dovzhenko N.N. Phase-Pole Control by Inverter Multiphase Induction Motor Drives // Elektrika. – 2005. – № 3. – P. 22-27.

4. Brazhnikov A.V., Belozyorov I.R. Inverter Multiphase Induction Motor Drive with Phase-Pole Control / Russian patent № 100863 dated 27.12.2010 (in Russian).