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The Software Solution for the Presentation and Analysis of the High Voltage Circuit Breaker Timing Measurement Results

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Abstract — **This paper presents design, architecture and implementation of the software solution for the representation and analysis of the timing measurement for high voltage circuit breaker analyzer devices. Five years' experience in the software solution development for the circuit breaker analyzer control and data acquisition has been summarized and brought out the one of the main parts of the circuit breaker testing chain – user friendly, reliable and accurate software tool for obtained result analysis and interpretation.**

Keywords-high voltage circuit breakers, circuit breaker analyzer and timer, power circuit breakers, software solution, software architecture, user experience design

I. Introduction

High voltage circuit breakers (HVCB) are extremely important for the function of modern electric power supply system. The breaker is the active link that facilitate the flow of current during normal operation and interrupt the current flow in the event of a fault.

Three phases fall under the circuit breaker testing umbrella: test preparation, testing (data collection) and test results analysis. The most time-consuming step is preparation, actual testing is the shortest step and data analysis is the crucial step. [1]

Instruments used to perform timing measurement of the HVCB are known under the name of Circuit Breaker Analyzer and Timers (CAT). Usually, those are portable field devices with the possibility to measure process of the trip or close operation for each breaking element of complete phase as well as calculating relevant additional parameters. [2]

The main function of the HVCB is to interrupt the current flow during the fault. If the breaking time exceed the defined time limits provided by the manufacturer, the HVCB will not be able to distinguish the arc formed in on the breaking element – will not be able to perform the operation successfully. Thus, the timing of a breaker is the time measurement of the mechanical operations in order to verify its integrity and good working order. For this purpose we are representing graphically the process of the operation of the breaking element (open or close state) as well as calculate the corresponding numerical results from the waveform.

An innovative method of HVCB condition monitoring exists in the measurement of its control circuit characteristics such as actuating coil (opening or closing coil) current waveform. This provides a useful insight into the operation of the HVCB and its condition. This measurement is defined by standard IEC-62271-100. According to this standard, timing result of the HVCB measurement should include coil current waveform as well as corresponding numerical results.

Since the HVCB is primarily mechanical device operated electronically, it has moving parts, components that allow electrical contact to separate or to close. Whether those contacts are in a vacuum, in oil or in a gaseous medium, it makes sense to test the moving parts of the breaker – a motion or "travel" test. [1]

In addition, a crucial maintenance test of a HVCB includes the measurement of contact resistances, which should, ideally and in the closed state be zero. Of course, realistic results should have values less than the upper thresholds defined in corresponding standards of the HVCB. These tests hold the collective name of Static Resistance tests. Beside Static resistance tests, which measure the resistance of the main contacts, there also exists another test which measures the resistance of the arcing contacts of the circuit breaker, providing, in some cases, a more precise fault recognition compared to other tests. In literature, these tests are known as Dynamic resistance tests [3].

II. Tests and Measurement Parameters

Timing test with additional parameters such as coil current monitoring and motion measurement detects incorrect mechanical adjustment or wear phenomena of circuit breaker. For this reason, testing is performed using different sequences: O (Open), C (Close), CO, OC and OCO. Each sequences provide us with different numerical parameters that can be calculated using waveforms.

To assess the condition of the HVCB, proposed software solution consists of graphical and numerical representation of the timing measurement result. Graphical segment of the result contains following waveforms:

- Main contacts timing
- Auxiliary contact timing
- Coil current
- Motion and velocity measurement

However, depending on the sequences various different numerical parameters are extracted from the waveforms. In the Table 1 there are parameters that are calculated using the software solution from the obtained waveforms using implemented algorithms.

TABLE 1

Sequence	Numerical results parameters
C	- Closing time for breaking unit, phase and breaker - Preinsertion Resistor - Resistor ON Time - Aux closing time - Aux opening time - Maximum coil current time and value - Analog channels maximum and minimum value - Motion stroke, overtravel and reound - Contact wipe - Average velocity in selected zone
O	- Opening time for breaking unit, phase and breaker - Aux closing time - Aux opening time - Maximum coil current time and value - Analog channels maximum and minimum value - Motion stroke, overtravel and reound - Contact wipe - Average velocity in selected zone -
CO	- Closing time for breaking unit, phase and breaker - Close-open time - Maximum coil current time and value - Analog channels maximum and minimum value -
OC	- Opening-time - Reclosing-time - Open-Close Time - Maximum coil current time and value - Analog channels maximum and minimum value
OCO	- Opening time for breaking unit, phase and breaker - Reclosing time - Open-Close time - Close-Open time - Maximum coil current time and value - Analog channels maximum and minimum value

III. USER INTERFACE ELEMENTS

As a final product, software solution needs an interactive and user friendly features rich interface. Following this guide, proposed and implemented software solution contains following tools for result analysis, interpretation and storage.

