USER INTERFACING FOR AN AUTOMATED CIRCUIT BREAKER MONITORING AND ANALYSIS

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Abstract – *User interface for an Automated Circuit Breaker Monitoring and Analysis system (CBMA) is described in this paper. CBMA is a new system solution for monitoring and testing circuit breakers based on an analysis of the recordings taken from the circuit breaker control circuitry using Digital Fault Recorders (DFRs). The system is designed and implemented at Electric Power and Power Electronics Institute (EPPEI), Texas A&M University for Reliant Energy HL&P utility company. The paper describes the overall system architecture as well as the implementation of the software part of the system. Special attention is given to the graphical user interface requirements, and the approaches used for meeting them. Advanced data integration, archival and dissemination of the analysis results over corporate intranet are the system features described in more details.*

1. INTRODUCTION

The circuit breakers are one of the most critical and important components of the power system. They are used to change system topology in order to accomodate distribution and transmission load flow needs. In case of the faults or hazardous events, circuit breakers isolate parts of the faulted system. Therefore, maintaining reliability of their operation is a very important task in utility companies. It demands monitoring and systematic testing of all installed breakers in the power system at regular time intervals.

Monitoring and testing of circuit breakers is usually based on the analysis of DFR recordings. Recordings are taken from the circuit breaker control circuitry using Digital Fault Recorders (DFRs), which are implemented as portable test sets. DFRs can be carried between different substations and connected to breaker's circuitry manually. After the breaker operation is manually initiated, DFR automatically collects samples of predefined analog and digital signals during the short time interval, and stores them in files. File format of the recordings depends on the type of DFR. File conversion should be applied on recordings in native file format to receive files in a standardized COMTRADE [1], [2] file format. As a result, maintance crew analyzes the recordings on the spot and determines circuit breaker performances based on the reconstructed signal waveforms and values of the relevant signal parameters.

New software system solution called Automated Circuit Breaker Monitoring and Analysis system (CBMA) was designed and implemented at Electric Power and Power Electronics Institute (EPPEI), Texas A&M University. Using advanced signal processing and expert system concepts, analysis module of the CBMA system automatically processes the DFR recordings and yields the reports about circuit breaker operation and performances.

One of the most important parts of the CBMA solution is the graphical user interface (GUI). It is used for interaction between user and software modules in performing various tasks during analysis of the DFR recordings. The GUI has to meet several requirements.

First, it should display input signals in convenient way, which will enable comparison of different signals at the same time instances. Both digital and analog waveforms should be shown on the same display. Correlation between one phase and three phase values should be displayed and easily compared. Comparison with predefined reference record cases should also be provided.

GUI has to provide information to the user about status of the processing. The analysis process consists of several steps. After each step is completed, appropriate message in the application status window should reflect the outcome of the finished stage. If processing fails, a message describing the error, step in which error occurred and possible error causes should be displayed. After processing is completed, analysis report describing results of testing and maintance procedures should be shown in a separate window, enabling users to compare results of the processing with the original signal waveforms taken from the circuitry.

GUI has to enable manipulating data stored in the database. It has to provide the operator with capability to search, filter, and view records and settings stored in the database, over long period of time. Functionality that will enable classifying records by the users, depending on the analysis report has to be implemented.

Signal processing and expert system analysis depend on the parameters whose values cannot be easily determined just by studying the algorithms and equations. Because of the complex relationships between different parameters and dificculties to model them, values of the intelligent system parameters are reached by experience, using probabalistic methods and procedures. The GUI has to provide functionality to the users which will enable them to view, edit and save signal processing and expert system settings. Users should be able to observe influence of those changes on the final analysis reports.

Last, information regarding results of analysis, settings and overall statistics of the tested breakers, should be available for dissemination to the users connected to the corporate network.

The first part of this paper describes overall architecture of the CBMA system. Follows description of the GUI implementation, both for the analysis and web applications. Special attention was given to the integration, storage and dissemination of the collected and analyzed data, which are described in the last section.

