AUTOMATED FAULT AND DISTURBANCE DATA ANALYSIS

Special Report for PS#2

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This paper gives a set of questions stimulated by twenty one papers submitted by the authors from twelve countries, two papers being submitted by the members of the WGB5.03 " Fault and disturbance data analysis including intelligent systems". The papers are written in response to the preferential subject PS2: Automated Fault and Disturbance Data Analysis. To facilitate the discussion, papers are classified in four groups arbitrarily titled: existing analysis practices, existing equipment and system solutions, fault location, and future trends. For each group, an introductory discussion points to the main trends expressed in the papers followed by the questions raised by the special reporter. The questions relate to both the issues raised in the papers and the ones formulated in the PS2 call for papers. The questions are aimed at facilitating a focused discussion on the subject.

Keywords: Fault, Disturbance, Intelligent Electronic Device, Automated Analysis, Protective Relaying, Substation Automation, Asset Management, Power Quality, and Fault Location

1. INTRODUCTION

Fault and disturbance data analysis is an important issue in any utility company. The importance is related to the impact that fault analysis may have on the speed of a system restoration, quality of a troubleshooting effort, deployment of a given maintenance strategy, risk analysis associated with the asset management, customer satisfaction, etc. With the utility business going though restructuring, deregulation, liberalization, privatization and other similar transformations around the world, it becomes critical that the above-mentioned impacts are realized at full extent while not exceeding a reasonable level of investment.

This paper poses questions about utilizing data collected by different Intelligent Electronic Devices and implementing various analysis approaches utilizing data integration and information exchange. Special attention is paid to the IED capabilities to provide data of interest as well as to the use of advanced database and communication designs for storing and disseminating both the recorded data and the results of analysis. The paper contains a variety of clarifying questions raised regarding the approaches presented by the contributing authors.

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2. EXISTING ANALYSIS PRACTICES

Six papers, one of which is the WG B5.03 summary report from a survey conducted on the subject, cover this topic. Based on the discussion presented in the papers, several interesting questions may be raised as follows.

Q#1: What is the equipment of choice when performing fault and disturbance analysis?

From the survey and other papers in this section it becomes evident that not just the data from a single intelligent electronic device (IED), but rather a variety of IEDs, may be used in troubleshooting the disturbances of interest. Some specific observations raised in the papers deserve further discussion:

- The WG B5.03 survey, paper 220, points out a trend in using digital relays more than any other IED type, even the fault disturbance recorder, for the analysis of faults and disturbances. What is the consequence of the difference in the recording performance characteristics of the relays when compared to the dedicated fault disturbance recorders regarding the available sampling rate, sampling synchronization, disturbance analysis software, communication capabilities, etc?
- The papers from Australia (201), India (206), Germany (204), the USA (214), and Korea (208) are summarizing various experiences in analyzing particular fault events in the distribution and transmission network as well as a variety of fault and no-fault events on the generators. While the data from digital relays and disturbance recorders was invaluable in understanding the causes and subsequent actions, what was the most desirable information that was not readily available and yet would have been very useful in the mentioned analysis cases?

Q#2: How important are the communication and analysis automation features of IEDs?

All the papers have pointed out the importance of communications and data analysis features of the IEDs used in the specific instances. The experiences regarding the use of communications and tools for data retrieval are quite diverse depending on the IED type used. The following aspects deserve further clarification:

- What are the options for collecting data remotely in the cases when the number of relays or disturbance recorders that may be involved in capturing an event of interest is rather large? Should there be a provision for pre-processing field data locally so that only the required information, not the entire field record, is sent to the remote site. What is the role of the "smart" triggers in the reduction of recorded data?
- Several papers have mentioned the convenience of the data format standards such as COMTRADE [1]. Is the COMTRADE standard sufficient to serve the standardization needs for communications and automated analysis or is there a need for the use and development of additional standards?

Q#3: Who are the users of the fault and disturbance data?

An undisputable group of users appear to be the protection engineers. The survey and a few other papers indicate some other utility groups that may be interested in this data such as operators, asset managers, power quality supervisors, etc. When considering other users, several important issues may surface as pointed out next:

- If groups other than protection engineers are using the data, do they have a need for different type of information and/or different analysis tools than what is used by the

protection engineers? Are the other groups interested in more historical and data trending capabilities than what is typically required by the protection engineers?

- If the other utility groups are using the data, what are the new requirements for data integration if the data is to be integrated in the SCADA, maintenance management workstation, power quality survey solutions, etc? Are the new standards needed for the database interfacing as well as the utility-wide dissemination using common utility IT solutions?

3. EXISTING EQUIPMENT AND SYSTEM SOLUTIONS

While several papers made a reference to the equipment characteristics and properties of the system solutions, seven papers by the authors from Romania (212), Japan (207), Germany (205), South Africa (219), Korea (209) and the USA (215, 218) provided more focus on the subject. The following are some questions that are prompted by the papers and general industry trends.

