

Integration of Data and Exchange of Information in Advanced LAN/Web Based DFR Systems

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Abstract – This paper analyzes the requirements for advanced data integration and information exchange in the DFR systems consisting of multiple types of DFRs and corresponding master station viewing software. After the application background and requirements are outlined, the paper points out to some possible approaches in using advanced programming concepts and languages as well as LAN/Web tools and communication services for developing the solutions that will meet the new requirements. Implementation approaches using the mentioned concepts and techniques are discussed and illustrated through examples of the DFR system solutions deployed in several utilities recently.

Keywords – Faults, Digital Fault Recorders, Automated Analysis, Local Area Network

I. INTRODUCTION

The traditional DFR systems consist of recorders distributed in substations and a master station located in a centralized office. A variety of communication procedures and protocols may be implemented for bringing the data from the recorders to the master station. Depending on the specific utility needs and requirements, the number of recorders per a substation/region may vary, and there may be multiple master station locations. Once the data is brought to the master station, it may be archived in a repository and viewed by the engineers involved in the analysis, using custom software supplied by the vendor of the given DFR system, at a later time [1].

Due to evolving needs and requirements, a given utility may acquire a variety of DFR system solutions and/or upgrades over a period of time. Typical situation is that a utility may end up having several DFR systems (recorders and matching master stations) supplied by different vendors, or several generations of the DFR

hardware and/or software supplied by the same vendor over the years. In most cases, the end result of the evolution is that installed systems do not allow an easy data integration and information exchange, which makes the use of the systems rather difficult.

The examples of the limitations in the area of data integration are: the lack of a common data base solution for storing the records coming from different types of DFRs and/or recording systems, inability to view all the records collected by different type of recorders and/or recording systems using the same viewing software, the need to have a number of data file converters to accommodate legacy data records that may not be available in the COMTRADE standard format, difficulty of interfacing different types of recorders and/or master stations using standard LAN protocols. The examples of the limited information exchange are: unavailability of automatic means for extracting the information required by different utility groups (protection, maintenance, system operators), the lack of convenient means for retrieving only the essential information from sometimes an overwhelming amount of recorded data, inability to disseminate the information over a LAN using standard LAN/Web services.

First, the paper discusses the application background leading to better understanding of the problem. The resulting implementation requirements are outlined next. Then, implementation options are described. Conclusions and references are given at the end.

II. APPLICATION BACKGROUND

The utilities employ DFRs to monitor state of the electric power system and its elements. Typically, DFR data records are uploaded to a master station computer, using DFR master station software. The viewing, analysis and classification of DFR records is performed manually [2].

This section identifies main problems in this “classic” approach. Some current and future steps toward providing integrated modernized solutions are discussed as well.

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A. Problems in Existing DFR Systems

Main problems of the “classic” approach to DFR systems solutions are summarized in the list below:

- DFR records cannot be efficiently analyzed manually due to an overwhelming number of records obtained in a moderately sized system.
- Use of different master station programs increases training costs since the master station software from different vendors have distinctively different features as well as the look and feel.
- Slow response (i.e. DFR data analysis takes time) is an impediment if several records supplied by different DFRs for the same event must be uploaded and analyzed.
- Highly-skilled people devote a lot of time to routine tasks because most of the records may just confirm the proper operation of the equipment being monitored.
- Non-selectivity (i.e. DFR records are not event prioritized) is an issue if the operator must sort out the records for the analysis purposes.
- Inefficient data archival and retrieval due to rather primitive means of storing and retrieving the data.
- Lack of ability to integrate data coming from different DFR types is evident when one attempts to integrate the different DFR systems and services.