- Cursor data – two vertical cursors able to move along x axis which provide amplitude values for each waveform at the certain position of the cursors as well as difference between time and amplitude values among two cursors. This feature is valuable in comparison of two point of interest on the waveform (e.g. closing time of the phase comparing to the motion waveform)
- XY Cursor - mouse pointer based cursor which provides time and amplitude value for certain point on waveform selected by mouse movement.
- Overlay - ability to overlay graphical results and compare numerical results on a single user interface. This tool includes ability to slide overlaid waveforms according the time or amplitude axis.
- View mode – chancing waveform representation mode

Some more of the features quite common as:

- Save result as file or export
- Create report – generates report using customized template as a final result of the HVCB testing.
- Appearance adjustment – changing waveform line width, color, style, waveform background, waveform grid properties etc.

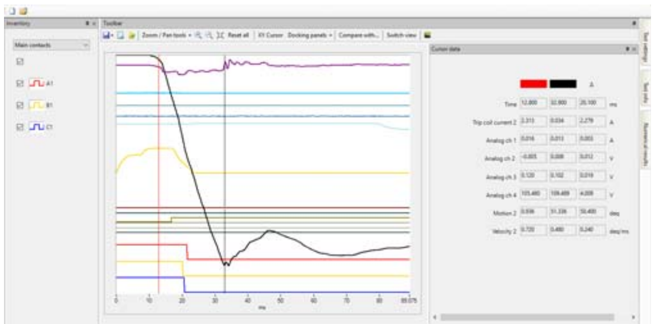


Figure 1 – Cursor data tool

IV. USER INTERFACE ARCHITECTURE

Previously described elements are arranged at the graphical user interface to form an easy to use industrial software solution.

The interface is organized in regions: top, bottom, left, right and middle corresponding with the locations of the docking panels.

Inventory tab on the left region contains group of signals with the feature to activate or deactivate each of the signal separately from each other.

Toolbar is by default positioned at the top region of the screen. Toolbar contains combination of dropdown menus and buttons.

Cursor data, Test info and Test settings windows are positioned in the right region of the window.

Central area of the main window is reserved for the waveforms. Position of the previously described panels can be rearranged and positioned by the user.

V. RESULT STORAGE

Since the obtained results must be stored for future analysis, comparison and reporting, implemented software solution provides following options for result storage:

- File
- Local database
- Export to Microsoft Excel
- Export waveform as image

and filter results by breaker type, number of breaks per phase, serial number of breaker ID, test type, result name or asset location parameters such as city, station name, country etc.

To make software solution more open for various type of test engineering and researchers, it implements feature to export waveform samples to the Microsoft Excel file, copy to clipboard or save as image file already plotted waveforms.

Data Aquistion and Communication

Even though the software architecture closely follows the standard tiered composition, layers composed of an interactive UI layer or Application Layer (APP Layer), a layer that defines all the necessary business rules and numerical algorithms (BLL Layer), and a layer that handles all the result storage (DAL Layer). [4]

Also, there exists a layer which solely purpose is to successfully handle the data acquisition process and instantiate the communication between the client and the device (COMM Layer). Given the definition of “communication” here is a bit broad, as it should be, considering the whole specter of needs and requirements of different kinds of settings for the acquisition of test results. RS232, Ethernet, USB and Bluetooth standard communications are all supported through this tier.

