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Estimation of operating modes of the self-excited current inverter with use SFI-wavelet transformation

Abstract: Application of the SFI-wavelet transformation for fault isolation in self-excited current inverter consider in this paper. Definition of the fault type based on the analysis of current and voltage spectrum constructed with the use of SFI-wavelet transformation.

Keywords: spectrum transformation, self-excited current inverter, discrete function-original.

Inroduction

Semi-conductor converters are the important part of modern power systems, power supply systems and the transformations of energy. The built-in diagnostics and control devices are necessary to use in this converter for improvement of their operational reliability. The task of the given devices is measurement of the converters parameters, it analysis and closedown of the converter in case of necessity (for example failure). The initial information for diagnostic is the curves of currents and voltage in control points of the circuit for intervals previous failure, during its occurrence and after failure [1].

As the measurement of control currents and voltage in the circuit is carried out at the discrete point of time, the received information can be submitted as discrete original functions of the currents and voltage depended of time. Therefore development of methods of analysis which use discrete transformations is urgent. One of effective discrete spectral transformations is SFI-wavelet transformation [2], which in this work is used for the analysis of non-sinusoidal currents of self-excited current inverter.

Construction of SFI-wavelet transformation of discrete functions.

SFI-wavelet transformation combines in itself advantages of two spectral transformations: symmetric transformation on final intervals (SFI) [3] and wavelet [4,5,6].

SFI-wavelet transformation allows finding two-dimensional spectrum of discrete original functions, making decomposition of it by special wavelet-basic functions, which are characterized by the following properties:

1) have zero average value on all interval of definition;
2) are limited in time;
3) have identical quantity oscillations, i.e. change a sing identical number of time.

The spectrum of the original function in basis SFI-wavelet transformation is calculated on the following algorithm:

1. The quantity of *K* discrete points of the original function *f(x)* at interval *T* is determined according to the Kotelnikov theorem. The original function represent as a row vector of its discrete value.
2. The family from *K* wavelet-basic functions ψ_N which determined on intervals *N*=1,2,…K is formed. Each of these functions is supplemented by zero points up to value K.

The family of wavelet-basic functions is formed by consecutive transition from function ψ_{N-2} to function ψ_{N-1}, which definition interval *N* changes on unit. The consecutive transition from one wavelet-basic function to another is similar to process of scaling of Mother's wavelet in the traditional wavelet analysis. Generally wavelet-basic functions ψ_N, is carried out in according with the formulas of the generalized SFI transformation [2].

The example of wavelet-basic functions family for *K*=9 is given in Figure 1. All function of this family has one change of a sing.

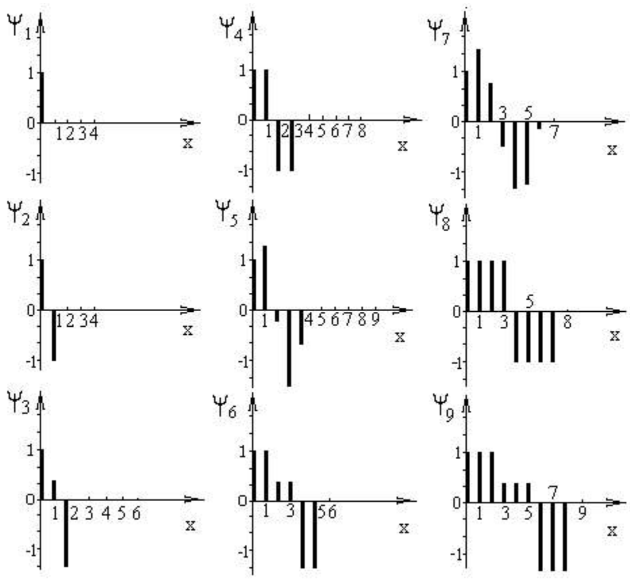

Fig. 1 Family of wavelet-basic functions

Each wavelet-basic function shift along an axis x on interval τ =0,1..., (*N*-1) in process of the SFI-wavelet spectrum forming. The shift is carried out by rules of m-shift on an interval *N* [2].

3. The matrixes of wavelet-basic functions $\mathbf{F}_\tau$ are formed.

$\mathbf{F}_\tau^T$=

	x=0 1 2 … *K*-2 *K*-1
N=1	$\psi_1(\nu, x \underset{L}{\theta} \tau)$
2	$\psi_2(\nu, x \underset{L}{\theta} \tau)$
⋮	…
K	$\psi_K(\nu, x \underset{L}{\theta} \tau)$

Matrixes of wavelet-basic functions $\mathbf{F}_\tau$ are formed with using the family of wavelet-basic functions moved on identical interval τ. Discrete point of each moved wavelet-basic function ψ_N represent in matrix $\mathbf{F}_\tau$ as a column *N*.