B. Moving Toward Integrated Solutions

First big step towards integration in the field of DFR systems was the introduction of the COMTRADE file format [3]. DFR vendors are gradually accepting a new format opening a door for easier data integration. Most of the vendors are still keeping their own native DFR file formats or developing new ones and just providing additional utility programs or commands for exporting data in COMTRADE file format. Unfortunately, this export-to-COMTRADE feature, in most cases, is not configurable for automated operation. Also, the COMTRADE format specification allows freedom, to some extent, on how to provide information inside the files. This leads to situations where different software packages supporting COMTRADE file format cannot exchange data among themselves due to the lack of standardized descriptions of the files and signals inside. In addition to the original COMTRADE standard specification [3], there are the latest IEEE revision [4] and IEC version [5]. Having three versions currently being used increases a possibility not to be able to exchange DFR data among different types of software packages due to inconsistencies between different versions.

One step further was the introduction of the standardized IEEE file naming convention for the time sequence data [6]. The proposed convention defines coded schema for naming the data files. Such file names can enable easier handling of large volume of files as well as unique file identification since the file name should contain unique information about the event: date, time, station, company, duration, location etc. Benefits of using this standardized file naming schema should encourage DFR and related software vendors to provide the support, which is not a common feature today.

There is still a lack of a standardized approach to communication protocols for DFRs and convention for providing information on parameters that describe system objects (signals and associated equipment) monitored by DFRs.

Having a standardized communication protocols would allow much easier integration of DFR systems and enable interchangeability of one type of DFRs with another. Future DFR systems may utilize standards like the one recently proposed by IEC [7]. Unfortunately, at present, we may still be far from that possibility. Currently, a common approach is to use master station software from each DFR vendor to download DFR data file in its native format to the PC workstation that is on the corporate Intranet. The master station software should be configured to automatically collect DFR data files and make them accessible through LAN. Preferably, DFR data should be automatically converted to the COMTRADE file format, but that feature is not common for all master station programs.

III. IMPLEMENTATION REQUIREMENTS

This section discusses the requirements for data integration and information exchange in advanced DFR systems. The following set of system implementation requirements has been identified:

- DFRs wiring. Each substation needs to be equipped with one or more DFR units that will provide monitoring of all important signals. For analog signals, it is recommended to monitor all three phases as well as the residual for both voltages and currents. For digitals, it is recommended to monitor as many as possible of the signals related to protection circuits such as primary and backup relay trip, breaker open and close position, breaker failure, carrier start and receive contacts etc.
- Communication interfaces. Each substation needs to be equipped with at least one communication channel (e.g. telephone line with modems, Ethernet, etc.) enabling easy access to DFR data. Communication has to provide an ability to query

DFRs for presence of new data as well as to enable quick data transfer.

- Collecting DFR data. Various schemes for collecting data from DFRs may take place. Typically, there is a need for vendor's master station software to be running continuously and collecting DFR data automatically. There are two typical setup configurations: 1) auto-poll, when master station software polls DFRs and downloads new data; 2) auto-call, when DFR initiates uploading of new data to master station software. An alternative option is to use third-party products for direct communication with and automated data collection from DFRs. This alternative solution may be hard to maintain because of variety of transfer protocols, native DFR file formats etc.
- Conversion of native DFR formats. All the DFR data needs to be converted to COMTRADE file format according to the most recent version of the standard, prior to any further processing. As mentioned in previous section, it is important that the DFR setup and conversion module allow providing of all the information about signals and equipment being monitored by DFR.
- File naming convention. System should provide support for more advanced file naming convention. It is preferred that the file naming conforms to the recent IEEE proposal [6].
- Component information. System should provide support for handling descriptions and important information on system components being monitored by DFRs. Example of these parameters are: transmission line and circuit breaker names, line length, line impedances, relation between signals and objects, etc.
- Analysis goals. Main goals of the analysis are: detection and classification of the fault or the disturbance; verification of the correctness of the protection system operation; fault location calculation. The analysis should be performed automatically, and triggered by the occurrence of new incoming DFR data.
- Broadcasting options. System needs to provide the means for automated dissemination of both DFR data and relevant additional information such as analysis reports, component parameters etc. System should provide automated file copying over corporate Intranet for the archival purposes as well as sending notifications and reports using emailing, faxing, paging and/or printing services.
- Centralized database and access to data. All the DFR data, once converted to COMTRADE,

together with the analysis reports and additional available information should be automatically stored into a centralized database. The database should allow an easy access and retrieval as well as advanced features for searching. Besides, "live" data such as DFR records and analysis reports, the database has to contain the system configuration data used to describe various components.