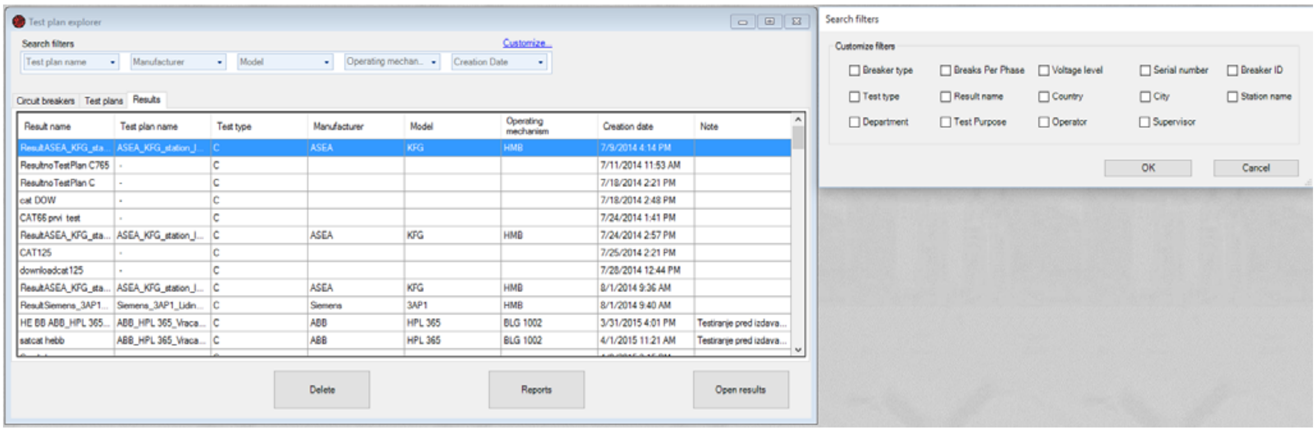


Figure 2 – Result search filters using embedded database storage

File storage use file format and structure specially designed to meet the requirements of low data redundancy, fast and reliable serialization and deserialization of the data.

The size of the stored result vary between 200-400 kB which is reasonably good ration between operation speed, compression and reliability.

Testing of HVCB is performed periodically, depending on the country policy or the policy of the company who is the owner of the assets. Common approach in the analysis is to look for the trends in parameters change over time. To make more convenient way searching for the specific result, the software use search filters. Most efficient way to implement filter based search is to use database instead of file based storage. For that particular reason, software use embedded database to store result and provide user with ability to search

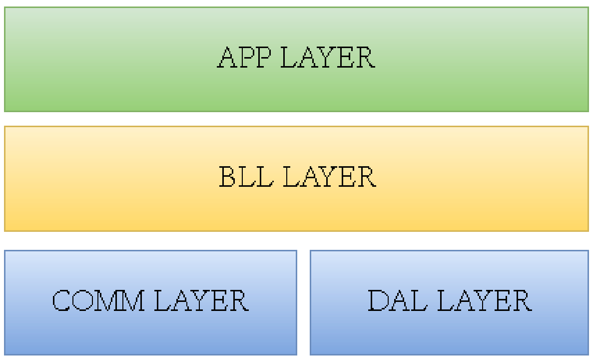


Figure 3 – The architecture

VI. RESULTS OVERLAY AND COMPARISON

As pointed out in previous sections, common approach in analysis of the HVCB is to look for the trends in parameters change over time. [5]

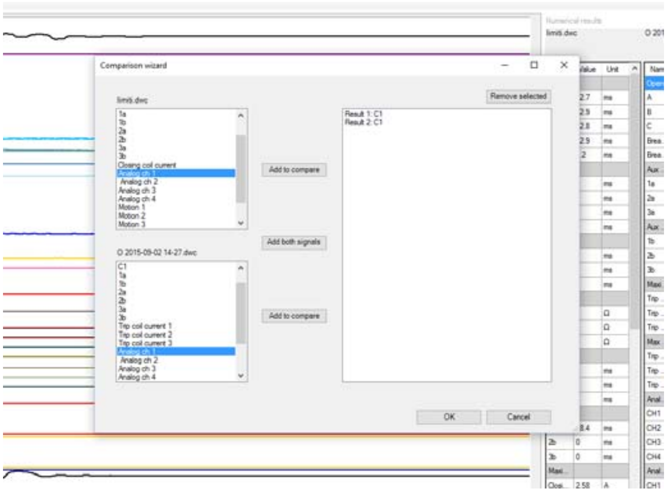


Figure 4 – Waveform selection wizard

That implies that the user must be provided with the tool to be able to overlay graphical results obtained in different time periods as well as to compare numerical results.

To implement this feature in the Software solution, the architecture of the single result user interface has been used. Furthermore, following tools in addition to single results tools are implemented:

- Result pan – selected result can be panned along X or Y axis over the other results. This feature is important if there is need to overlay different points in time of two results, to achieve synchronism between measurement start times of different results etc.
- Selection wizard – During the result overlay, user is provided with numerus waveform (cca. 46 different waveforms for 2 overlaid results). Making visible or disabled waveforms one by one is quite unnecessary additional effort. For that reason, Software solution includes Selection wizard. User is able to select a single waveform from the first result and software will look for related waveform in the second result and select it automatically. Then, with one click user is able to activate both signals. However, single waveform can be selected as well.