2. SYSTEM ARCHITECTURE

Figure 1 shows the architecture of the CBMA system. The architecture is split between two locations: the substation where the circuit breaker data is acquired and central repository, where collected data are stored. Software that resides on a laptop at a substation will be referred as a client solution and software that resides on the server at the central repository will be referred as the server solution.
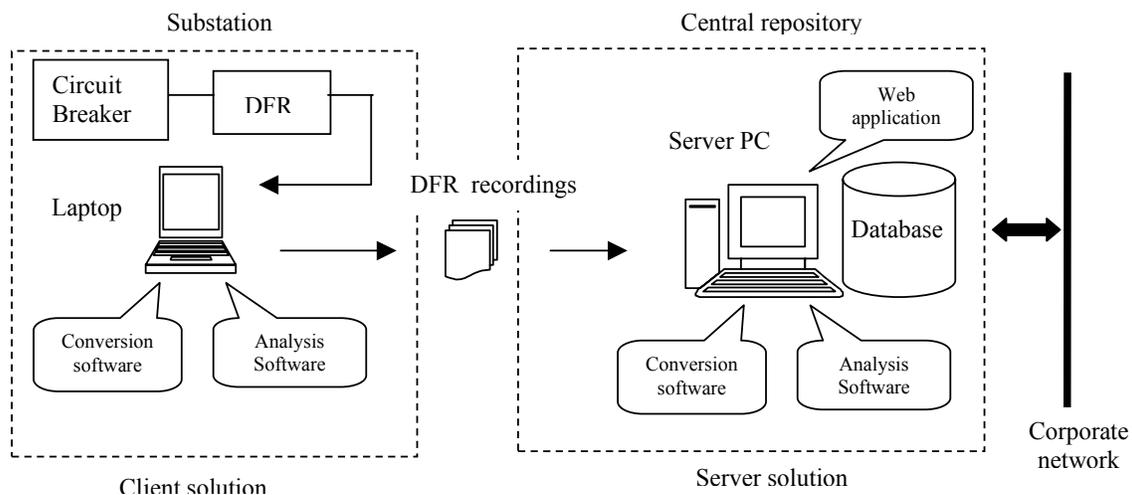

Figure 1. System architecture

A. Client solution

Client solution consists of the following parts:

- Conversion software
- Analysis software

File format of the DFR recordings depends on the DFR type. The conversion software converts data files from the native Rochester DFR format to the COMTRADE, and gives them a random file name. Analysis software renames the files using IEEE file naming convention [2] and information stored in recording header file, thereby uniquely identifying single recording. After renaming, software performs extraction of the pertinent signal parameters using signal processing algorithms and related settings [3]. Upon completion of this phase, expert system emulates reasoning of the human expert using: hardcoded knowledge base in the form of rules, settings and extracted signal parameters. Result of the processing is a report about circuit breaker operation, based on the

conclusions drawn from DFR recordings. After finishing testing of a particular breaker, reports and converted DFR recordings are not kept, and only native files are distributed to the central repository. Figure 2 displays architecture of the analysis software.
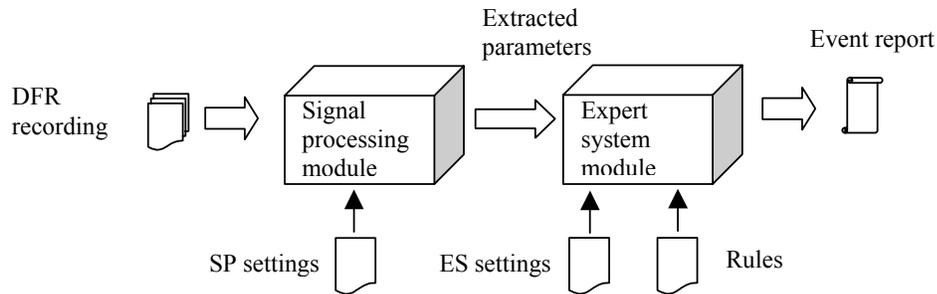

Figure 2. Architecture of the analysis software

B. Server solution

Installed and configured at a central repository, the server solution consists of the following parts:

- Conversion software
- Analysis software
- Database
- Web application

Conversion software has the same functionality as in the client solution. Analysis software, apart from the previously described, contains additional interface for adding and changing signal processing and the expert system settings. Those settings are internally used by signal processing and expert system modules. Functionality for storing data to the database is also part of the analysis software installed on the server. Database is used for keeping all circuit breaker records and analysis results over long period of time. Database also contains signal processing and expert system settings.