In matrix $\mathbf{F}_\tau$: x are numbers of discrete value of the original function, $\psi_K(\nu, x \underset{L}{\theta} \tau)$- wavelet-basic functions chosen from set of basic functions of generalized SFI transformation, which have one change of a sing; ν - number of the chosen function in initial set; τ - the interval, on which is moved wavelet-basic function; *L* - module of shift, which is defined by a kind of used shift [2].

4. The row vector of the original functions values is consecutive multiply on each of matrixes $\mathbf{F}_\tau$. As a result is a row $\mathbf{Y}_\tau(\tau, N)$ in a matrix of spectral coefficients $\mathbf{Y}_\nu$:

(1) $$\mathbf{Y}_\tau(\tau, N) = f(x) \cdot \mathbf{F}_\tau ,$$

where *f (x)* - discrete original function, $\mathbf{F}_\tau$- matrix of wavelet-basic functions.

6. The matrix of spectral coefficients $\mathbf{Y}_\nu$ is formed.

		N=1	2	…	*K*
	τ=0	$\mathbf{Y}_0(0,1)$	$\mathbf{Y}_0(0,2)$	..	$\mathbf{Y}_0(0,K)$
$\mathbf{Y}_\nu$ =	1	$\mathbf{Y}_1(1,1)$	$\mathbf{Y}_1(1,2)$	..	$\mathbf{Y}_1(1,K)$
	⋮	…	…	..	…
	K-1	$\mathbf{Y}_{K-1}(K\text{-}1,1)$	$\mathbf{Y}_{K-1}(K\text{-}1,2)$	..	$\mathbf{Y}_{K-1}(K\text{-}1,K)$

7. Matrix $\mathbf{Y}_\tau$ is normalizing.

Obtained matrix of spectral coefficients represents SFI-wavelet image of the initial discrete original function *f(x).*

Use SFI-wavelet transformation for localization of malfunctions.

The discrete functions of currents and voltage researched during the work of system are considered further as the discrete functions-originals. For this function-originals calculate SFI-wavelet spectrum on some interval T, which is defined by features of work of the circuit.

During the analysis it is supposed, that the probable malfunctions and their influence on the curve of currents and voltage are known beforehand.

The matrix of spectral coefficient $\mathbf{Y}_\nu$ (or SFI-wavelet spectrum) is defined for each function of a current and voltage. For correlation obtained SFI-wavelet spectrums with operation mode of the converter we shall enter the following designations:

- $\mathbf{Y}_{\nu\ \mathrm{norm}}$ - the matrixes appropriate to a mode of properly work;
- $\mathbf{Y}_{\nu\ \mathrm{def}}$ - the matrixes appropriate to malfunction of the converter;
- $\mathbf{Y}_{\nu\ \mathrm{current}}$ - the current matrixes constructed for functions, which characterize the current work of the converter.

In case of a malfunction it is possible to define a type of the current malfunction by comparison of the matrix $\mathbf{Y}_{\nu\ \mathrm{current}}$ with matrixes constructed for known malfunctions.

As an illustration told we shall consider application SFI-wavelet transformation for definition malfunction's type in the circuit of the self-excited current inverter (Fig. 2) given in paper [1].

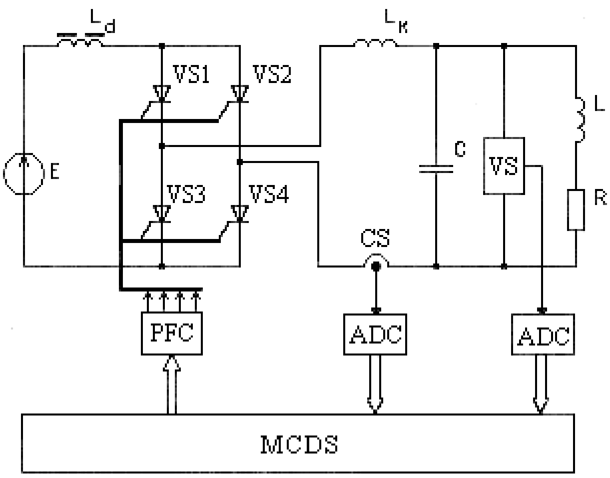

Fig.2 Self-excited current inverter

In a fig. 2 the following designations are used:

MCDS - microprocessor control and diagnostics system; PFC - pulses forming scheme; ADC - analog-digital converter; CS – current sensor; VS- voltage sensor .

