SYSTEM FOR QUALITY TESTING OF RIPPLE CONTROL RECEIVER

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Abstract: The paper presents a system for automatic quality testing of ripple control receivers. The described system enables both tolerance and type tests in production and also a number of other tests for developing of ripple control receivers. It consist of a power generator of a complex testing signal and of a software package used for a digital generation of a testing signal, for an autocalibration and a software calibration of the whole system and for a control of an automatic quality testing.

Keywords: Quality testing, Ripple control receiver, Test signal generation, Autocalibration, Software calibration

1 INTRODUCTION

Ripple control receivers (RCRs) allow to control a load of the distribution network. Using RCRs it is possible to put down load peaks by alternations of power take-off from the distribution network during a day. RCRs are controlled from the central load-dispatching office based on an actual load of network. The control signal (message) is transmitted to the RCRs using a distribution network. These message is generated by keying of carrier wave with frequency equal to ***control*** frequency of RCR. The frequency of carrier wave is in the range from 150 Hz to 2 kHz and its amplitude is usually from 2 V to 10 V. A great amount of various non-linear electrical appliances produce non-linear disturbances in distribution network. RCRs have to properly distinguish between a disturbance and the coming message and have to correctly respond to this message. A correct response of RCR (type tests) and its disturbance resistance (tolerance tests) are defined. An automatic execution and an evaluation of these tests are required, because both tolerance and type tests are very time consuming.

2 SYSTEM CONFIGURATION

A special test signal must be generated for testing of the RCR. Therefore the multifunction PC plug-in board is used as for the generation of this test signal, as for the reading of the status of switches of the tested RCR. The generated signal is amplified using a power amplifier and then it is transformed to the output voltage in the range from 80 to 260 V. The all components of the output high voltage waveform are measured using one of an analog input of the same multifunction board. The resistive divider and isolated amplifier are used for it (see chapter 3). The block diagram of the developed system is shown in Fig. 1.

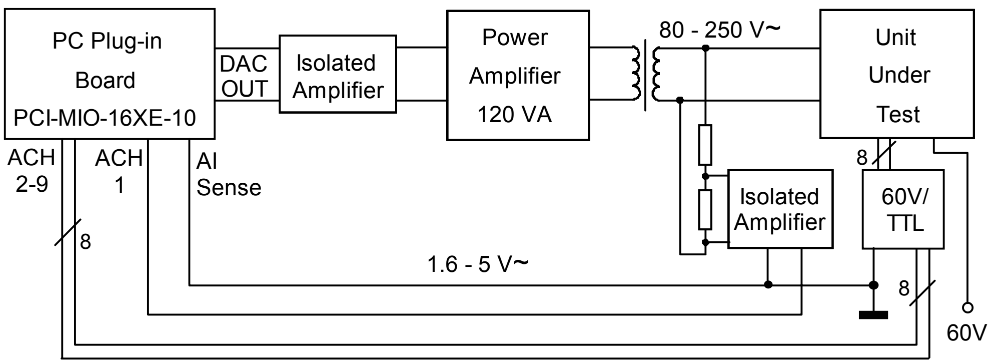

Fig. 1. Block diagram of the developed system

The voltage that is switched using output relays should be higher than 60V for their correct function. Therefore the 60V/TTL converter must be used for the conversion of a switching voltage to a TTL signal, which is monitoring by the plug-in board.

3 GENERATION OF TEST SIGNAL

A test signal is generated digitally and it can consist up to six sinusoidal components. The first component is the basic line voltage, the second one is the control message. The third, fourth and fifth components are three harmonic components of line voltage. These three components represent a harmonic disturbance and their occurrence is optional. The last component represents a non-harmonic disturbance. The frequency of the basic line voltage can be set about 50 Hz or 60 Hz and its occurrence is optional. The control sinusoidal signal (the message) is keyed and its frequency is chosen by user. Also three harmonic components of line voltage, which frequencies are the nearest to the frequency of the message wave, are keyed. The parameters of a non-harmonic disturbance component depend on user demand and its occurrence is also optional.