- User interfacing. System needs to provide tools for searching, accessing, and viewing DFR data, analysis reports as well as the system configuration data. All the user interface tools need to be universal and enable viewing the information in the same way regardless of the origin and DFR type.
- Technology compatibility. Integrated system needs to be compatible with PC systems running Windows operating system as well as to be capable of using available communication and network protocols and web technologies for intensive data exchange.

IV. IMPLEMENTATION OPTIONS

An integrated DFR system solution can be configured in several different ways to match various system architectures and to serve the various needs of different users. Example configurations of systems recently deployed in the utilities are illustrated in the following sections.

Described configurations are based on the suite of software applications called DFR Assistant [8]. This software features a client/server platform where both client and server applications can be configured in several ways in order to better accommodate the specific system requirements.

A. *Integration Building Blocks*

This section describes main integration building blocks used for configuring the client and server applications. Later, in the following sections, these building blocks will be used to describe different implementation options. The building blocks are:

- File format filters – modules for converting native DFR data files into COMTRADE file format.
- Expert system – module for analysis, classification and fault calculation.
- DFR Communication – optional module for direct interfacing to DFRs (without master station).
- Broadcaster – module that provide services for dissemination of both DFR data and analysis reports (fax, email, print, page, web).

- Database – centralized database for archival of DFR data, analysis reports, system configuration.
- System Analysis – module for more elaborate substation and system-wide analysis.
- GUI – set of user interface applications.
- Web Server – centralized web-based application for Intranet access to DFR data and reports via corporate network.

B. Autonomous System

This is the simplest configuration. It is characterized by possible absence of the system database and centralized data distribution services. In this case, a system is usually reduced to providing the conversion to COMTRADE format, analysis, broadcasting of DFR data and analysis reports, and viewing the records and analysis reports by multiple users [9]. Figure below illustrates the architecture of this type of the system.

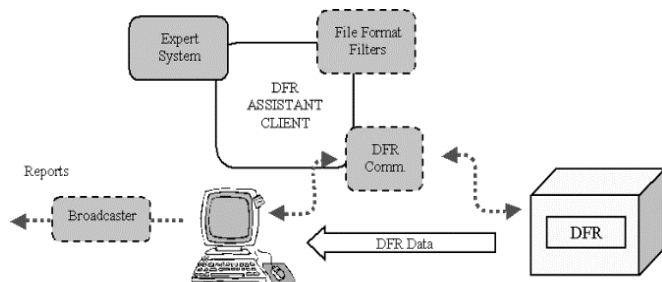


Fig. 1. Configuration of the Autonomous System

Typically, a solution is installed on a single PC and accesses DFR data files on the master station computer via LAN. Normally, master station software can be installed on the same PC, or the system directly queries and reads event data from DFRs. This configuration is recommended for a small number of recording devices.

This type of the system is characterized by the analysis centered on a faulted transmission line in the monitored substation. As a result, DFR files are converted to COMTRADE format and accompanied with an analysis report.

Adding the Communication module, File Format Filter modules and Broadcaster module can upgrade the configuration discussed above. This provides direct link between the analysis system and the recording device, direct importing of files in native formats of the recording device, and transmission of the analysis reports to the registered users.

System-wide analyses is not supported nor are the centralized data archival and dissemination. DFR data

and reports are copied to selected folders on the local computer only.

C. Centralized System

This is a more complex version of the DFR Assistant based solution and all the implementation issues described in the requirements section are involved in this case. The system is characterized by the centralization of all the system functions. This configuration is normally implemented for systems consisting of multiple DFRs and master stations provided by different vendors. Computer hosting the DFR Assistant applications is usually a dedicated one and data downloading is done using separate master station computers that make DFR data files available through a LAN connection [10]. This configuration can be implemented with a single computer, too. Figure below illustrates the architecture of this type of the system solution.