The diagram of a current Ic flow through the capacitor C is analyzed with use the SFI-wavelet transformation.

Sampled diagrams of a current Ic on an interval T in case when converter function properly (the case of normal work) and for cases disruption of the capacitor battery C, disruption of inductor Lk and disruption of the thyristor VS are represented in Figure 3.

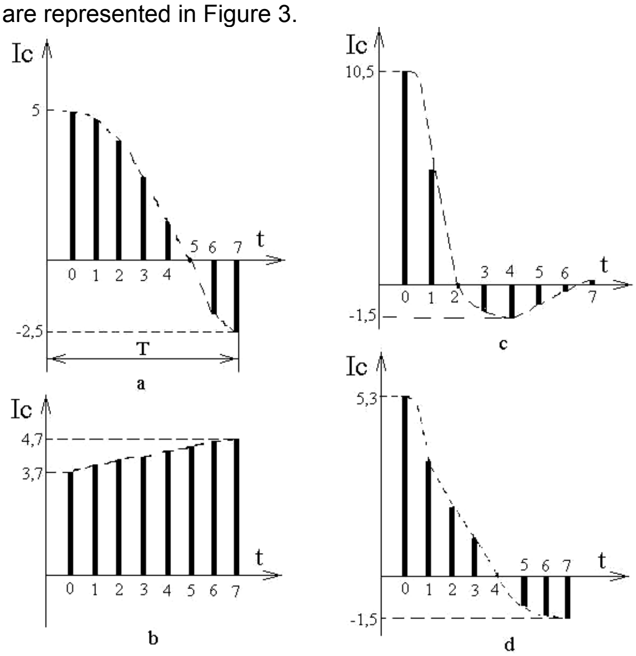

Fig. 3. The diagram of a current Ic for cases of normal work (a), disruption of the capacitor battery C (b), disruption of inductor Lk (c), disruption of the thyristor VS (d).

Wavelet-basic functions ψ1- ψ8 of family represented in a Fig. 1 used below for construction of a SFI-wavelet spectrum of the discrete original functions Ic.

The SFI-wavelet spectrum of a current Ic can be presented as a three-dimensional surface or as its projection to a plane *Nτ*.

Representation of a spectrum as a projection to a plane Nτ shows dependence of spectral coefficients on a considered interval N and shift τ more evidently.

In Figures 4-7 are given SFI-wavelet spectra of a current Ic for various operation modes of the converter.

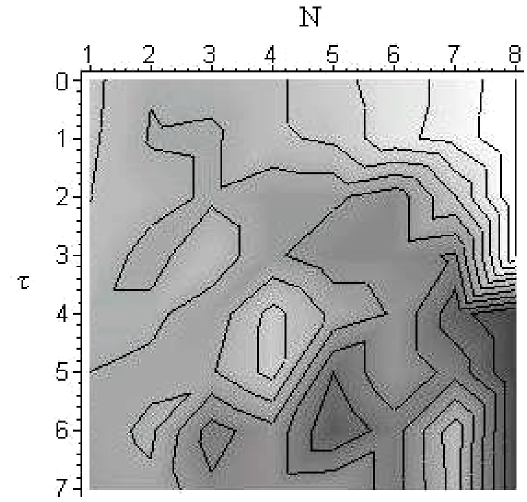

Fig. 4. Normalized SFI-wavelet spectrum of a current Ic for a case of normal work.

Change of spectral coefficients in a plane Nτ is displayed in density of an arrangement isolines and shades of grey color. The more richly located isolines the more difference between coefficients. To the maximal value of coefficients there correspond light sites of figure, minimal - dark.

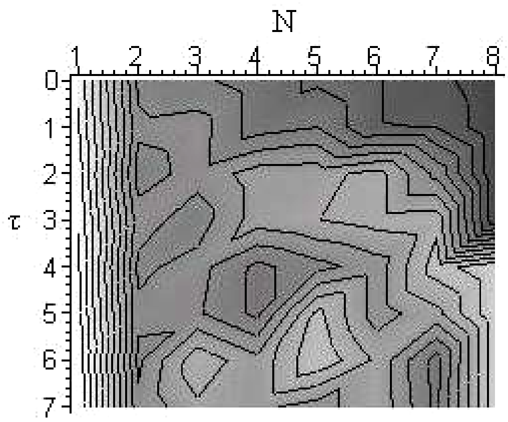

Fig.5. SFI-wavelet spectrum of a current Ic for a case of disruption of the capacitor battery C.