Because the digital generation of all used sinusoidal components and their addition is very time consuming operation, the table of samples of each sinusoidal component is generated before start of single tests for a reduction of time. Then the competent data are read from this table and single components are summed to the complex test signal (all in digital form). The keying of the control sinusoidal signal (the message) and of some disturbing signals is possible according the control data. A complex data array (keyed wave in digital form) is stored into the computer memory, then the data are transferred into the D/A converter of a plug-in board using DMA transfer and a new data array is generated during this time. The internal timer-counter is used for all timing, but the generated signal can be also synchronised with a line frequency. The good stability and accuracy of all parameters of the test signal is required:

- Basic harmonic component:	voltage range: 80 - 255 V, accuracy: 0.5 %, THD < 0.3 %;
	frequency range: 46 - 64 Hz, accuracy: 0.1 Hz
- Higher harmonic components:	voltage range: 0 - 50 V, accuracy: 0.5 % or 20 mV
- Control signal:	voltage range: 0.3 - 50 V, accuracy: 0.5 % or 20 mV;
	frequency range: 100 - 2000 Hz, accuracy: 0.1 Hz
- Disturbing signal:	voltage range: 0.3 - 50 V, accuracy: 0.5 % or 20 mV;
	frequency range: 100 - 2000 Hz, accuracy: 0.1 Hz

The software calibration is used to achieved the required precision. The real values both of the reference voltage and of the reference frequency of the PC plug-in board and also of the dividing ratio of the resistance divider at the power output is determined using the precise AC voltmeter connected to the power output and the counter connected to the low-voltage output. The measured values serve to correction of the reference voltage and of the reference frequency and to setting of correct parameters of the basic harmonic component of the high voltage signal at output. They are inserted into a calibration table and all correction constants are recalculated.

Actual RMS value of all components of the generated test signal (at the power output) depends on their frequencies, on an actual load of the power output (maximum load 40 VA) and on a time instability of the power amplifier. These effects must be corrected. An autocalibration procedure is used for this purpose. The test signal from the power output is adapted to the level of the analog input of a multifunction board using the resistance voltage divider and the isolated amplifier. The same PC plug-in board (analog input, channel 1) is used for digitising of the output signal (see Fig. 1). A method of an interpolated FFT [1] is used for signal processing to determine the correct RMS value of all signal components [2]. This method makes it possible to suppress a leakage error.

The FFT works with limited number of input and output samples *N*. A corresponding frequency resolution can be found as

$$\Delta f = \frac{f_s}{N} \tag{1}$$

where f_s is the sampling frequency and N is the number of points of the FFT used. From (1) it follows that the basic FFT frequency analysis is accurate only for the frequencies of harmonic components, which are integer multiples of the spectral resolution. (For example, for Δf = 1 Hz, corresponding frequency components are 0, 1, 2, ..., $N.\Delta f/2$). Since N is a positive integer, accurate analysis is possible only for signals with frequencies synchronised with the sampling frequency f_s ("coherent sampling").

If a signal/sampling synchronisation is not provided, an error called leakage occurs [1]. Any harmonic component in this case is not represented by a single line, but by a group of spectral lines. There is a local spectral maximum corresponding to each of these groups at the position of the k_1-th multiple of the spectral resolution Δf, for which is valid

$$k_1 \Delta f - f_1 = \min_{k=0..N/2} \left(k\,\Delta f - f_1 \right) \tag{2}$$

where f_1 is the frequency of a harmonic component.

The amplitude of the spectral component corresponding to the k_1 multiple of the Δf and amplitudes of the other spectral lines in the surrounding of the local maximum depend on the shape of the time window used for input signal windowing. Based on the magnitudes of spectral lines and on the window shape, it is possible to find the RMS values of all spectral line with high accuracy.

It was found that rectangular window (i.e. no window at all) is not suitable for this analysis, because its ability to suppress the spectral lines in the surrounding of the local maxima of the spectrum of the measured signal is insufficient, neighbouring groups of spectral lines may overlap, and the accuracy of the spectrum analysis is degraded. From the points of view of both accuracy and computational simplicity, most suitable type of window for this application is cosine window, described by

$$w_p(n) = \sum_{r=0}^{P} V_r \cos\left(\frac{2\pi\, n\, r}{N} \right) \tag{3}$$

where P is the window order and V_r are the window coefficients.

The window coefficients in (3) should be chosen so that there be a maximal suppression of the undesirable spectral components in the surrounding of the local maxima. These demands are fulfilled for windows of Rife-Vincent type, first class. Their coefficients are given in Table 1.