Web application enables users connected over corporate intranet to access data stored in the database. Using common internet browser software, authorized users can search, view and classify recordings and analysis results. There is also an interface for viewing signal processing and expert system settings. It enables file download and upload from any computer connected to the network. Special attention is given to the graphical presentation of the statistics related to the recordings and circuit breakers in the system.

3. GUI IMPLEMENTATION

GUI module is divided in two parts. First part pertains to the analysis module, and the second to the Web application module.

Analysis module

Analysis module is implemented in MS Visual C++ programming language and MFC 4.2 library of classes. The same language and library were selected for implementation of the corresponding GUI. Screenshot shown in the Figure 3 depicts main window of the analysis module comprised of the "waveform window" marked with (1), "signal parameters window" (2) and "status window" (3).

Figure 4 lists all input signals displayed in the "waveform window" of the analysis software. Both currents and voltages are displayed in the same window, one under the other, enabling comparison of the breaker behavior at the same time instances. In separate dialog, up to 5 different records can be selected for overlaying in the waveform window, together with the reference cases for particular breaker operation. Different records can be shown in user selected and customized colors emphasizing waveforms and breakers performances of a particular record.
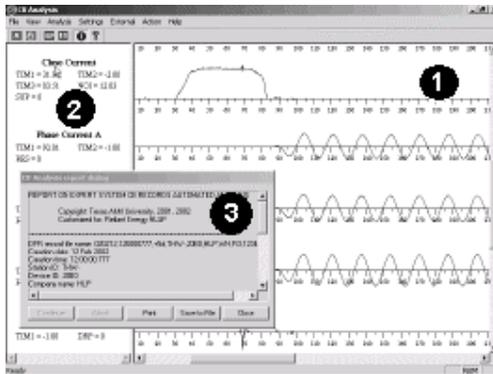
Figure 3. Screenshot of the analysis module main window

Group	Signal name
Digital signals	Trip Initiate
	Close Initiate
	X Coil signal
	Y Coil signal
Contacts	"A" Contact
	"B" Contact
DC Voltages	Control DC Voltage
	Yard DC Voltage
Coil Currents	Trip Coil (TC) Current 1
	Trip Coil (TC) Current 2
	Closing Coil (CC) Current
Phase Currents	Phase Current A
	Phase Current B
	Phase Current C

Figure 4. Input signal names

"Signal parameters window" displays signal names and values of extracted parameters. "Status window" is modeless, scrollable window, which displays processing progress. This window displays error message if analysis fails or if processing is interrupted by the user. When processing of a single record is completed, analysis report is displayed within this window. By scrolling it, user can view list of expert system rules fired, reflecting relations between extracted parameters, tolerances, hardcoded rules, and breaker performances. At the end, maintence and repair information customized for each type of breaker is given, directing operators how to handle detected breaker problems.
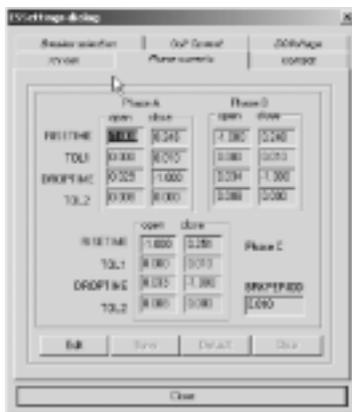
Figure 6. ES settings dialog screenshot

Setting consists of a set value and a tolerance. The set value represents the expected normal value for a parameter and the tolerance specifies the degree of freedom that the parameter is allowed to deviate and still be considered normal. There are also other settings that specify a maximum limit that the parameter must be under, to be considered normal. Figure 6 displays dialog for changing expert system settings. Dialog for changing signal processing settings parameters has similar user interface. It is tabed dialog where each tab coresponds to the single signal. User can select breaker manufacturer and breaker type and then view, edit, save or delete settings pertaining to that breaker type. There are different settings values as well as tolerances for open and close breaker operation. All settings are stored in a custom format files, that can be easily transfered among different computers, or stored to the database.