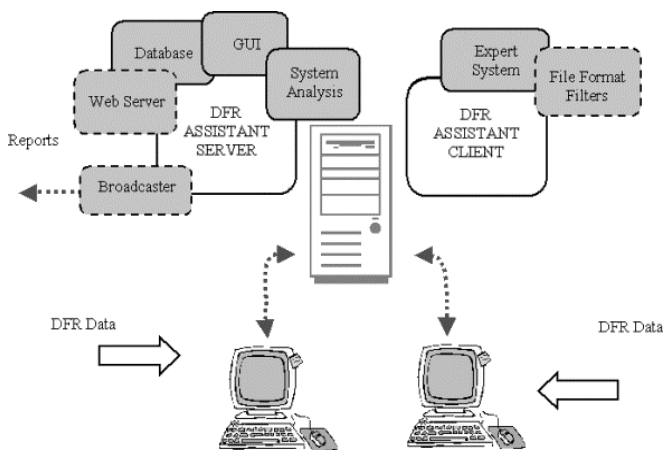


Fig. 2. Architecture of the Centralized Configuration

In this system, both the client and server are installed on the computer at the central location (e.g. in the central office). DFR event files are transferred to DFR Assistant computer (e.g. using DFR Master Station software and copying DFR data files via LAN). Therefore, only an indirect link between DFR Assistant and DFRs exists. Event files can be in either the COMTRADE or the native DFR format if optional conversion modules are added.

This type of the system is characterized by the two-tier analysis. First, the Expert System module carries out the analysis centered on the faulted transmission line in a substation. Second, the System Analysis module performs more elaborate, substation- and system-wide analysis.

Centralized data archival (of event reports and event data) is an inherent feature of this system. The addition of optional Web Server, Broadcaster and Report Viewer provides sophisticated and user-friendly data and report dissemination.

D. Distributed System

This configuration is characterized by the centralized data archival and dissemination (Server) on one side and distributed event analysis (Client) on the other side. This configuration is normally implemented for systems consisting of large number of DFRs [11]. Faster time response is an additional reason for the selection of such a system. Computer hosting *Server* is usually very distant from Client computers(s). Event data transfer from DFRs to local PCs can be done using separate computers (master station computers) or directly using DFR Communication module. Fig. 3 depicts the architecture of this type of the system.

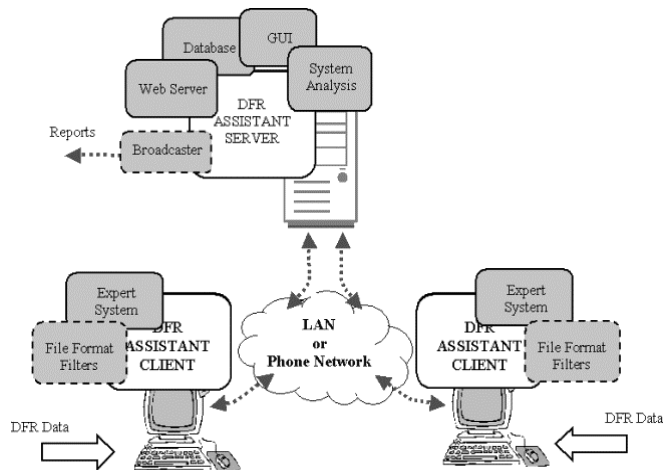


Fig. 3. Architecture of the Distributed Configuration

The system is also characterized by the two-tier analysis. First, the Expert System modules on local computers carry out the analysis centered on the faulted transmission line in a substation. Second, more elaborate, substation- and system-wide analysis can be performed by the System Analysis module (part of the Server).

Centralized data archival (of event reports and event data) is an inherent feature of this system. As before, the existence of the Web Server and Broadcaster provide for sophisticated and user-friendly data dissemination.

V. USER INTERFACE

For all described implementation options, there is a set of universal tools for user interfacing. Configuring

the solution and entering system data parameters are done by System Builder (Fig. 4).