Table 1. Coefficients of Rife-Vincent type windows

$P\downarrow$	$r = 0$	$r = 1$	$r = 2$	$r = 3$	$r = 4$
1	1/2	-1/2	-	-	-
2	3/8	-4/8	1/8	-	-
3	10/32	-15/32	6/32	-1/32	-
3	35/128	-56/128	28/128	-8/128	1/128

Based on this results the amplitude of all components of generated signal is corrected. The above mentioned calibration method enables to achieve the required precision.

4 READING THE STATUS OF SWITCHES OF RIPPLE CONTROL RECEIVER

It is necessary to observe a response of a tested receiver to a test signal in a defined time during sending a message. The user can create the status table of an expected switching of receiver relays. Then the check of a relay switching is provided during the time interval (with sample period 10 ms), which is defined in the status table.

The information about the setting of relays are binary data. Digital inputs of a PC plug-in board should be used for reading of them. However, the used PC plug-in board (PCI-MIO16XE-10) cannot use DMA transfer for digital inputs (DMA transfer is necessary for a determination of the time of a relay switching checking with the demanded accuracy). Therefore the analog inputs of the PC plug-in board are used for this purpose. The analog input channels 2 to 9 are used for this purpose and the voltage levels measured in these inputs represent actual position of relay contacts.

5 SETTING THE PARAMETERS OF TESTS

The maximal variability of the test signal is necessary for both tolerance and type tests. All parameters of all components of the complex test signal should be controlled using a software. Their setting (including an automatic change of some of them) is defined using a setting tables and panels. The operating software is user friendly and it enables to set following basic values:

- The amplitude and the frequency of the sinusoidal power supply.
- The amplitude and the phase shift of harmonic components, which are contained in the power supply. These harmonic components can be interrupted in defined time intervals (keying of harmonic components).
- The amplitude and the frequency of a disturbing signal, this disturbing signal can be also interrupted in defined time intervals (keying of a disturbing signal).

- The amplitude, the frequency and the time length of each control pulse and the time interval between two control pulses.
- The start and stop time of power supply drop out.
- The lower limit, the upper limit and the step of change of defined parameters of generated components of test signal can be specified for automatic tests. The user can provide also a repetition rate of one step in complex tests.

6 AUTOMATIC TESTING

An automatic measurement process is necessary for some more complicated tests of RCR. ***These tests usually look out for a limit value of any parameter of message(a co rušení?) depend on changes of another parameter of message(a co rušení?). The limit value of the first parameter is defined as border between performance of chosen conditions and non-performance of chosen conditions under the characteristics given by the second parameter.*** The measurement of a sensitivity curve can be used as an example. A correct message is generated in this case and an automatic testing process changes the frequency and the amplitude of a message carrier wave. Based on an actual state of RCR relay switches (witch are read simultaneously), the software can find (for actual frequency) the limit value of the carrier wave amplitude for the correct function of a tested RCR. This measurement is provided for each of chosen frequencies. The user panel for setting parameters of these automatic measurements is shown in Fig. 2.