Settings values and tolerances can affect results of the signal processing and expert system reasoning, and changes made to them, may result in firing different rules, during the expert system reasoning. The changes in the signal processing and expert system parameteres can be observed in list of rules of the final analysis report

Web application module

Web application is implemented in new ASP.NET technology [4], based on server side processing of the user's requests. Users that want to access data stored in the database, can request dynamically generated web pages using internet browser software supporting HTML 3.0 markup language or higher. Requests are initially processed by the IIS (Internet Information Services) Web server, which recognizes the type of the request and lets the ASP.NET module to deal with it. ASP.NET module then places the request in new class definition in ASP namespace. The new ASP class is instantiated as an object in the CLR (Common Language Runtime). After calling the render method for that object, an appropriate HTML content is returned via ASP.NET module to the IIS, which then sends the HTML to the client that originally made the request. The database access is performed through the CLR, and objects from the ADO.NET libraries, using SQL commands. Web application functionality is programmed using new programming language C# from .NET suite of languages. Tools used for programming are Microsoft Visual Studio .NET Professional Edition and Microsoft NET Framework 1.0.

Since number of the users accessing the database and changing their data through the web application is limited, database is installed on the same server as the web application. Because of support of the SQL (standard query language) and simple user interface, MS Access 2000 is chosen for implementation of the database. SQL is extensively used for querying database using multiple criteria as well as searching, editing and storing data. Figure 7 is a screenshot of the web page showing the results of the database query. It contains the table with columns enabling sorting DFR records by the record name, substation name, date of the recording, breaker manufacturer, breaker type, breaker identification number, breaker operation and classification. Data can be searched for one particular date, or for an interval of dates. Criteria for searches are same as those listed for the sorting. In the last column of the table there are link buttons, which can redirect users to the pages showing the analysis reports and signal waveforms. Accessing web application online, users can classify record by selecting appropriate classification from the dropdown list box and save new classification to the database. Results of the query can be exported to the CSV (coma delimited) file format commonly supported by most of the spreadsheet programs.


*Figure 7.*Results web page screenshot
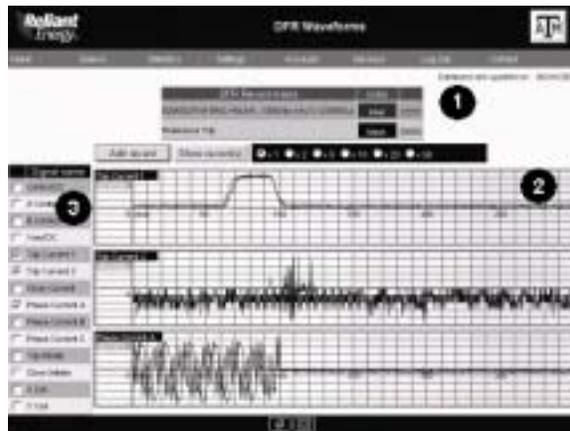
Figure 8. Waveform web page screenshot

Figure 8 is a screenshot of the page showing the DFR signal waveforms. There is a table showing the DFR record name, and selected color used for drawing the waveform, marked with (1). Users can add or delete DFR records to/from the table through a custom dialog, invoked by clicking on the button "Add record". There is a list of radio button controls, which enables selecting discrete values for zoom ratio of the pictures showing the signal waveforms. List of the checkboxes marked as (3) is used for selecting signals from the DFR record that should be displayed in the images (2) on the right. Those are dynamically generated images, which reconstruct selected signal waveforms from the DFR records stored in the database and embed them on the fly in the requested HTML pages. Images can be scrolled in both directions (horizontal and vertical). Values of the signals can be read and compared using the grid.
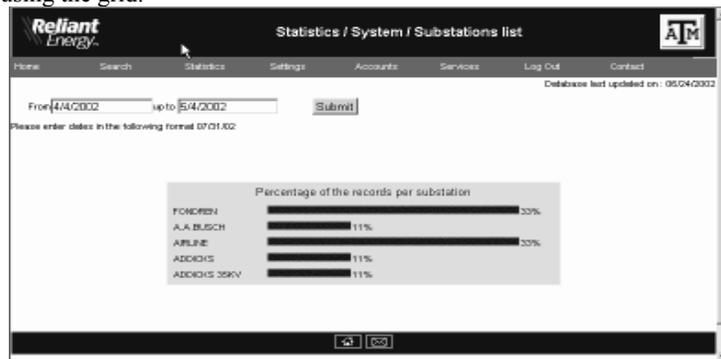
Figure 9. System statistics web page screenshot