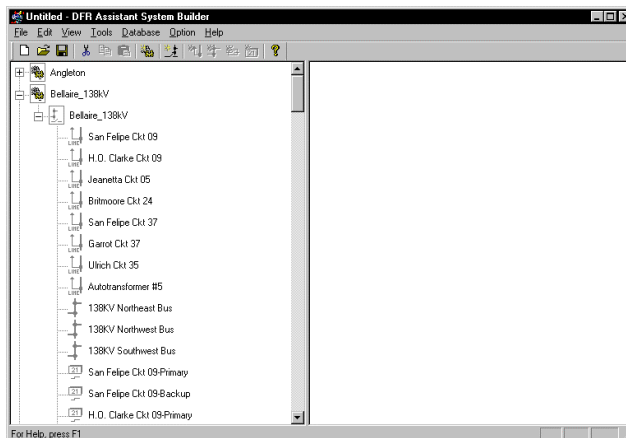


Fig. 4. System Builder – Setting up the system configuration

All the DFR data and reports are stored in the centralized database and available on the web through corporate Intranet (Fig 5.).

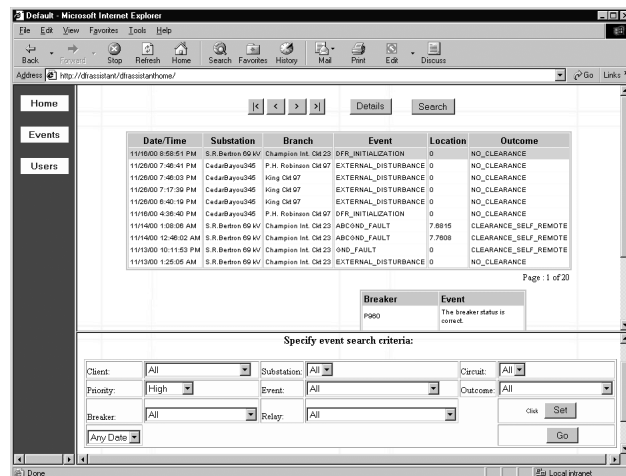


Fig. 5. Web Access to the Centralized Database

Navigation through the event table and specifying search criteria enables user to quickly locate events of interest. Detailed inspection of the waveforms and reports can be done with a universal viewer (Fig 6.).

VI. CONCLUSIONS

Moving toward integrated solutions is gradually driven by the standards related to DFR file formats and file naming, but implementation of these standards is still not a common practice. There is also a lack of the standardized approach to communications as well as to describing the components parameters.

This paper outlines application background and implementation requirements for integration of data and exchange of information in modern DFR systems.

Based on the discussion, three general implementation approaches are described using common building blocks in different configurations. In all of the implementation options, configuring the system data as well as the archiving and accessing the DFR data and reports is done by using an universal set of user interface tools.

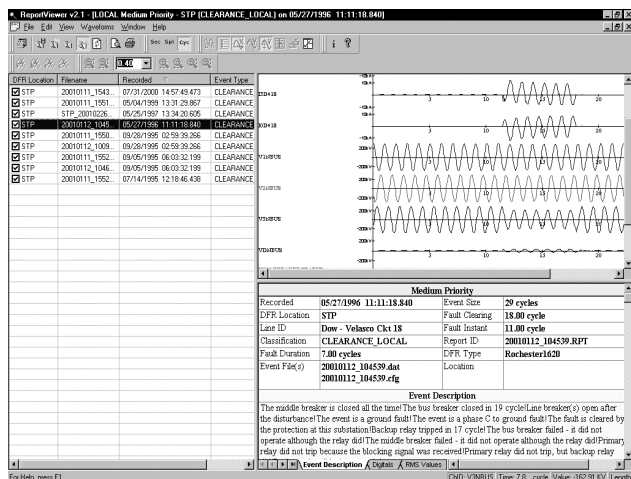


Fig. 6. Universal Solution for Viewing Data and Analysis Reports

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VIII. BIOGRAPHIES



Mladen Kezunovic received his Dipl. Ing. Degree from the University of Sarajevo, the MS and PhD degrees from the University of Kansas, all in electrical engineering, in 1974, 1977 and 1980, respectively.

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