MV bay controller with integrated protection, power quality analysis and extended self-testing functions

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1. Introduction

A modern e-diagnostic system for MV electrical distribution grid is based on multifunctional bay controllers with integrated protection and power quality analysis functions and extended active on-line self-diagnostics. The data collected in the controllers may be used for central monitoring of the grid and individual objects connected to the grid over a vast area as well as to locally compensate reactive power and harmonic distortions. Therefore the bay controllers must fulfil highest requirements concerning accurate measurements of time relations among numerous analogue and digital signals. To this end sophisticated methods of signal processing have been employed.

These end units are greatly responsible for the reliability of the whole diagnostic system. Therefore they should be equipped with effective on-line self-testing functionality covering as many of their features as possible. Particular attention should be paid to the analogue input channels, which could not be actively on-line tested so far. A method of such testing is presented in this paper. A concept of a multifunctional bay controller performing all necessary functions needed for its operation as an end unit in an e-diagnostic system for MV electrical distribution grid is also presented. For purposes of exemplification one function of such a controller is described in this digest.

Keywords: e-diagnostics, bay controller, power quality, on-line testing

2. Novel system of testing of digital bay controllers

Two main groups of actions are postulated which significantly enhance the scope of testing of digital bay controllers:

- on-line self-testing comprising check sums of important program and data areas (settings, event log, active interlocks, passwords), successive RAM test, battery, operability of measurement channels, accuracy of the analog-to-digital converter, internal voltages. All these actions are carried out to some extent in different controllers present on the market and the new system does not ignore them; a novel proposition is to extend the scope of on-line testing of the analog channels in such a way that whole channels, beginning from the controller input terminals, are actively on-line tested.
- remote automatic testing of bay controllers, which comprises opening of the breaker, its disconnection from the bay (by moving the truck out), checking all digital inputs and outputs (from input to output terminals), checking selected functions of the controller (eg. current, ground fault and voltage protections), making a report, moving the truck back in and closing the breaker.

3. Time relations measurement techniques

The best way to measure time relations between signals is to use constant sampling frequency. But in this case for varying line frequency some errors arise during FFT computations. Therefore another method has been proposed consisting in resampling the signals entirely in the digital domain.

The sampling frequency has been chosen with the aim of simplifying the antialiasing filters that precede the analog to digital converter. The bandwidth of the signal that has to be accurately reproduced is 2 kHz, so the cut-off frequency of the antialiasing filter should be considerably higher. On the other hand the signal frequency components at half the sampling frequency should be adequately suppressed. Assuming that simple two pole RC antialiasing filter is to be used the sampling frequency should equal at least 16 kHz.

At 1024 samples per 10 line periods, the ideal sampling frequency f_{si} is calculated from the equation

$$f_{si} = (f/10)\cdot 1024 = f \cdot 102.4 \qquad (1)$$

where f is the line frequency.

The relative accuracy Er(f), as a function of f, with which f_{seff} approximates f_{si} is equal to

$$\mathrm{Er}(f) = 1 - (f_s/f)\cdot(1/102.4)\cdot(N/M) \qquad (2)$$

The resampling technique resulted in high accuracy of signal spectrum determination which has been illustrated in Fig. 1.

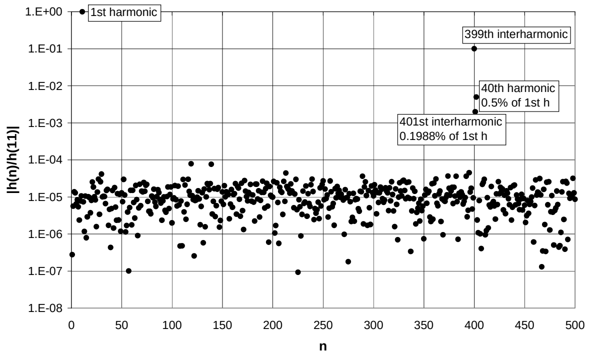

Fig. 1 FFT spectrum of a current waveform with fundamental equal to 53 Hz, after resampling with $N = 600$ and $M = 1769$

4. On-line self-testing of measurement channels

In order to test complete analog channels on-line, the input terminals included, it is proposed to periodically connect from outside additional test signals of known value (eg. 10-15% of the nominal value) to the input terminals and measure the reaction of the channel under test to the sum of the normal operation signal and of the test signal. If this sum differs from the normal operation signal by the value of the test signal it is assumed that the measuring channel is working correctly. In the opposite case either the channel under test or the testing circuit is defective. Practical implementation of this method of testing requires an external circuit which generates and connects the test signals to the input terminals of the controller (in parallel or in series with the operating signals). The internal software of the controller sequentially gives orders to connect the test signal to a given input, calculates the increase of signal observed at this input, compares it with the known value of the test signal and formulates the result of the test. Additionally, in order to eliminate the influence of the operating signal, changed for the moment of testing, on the normal protection algorithms of the controller, the internal software subtracts the test signal from the measured sum of signals and transfers the operating signal, not modified by the test, to these algorithms. Therefore the testing does not disturb normal operation of the bay controller.

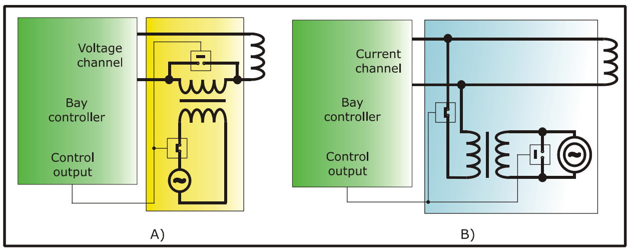

Fig. 2. Simplified diagrams of testing signal driving circuits. A) voltage channel, B) current channel.

The external circuit connecting the test signals to the terminals of the bay controller is composed of two parts. One of them connects test signals to voltage inputs, the other to the current ones. The voltage test signal is connected in series with the operating voltage signal, whereas the current test signal is connected in parallel with the current operating signal. The idea of the test signal connecting circuits is shown in Fig.2 (switches shown in the moment of testing).

It should be emphasized that this method allows for complete active testing of analogue channels without stopping normal operation of the tested bay controller. The method is patent pending.

5. Conclusion

The methods presented in this paper allow comprehensive on-line testing of bay controllers operating as end units in a wide area e-diagnostics system for MV electrical power grid without affecting their normal operation. Full testing of analogue input channels increases reliability of the bay controllers and of data collected in various points of the grid, which may be used for central monitoring of the grid and of its components as well as to locally compensate reactive power and harmonic distortions. Further work is being carried out to find practically applicable algorithms and solutions for the test signal driving circuits.

Acknowledgement

This research work is carried out within a larger research project financed by public money granted for science (Structural Funds, proposal number POIG.01.03.01-00-072/08).

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