There are two kinds of statistics available: system level and substation level. System level statistics for given date or interval of dates displays how many records in the database pertains to each substation, each breaker manufacturer, each breaker type and percentage of the breakers in the system tested. Substation level statistics shows the same kind of information for selected substation. Statistics information is shown using bar graphs that are dynamically created and embedded in the web page from the data received by querying the database records. Figure 9 displays the web page showing the system level statistics - percentage of the records per each substation.

4. DATA INTEGRATION, ARCHIVAL AND DISSEMINATION

Most of the DFR vendors are still keeping their old native DFR file formats or developing new ones, providing additional utility programs for exporting data to COMTRADE file format. Therefore, by supporting atandardized COMTRADE file format, CBMA enables easier data integration of the recordings from different DFRs.

Additional feature of the software is the usage of the IEEE file naming convention for the time sequence data [6]. Proposed convention defines shema for naming the data files. File name compliant with the proposed convention contains unique information about the event: date, time, substation, company, breaker type and manufacturer, identification number etc. By using the IEEE file naming convention, handling of the large volumes of the record files is notably facilitated.

All DFR data converted to COMTRADE file format, analysis results and settings are stored to the database. The database allows easy access and retrieval as well as advanced features for searching stored data. It is used as central repository of all collected and analyzed recordings. Because of the data integrity and security issues, special procedures are developed and implemented to backup data on regular time basis.

Dissemination of the data is enabled through the web application. All requested data are dynamically embedded into the HTML web pages that are returned to the users. Only the HTML code describing the finished page is sent to the browser, hiding the page's logic on the server and reducing the time needed for data transfering and displaying in the user's browser software.

5. CONCLUSION

This paper introduces a software solution aimed at automated monitoring and testing circuit breakers in power systems. Presented GUI for the solution meets the following requirements:
- It displays input signals captured by DFR as well as status of the processing and analysis reports. It also reports errors and their causes after each processing step. Users have opportunity to visualy inspect and compare acquired signal waveforms with reference cases. There is also capability to compare the analysis results with the input signal waveforms.
- Through the GUI, database access is enabled. Users can search, filter, view, classify records and analysis reports.
- Using GUI, signal processing and expert system settings can be view and changed, and impact of these changes can be observed in the analysis report.
- Usage of the COMTRADE file format supports data integration of the DFR recordings that stem from different circuit breaker vendors. Usage of the IEEE file naming convention further simplifies the data handling
- Web application enables dissemination of recorded data and analysis results over the corporate intranet to all authorized users. They can review the recordings and results, repeat the analysis with the same or different parameters and compare the results.
- Finally, overall statistics of the tested circuit breakers in the system can be observed, giving the information about an outcome of the testing at the substation or system level.

REFERENCES

[1] IEEE Std. C37.111-1991 "*IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*", IEEE Inc.,1991.
[2] IEEE Std. C37.111-1999 "*IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*", IEEE Inc.,1999.
[3] Kezunović, M., Nail, C., Ren, Z.,Sevcik , D.R., Lucey, J.,Cook, W., Koch, E., "*Automated Circuit Breaker Monitoring*", IEEE PES Summer Meeting, Chicago, July 2002.
[4] Anderson, R.,Francis, B.,Homer, A.,Howard, R., Sussman D., Watson K. "*Professional ASP.NET 1.0 – Special Edition*", Wrox Press Ltd., Birmingham, UK
[5] "*CLIPS – Reference Manual*", Artificial Intelligence Section, Johnson Space Center, Houston, Texas, Septermber 1987
[6] "*File Naming Convention for Time Sequence Data*", Final Report of IEEE Power System Relaying Committee Working Group H8, 2001 Fault Disturbance Analysis Conference, Atlanta, Georgia; and the Spring 2001 Meeting of the IEEE Power System Relay Committee