Q#4:What are the most useful functions of the existing equipment and system solutions?

The vendors are making strives to provide more versatile and effective functions. When evaluating the uses of the functions, several issues may arise:

- The papers 212, 207, 209 and 218 put an emphasis on the variety of data coming from digital relays and fault disturbance recorders. Is there any particular functionality of digital relays or disturbance recorders that facilities the fault and disturbance analysis the most? What are the most desirable functionalities for data retrieving and displaying for digital relays and disturbance recorders?
- The papers 205 and 219 are looking at the system-wide collection and analysis of data. What are the most desirable system-wide functionalities that facilitate data storage and retrieval as well as system-wide analysis of fault and disturbance data? Are the existing solutions for the system-wide data handling appropriate, and what may be the most pressing needs for improvements?

Q#5:What are the new uses of the traditional equipment and data?

As the equipment and data are being more widely used, variety of new uses is being envisioned. Several ideas along those lines are mentioned in the papers and observed in practice:

- The paper 205 is proposing a variety of new data uses such as for relay testing and circuit breaker monitoring. The paper 219 mentions the data uses for improvement in the alarm processing. The paper 212 points out the benefits in facilitating network restoration, and the paper 207 states the uses for the power quality and system-wide phasor measurement applications. The paper 209 emphasizes the use of digital relays for fault location and power quality monitoring. The paper 218 elaborates on the use of digital relay capabilities for power quality monitoring. How far are we from readily utilizing the fault and disturbance data for the mentioned purposes? Are the proposed uses requiring specialized software and/or customized hardware?
- The new uses of fault and disturbance data are typically based on availability of advanced software packages for data analysis and displaying. Are the hardware and software developments “matched” in the complexity and user options? Do we have enough application software packages to match the variety of existing fault and disturbance data uses and what are some of the examples of the specialized software solutions?

Q#6:What are the limitations of the existing equipment and system solutions?

In reporting the experiences with the use of existing solutions, the authors did not point out any striking limitations. However, some interesting issues may still be unresolved:

- The "explosion" of data is evident and the need to store and process data at the source may be needed to avoid data overflow. Several papers, including paper 215, are discussing this issue. What are the existing equipment and system solutions features that allow an easy handling of high volumes of data? What is the role of substation integration standard IEC 61850 in this regard [2]?
- The need to integrate data across different data acquisition IEDs is evident. How is this process facilitated by the existing solutions and standards? What are the experiences in achieving the goal of broad integration of fault and disturbance data?

4. FAULT LOCATION

The fault location considerations are so much an integral part of the fault and disturbance analysis that it is unavoidable to discuss this issue each time the fault and disturbance are mentioned. Four papers from Korea (209), the USA (217), Canada (202), and Malaysia (210) are addressing different issues related to the novel fault location implementations.

Q#7:What are the shortcomings of the existing fault location techniques?

This question is relevant in the context of special applications and/or implementation approaches reported in the mentioned papers:

- For parallel transmission lines (discussed in paper 209), what are the modifications needed in applying "standard" phasor (impedance)-based fault location techniques?
- For distributed feeders fed by distributed generation systems (discussed in paper 217), what are the obstacles of applying "standard" phasor (impedance)-based fault location techniques?
- For series compensated long transmission lines and three terminal lines (discussed in paper 202), what are the limitations in applying "standard" phasor (impedance)-based fault location techniques?
- For two-terminal transmission line applications (discussed in paper 210), what are the limitations of the "standard" phasor (impedance)-based fault location techniques and why the traveling wave-based solutions may produce better results?

Q#8: What are the implementation requirements for the existing fault location approaches?

Most of the fault location algorithms are implemented using digital relays. Some other ones are implemented using disturbance recorders or dedicated fault location hardware. The implementation requirements deserve further discussion:

- What prevents implementation of any of the known fault location algorithms on any of the mentioned IEDs? Should the fault location implementations be hardware dependent or can they be made hardware transparent?
- Most of the fault location techniques are requiring extraction of phasors prior to the algorithm computation. Is the reduced accuracy of phasor extraction in the case of high-speed (one cycle) breaker operation (causing limited length of recorded data) affecting the accuracy of "standard" phasor (impedance)-based fault location algorithms?

- The traveling wave based methods are requiring accurate reconstruction of high frequency components of the fault waveforms. Is the accuracy of this approach affected by the frequency response limitations of some of the typical instrument transformers such as the capacitor coupled voltage transformers?

Q#9: Are there any new fault location applications/implementations that still require further research?

Fault location solutions seem to be constantly improving to accommodate new applications and/or implementation approaches. The following issues may require further research:

- In many utilities digital relays and/or other suitable IEDs are not available at each transmission line terminal. What are suitable fault location techniques in the case the fault waveforms are captured only at a few substations in the transmission system?
- In many sub transmission systems, there are tapped lines and feeders with no IEDs available to perform measurements of fault waveforms. What are the most suitable fault location techniques for such applications?
- Time-domain synchronized sampling techniques for fault locations are not used in today's practice. The availability of synchronized phasor measurements is becoming more frequent. Are there any new opportunities in using time-domain or phasor-based fault location techniques utilizing synchronized sampling through GPS receivers?