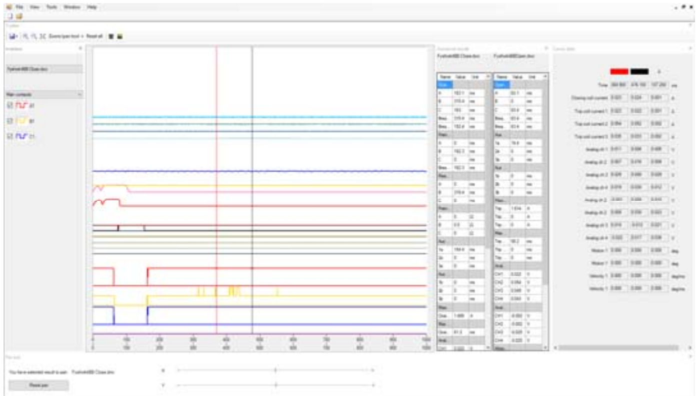
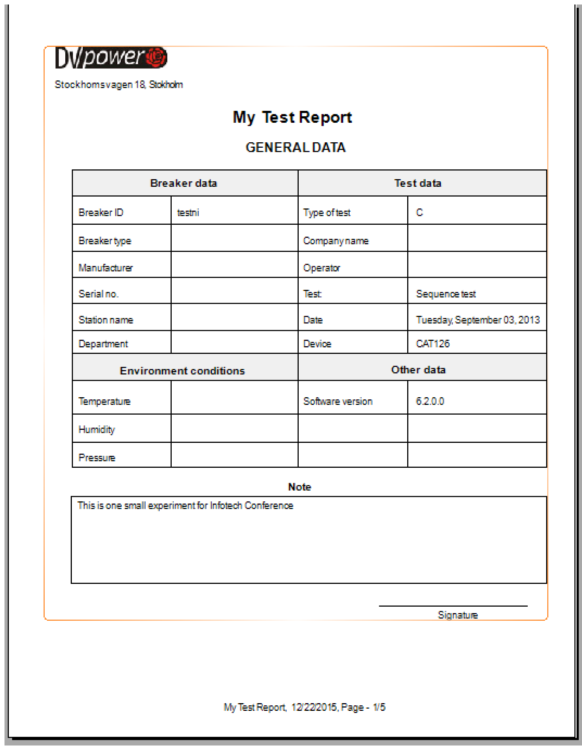


Figure 5 – Result overlay user interface

VII. REPORTING

Either the test is performed by in-house stuff, external testing company or individual for research purpose, test result has to be organized in the form of formal report. This software solution provides feature to generate customizable test report. User is able to customize header section in form of changing company logo, address, title, notes, comments etc.

The report is consisted of the front page with the general data, the numerical results section, the graphical results section as well as the settings section using which the result has been obtained.



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My Test Report

GENERAL DATA

Breaker data		Test data	
Breaker ID	testni	Type of test	C
Breaker type		Company name	
Manufacturer		Operator	
Serial no.		Test	Sequence test
Station name		Date	Tuesday, September 03, 2013
Department		Device	CAT126
Environment conditions		**Other data**	
Temperature		Software version	6.2.0.0
Humidity			
Pressure			

Note

This is one small experiment for Infotech Conference

Signature

My Test Report, 12/22/2015, Page - 1/5

Figure 6 –The report front page form

VIII. CONCLUSION

The developed software solution in addition to the HVCB analyzer and timer provides fast, reliable and comfortable testing. It ensures flexibility in data analysis, provides different approaches of storing and cataloguing obtained results as well as generating customized reporting forms.

Of course, this is not the end of the research & development since there is a wide range of possibilities to improve the Software solution.

One aspect of the improvement is the user experience (UX). User's feedback is of crucial importance for this as well as the application of UX and user psychology theories.

Another aspect is the performance. Certain parts of the Solution are subject to optimize regarding usage of multicore processors as well as optimization for use at the low performance hardware configuration.

REFERENCES

[1] J.Levi "Timing and Motion Testing", Electricity Today, September/October 2014, Volume 27, No7

[2] K.Obarcanin, A.Secic, N.Hadzimjelic, "Design and Development of the Software Solution for Analysis and Acquisition of the Hight Voltage Circuit Breakers Dynamic Resistance Measurement Results", MIPRO 2015, Opatija, Croatia

[3] M.Landry, A.Mercier, G.Ouellet, C.Rajotter, J.Caron, M.Roy, "A New Measurement Method of the Dynamic Contacts Resistance of HV Circuit Breakers". 2006 IEEE PRES Transmission and Distribution Conference and Exposition Latin America, Venezuela

[4] I.Gorton, "Essential Software Architecture", Springer-Verlag Berlin Heidelberg 2011.

[5] R.D.Garzon, "High Voltage Circuit Breakers – Design and Application", Second edition, CRC Press , 2011.