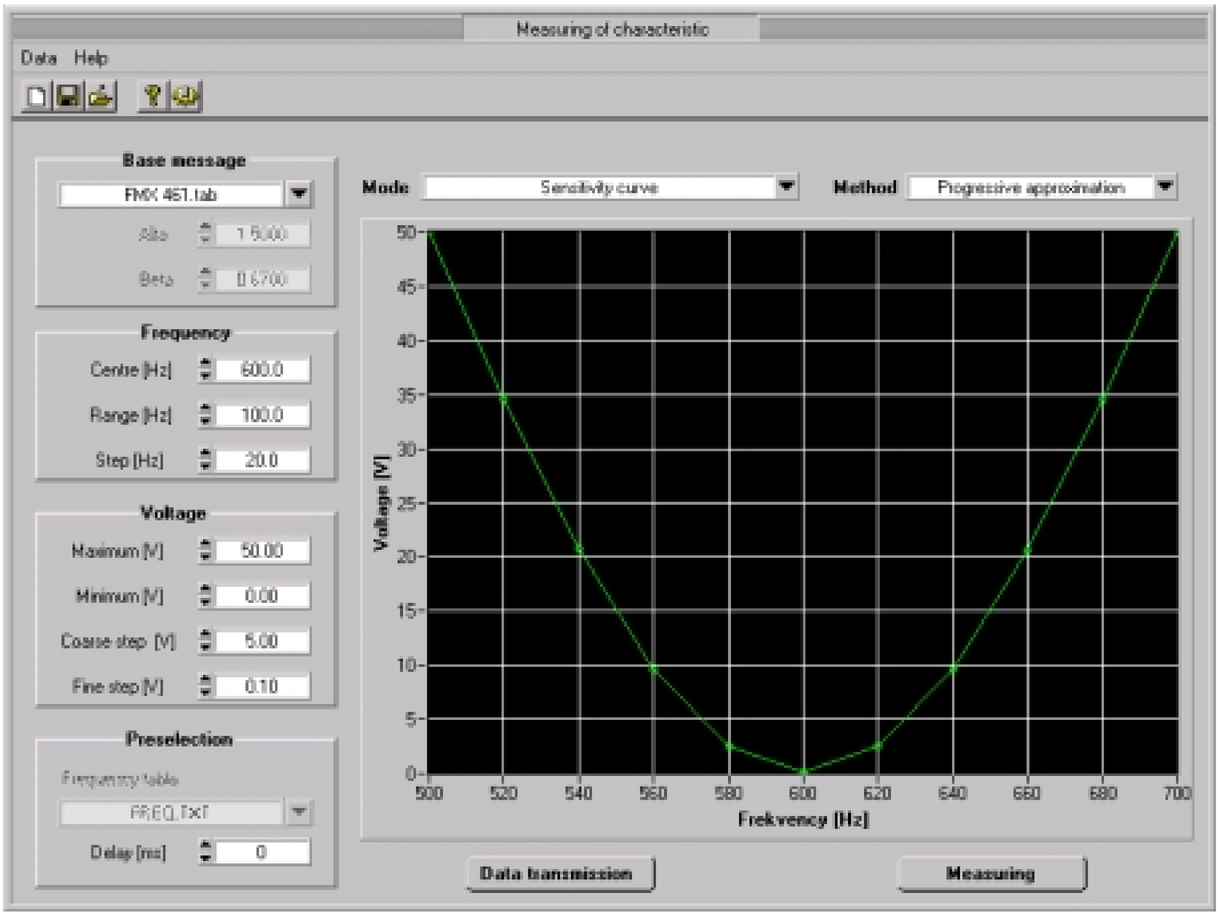

Fig..3. Input panel for test models definition and checking.

The method using fix step can be used for this measurement. The user specifies the lower limit, the upper limit and the step of a change of a defined parameter of the test signal. The program automatically increase the value of this parameter so long until required conditions are not accomplished. In this case only small step must be used for precise measurement and it is very time consumption, because the destination of one measured value can be also very time consuming (from about ten second till about ten minutes). It means, that the time interval e.g. for measurement of one sensitivity curve can take about an hour or more.

To achieve a shorter time of test, the method with progressive approximation was designed and used. The user specifies also in this case the lower limit, the upper limit and the required resolution of setting of tested parameter. The program starts to test at the half of input range and it automatically increase or decrease value of tested parameter a half of previous step according to the performance of a chosen condition. This method decrease a total time of measurement, but some problems can arise. ***Chosen conditions may be fulfilled several time during measuring in defined interval for some dependencies, but important is only the first correctly reaction of RCR. In this case can not be applied the progressive approximation method, because it is able to get on a wrong value.***

Therefore the third method was designed for this case. The limit value of tested parameter is found only approximatelly in the first part of this sub-test using a large fix step of selected parameter. In the second part of this sub-test the same method is used, but the fix step is several times smaller to achieved the required resolution.**???** ***First the program find the limit value by the method with linear step using coarse step and second the value is found exactly by method with progressive approximation using fine step. This method is more time consuming than the progressive approximation method, but this third method remove eventual errors from measured dependence.***

If the type characteristic of tested RCR is known, the time of measurement of real characteristics can be even more decreased, because the assumed range in which the examined limit value of tested parameter is located, can be usually specified before.

The high and lower limits, the resolution and the method used are saving into a file. Also the results of running tests are saved on harddisk and the operating software generates test protocol at the end of automatic testing process.

6 CONCLUSION

The system for quality testing of ripple control receivers mentioned above makes it possible to automate both tolerance and type tests for development and production. It enables to extend the range of performed tests, because they are very time consuming without an automation. The used calibration procedure makes it possible to achieve the high precision of a setting of all parameters of the testing signal. It is possible to assume, that using this testing system make shorter the developing time of new types of RCR and increase the quality of production, of course.

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