4. FUTURE TRENDS

This group of questions relates to the subjects covered by eight papers, one submitted on behalf of WG B5.03 (221), and others submitted by the authors from the USA (215,216), Switzerland (203), Norway (211,co-authored by an author from Sweden), Russia (213,also co-authored by an author from Sweden), and two from Korea (208,209). The papers are exploring some new applications and/or technologies related to the fault and disturbance analysis.

Q#10:What are the new applications?

Fault and disturbance analysis may include different considerations, but it is typically centered on evaluation of the protective relay operations and the consequences. However, some other applications/considerations may also be explored:

- The paper 211 is introducing the concept of the risk-based maintenance consideration. How the data related to the fault and disturbance analysis can be utilized for maintenance optimization and scheduling purposes?
- The use of information theory and relay modeling is suggested for improvement in determination of relay settings in paper 213. What are the uses of modeling and simulation in fault and disturbance analysis?
- The power quality analysis is frequently mentioned in conjunction with relay operations and/or recording capabilities (papers 207, 209, 215, 218). What are the power quality considerations that should be a part of the fault and disturbance analysis? What are the requirements for digital relays if were to be used as power quality monitors?
- The paper 208 mentions the need for using dynamic disturbance recorders for observing stability oscillations as a part of the analysis. What are the requirements for digital relays and other IEDs if were to be used as dynamic disturbance recorders?

Q#11:What are the most promising new technologies for fault and disturbance analysis?

The paper 221, submitted on behalf of WG B5.03, makes an effort to identify future trends in utilizing advanced technologies for fault and disturbance data analysis. Another paper from the U.S.A. (216) points out the benefits of using substation automation technologies for integrating the relevant field data. Several questions may be posed along the lines of the new technology uses:

- The need to use substation automation, high-speed communications, and software integration technologies seem to be a visible trend. What is the role of the IEC 61850 interfacing, spread spectrum wireless communications, XML and other advanced technologies in improving fault and disturbance data integration and analysis?
- The Internet and web applications seem to be penetrating every day life. What are the advantages of using these standard technologies in implementing fault and disturbance analysis solutions?
- The automation needs for fault and disturbance analysis are rather obvious. What is the role of intelligent techniques such as expert systems, neural nets and fuzzy logic in implementing automated solutions for fault and disturbance analysis?

Q#12:What are the new implementation requirements?

Implementing new solutions for fault and disturbance analysis still remains a fast growing area. The papers 216 and 203, from the U.S.A. and Switzerland respectively, are exploring various requirements for the new implementations. A number of questions deserve further discussions:

- One requirement mentioned by many papers is the need to integrate data from multiple IEDs to facilitate fault and disturbance analysis. What are the appropriate standards for database design and user interfacing that should meet this requirement?
- Data formats and communication protocols are essential in performing data integration and analysis. What are the requirements that need to be explored, beyond the ones defined by today's standards (COMTRADE, IEC 6185, IEEE File Naming Convention, Common Information Model,etc), that need further standardization [1-4]?
- Using the standard networking solutions is a common approach in implementing the fault and disturbance analysis systems. Are the common client-server solutions sufficient to meet the requirements for implementation of the system-wide fault and disturbance analysis solutions or do we need to explore new software technologies such as agent-based solutions?

5. CONCLUSIONS

Based on the ideas presented in the mentioned papers and related questions, the following four major areas of interest for the discussion have been identified:

- **Existing Analysis Practices.** Many examples of how the advanced IEDs and substation automation solutions are facilitating the analysis are presented. The main question remains if the existing practices are adequate, and if not, what are the most desirable improvements.
- **Existing Equipment and System Solutions.** Variety of equipment and system solutions are used for the analysis today. What are the most desirable equipment types and what are the most useful application functions remains yet to be identified in the future.

- **Fault Location.** This important fault and disturbance analysis function been implemented in a variety of solutions over the years to fit new and difficult applications. It appears that a number of new challenges can still be identified in this area for future solutions and research.
- **Future Trends.** Overwhelming evidence is that future trends are aiming at automating the analysis and utilizing most efficient and flexible communication and software integration technologies. Selection of the most relevant existing and development of new standards seem to be still a very relevant task for the future.

6. REFERENCES

[1] IEC Std. 60255-24, "Common format for transient data exchange (COMTRADE) for power systems", First Edition 2001-05, International Electrotechnical Commission, 2001.

[2] IEC Std. 61850, "Communication Networks and Systems in Substations", work in progress, International Electrotechnical Commission, [Online]. Available: www.iec.ch

[3] "File naming Convention for Time Sequence Data", Final Report of IEEE Power System Relaying Committee Working Group H8, 2001.

[4] Common Interface Model (CIM), IEC 61970-301, International Electrotechnical Commission, 2002.