SFI-wavelet spectra represented in Figures 4-7 essentially differ on appearance that allows qualitatively defining a kind of malfunction. Besides as the given spectra are constructed on the basis of matrixes $\mathbf{Y}_{\nu}$, it is possible to define differences of spectra for various operation modes not only qualitatively, but also quantitatively.

The quantitative differences between spectra can be defined by subtraction of the current matrix $\mathbf{Y}_{\nu\ current}$ from some etalon matrix $\mathbf{Y}_{\nu}$. As the etalon matrix can be used one of the matrix for known operation modes of converter

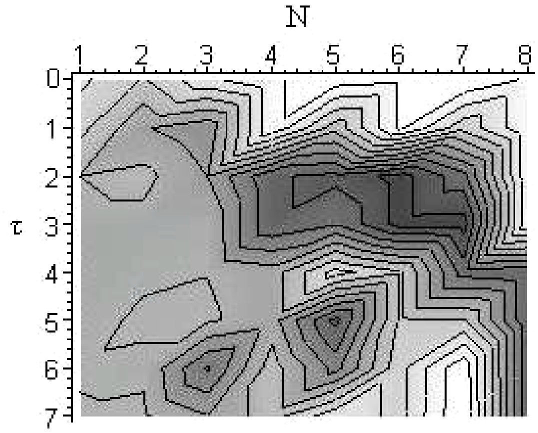

Fig.6. SFI-wavelet spectrum of a current Ic for a case of disruption of the inductor Lk.

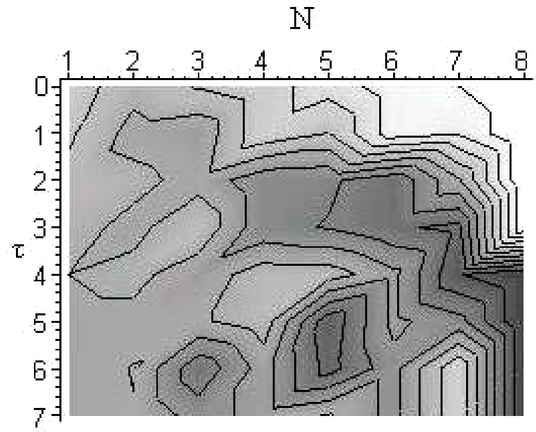

Fig.7. SFI-wavelet spectrum of a current Ic for a case of disruption of the thyristorVS .

(for example matrix $\mathbf{Y}_{\nu\ norm}$ or $\mathbf{Y}_{\nu\ def}$). The matrix, received as a result of subtraction, call distinction. It is denote as $\mathbf{Y}_{\nu\ dist}$ with literal indication of operation mode. For example, $\mathbf{Y}_{\nu\ dist\ N}$ is a spectrum received by subtraction of the spectrum $\mathbf{Y}_{\nu\ current}$ from an etalon spectrum $\mathbf{Y}_{\nu\ norm}$, appropriate to normal work.

Use as etalon SFI-wavelet spectrum $\mathbf{Y}_{\nu\ norm}$ allows by the form of a distinction spectrum define:

1- operation mode of the converter - normal work or emergency;
2- type of disrepair in case of emergency (for example, disruption of the condenser, inductor or thyristor);
3- deviations of element's parameters of the converter from the established value.

This opportunity is caused by that the change of parameters entails change of the form of currents and voltages in control points of the circuit, so also change appropriate by them SFI-wavelet spectra. In case of properly work of the converter all elements in a distinction matrix $\mathbf{Y}_{\nu\ dist\ N}$ are equal 0. The difference of coefficients of a matrix from zero testifies to presence of malfunction or about change of element's parameters of the converter.

The SFI-wavelet transformation allows to reveal short-term bursts and changes in the form of currents and voltages as can operate with discrete functions having any number of discrete points K (K - integer). Thus, increasing quantity of discrete points of the initial original function allow improve adequacy of analysis and reliability of showing up character of currents and voltages in the researching converter.

Conclusions

Use SFI-wavelet transformation for the analysis of the diagrams of currents and voltages describing work of the semi-conductor converter, allows to estimate a condition of system as qualitatively - on appearance appropriate of a SFI-wavelet spectrum, and quantitatively - by calculation of distinction spectra.

The basic advantage of spectral SFI-wavelt transformation is the simplicity of spectrum's construction algorithm based on work with matrixes, and directivity of the given transformation on microprocessor realization.

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