FAULT AND DISTURBANCE DATA REQUIREMENTS FOR AUTOMATED COMPUTER ANALYSIS SUMMARY PAPER

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ABSTRACT

This paper briefly describes the special publication, "Fault and Disturbance Data Requirements for Automated Computer Analysis", prepared by Working Group I11 of the Relaying Practices and Consumer Interface Protection Subcommittee of the IEEE Power System Relaying Committee. The publication describes the analysis objectives and the data necessary to facilitate automated analysis. The address for ordering a copy from the IEEE is in the reference section.

INTRODUCTION

Fault recording practices have advanced from individual substation recorders to a network of remote units which transfer fault data records to a central computer for analysis. The analysis process presently consists of examining waveforms and measuring time intervals between various events within the records. This process is labor intensive and requires considerable knowledge and skill. Manpower limitations may result in the failure to identify items needing correction before large financial losses occur.

If rigorous sets of data were acquired, the analysis process could be automated to present data in more meaningful forms and distinguish between normal and abnormal operations. Abnormal operations may require additional manual analysis but much labor would be saved by not having to examine the detail in all fault records.

The process of automating the analysis of data from digital fault recorders is presently limited. The information available is insufficient and not in a form appropriate for automated analysis. These shortcomings may be overcome by a cooperative effort between users and manufacturers whereby users adopt the practice of monitoring the more rigorous set of quantities described herein and manufacturers provide information in the forms necessary to support automated analysis.

Recording a more rigorous set of quantities requires more data channels than presently used. This will add to the cost of remote units. However, the overall cost of acquiring and analyzing data should be far less because of the analysis labor saved through automated analysis.

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Also, it may be possible to integrate most, if not all, data requirements into one type of data acquisition system.

The data required for one type of analysis may be quite different than that required for another application. Therefore, data requirements have been divided into seven different application areas in order to describe the most efficient set of parameters for each area. The application areas included in the publication are:

- Fault Clearing Analysis
- Power Swing Conditions
- Undervoltage Conditions
- Fault Location Information
- Underfrequency Conditions
- Dynamic Conditions on Generators
- Data for Relay Testing

The section on Fault Clearing Analysis is presented in this summary paper to show what the publication covers. Each application area is discussed in the publication using the same outline.

FAULT CLEARING ANALYSIS

Introduction

This section defines the operational data needed to analyze the performance of protective relay systems during faults on the electrical system. All data obtained from the digital fault recorder (DFR) system should be in a format ready to diagnose the performance of the protection and control systems.

Types of Conditions to be Captured

The DFR should be designed to capture data associated with abnormal conditions that occur on generation, transmission or distribution systems. This operational data must show the performance of:

- The protective relay system during fault conditions.
- Circuit breakers and other major substation equipment.
- Automatic reclosing systems.

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Analysis Objectives

The DFR should provide sufficient data so the following clearing information can be obtained:

- The fault duration or clearing time (all phases) and the magnitude of the fault current including the type of fault (single phase, multiphase, evolving) and the phases involved.
- Analog waveform data on all voltages and currents to display harmonics, ferroresonance conditions, transient voltages, breaker restrikes, or arcing.
- Status of breaker-position and station-tripping and blocking-scheme outputs to permit timing sequence evaluation.
- Data for analysis of other circuits under study, such as the performance of relaying communications channels, and time code channels.
- Fault location is highly desirable on long lines and cables. This subject is covered in the section on fault location.

Types of Data Required for Analysis

To provide data necessary for automated analysis, the following quantities are required:

- Bus phase voltages:
  Depending upon the station configuration, bus and/or line voltages (phase-to-ground) should be monitored. A minimum of three phases per voltage class should be provided.

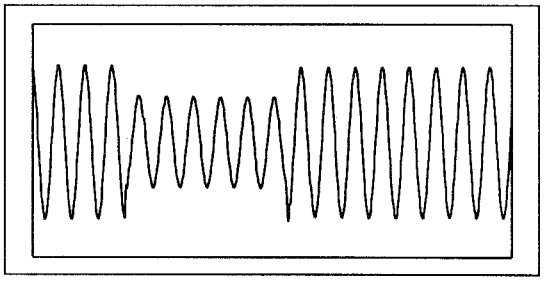

Figure 1

Figure 1 shows one phase of a typical bus voltage to be used for the fault clearing analysis. Sufficient pre-fault, fault, and post fault data must be available for computer analysis to determine all voltage conditions.

- Bus residual voltage :
  This is necessary for analysis of reclosing schemes and relay operations.

- Line phase currents:
  Currents from all three phases on each line monitored. One example of a line phase current during a fault condition is shown in Figure 2

Proper automated analysis depends upon accurate calibration, scaling, and waveform fidelity during the fault condition.

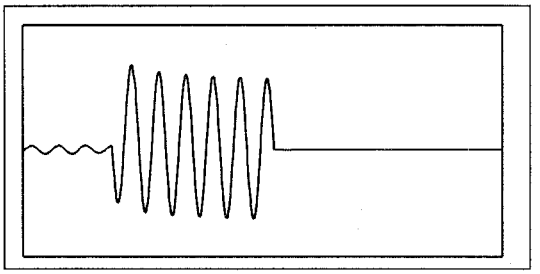

Figure 2

- Line residual current :
  This quantity is an absolute must to analyze any type of disturbance on a power system. Most faults can be analyzed by using this quantity and the three phase to ground voltages.

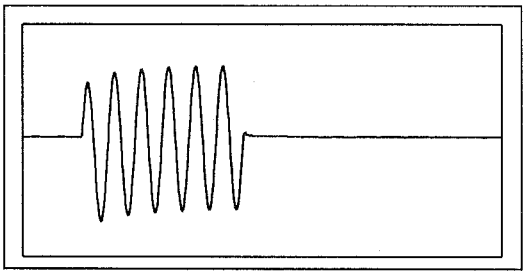

Figure 3

Figure 3 shows a typical line residual current during a fault condition that must be recorded to properly classify the fault, and automate the analysis of the fault data. Many times, the waveform is not "typical" and may include such phenomena as a breaker reignition condition after the initial fault clearing. This case is shown in Figure 4. The neutral current stops flowing as the fault is cleared, and several cycles later current starts flowing again due to the reignition condition.

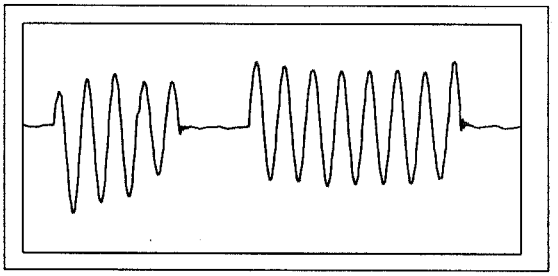

Figure 4

Waveforms such as this depict abnormal conditions, and would be part of the data available for automated analysis.

- Pilot channel data:
  The data should include both transmitter and receiver status on all power line carrier, fiber optic, audio tone, pilot wire, and microwave circuits.
- Breaker, station tripping, and blocking status data:
  Auxiliary contacts show when status points changed state.
- Control contact performance:
  Trip-close information and where and what initiated the operation is a must for analysis.
- Relay target data:
  Presently, outputs with this information are not available from all relaying systems, however, any system that is to perform automated power system analysis must include target data.
- Time code information:
  Time should be accurate to a minimum of one millisecond and it should be possible to determine the time for each data sample. This accuracy is necessary when comparing fault data from different stations. GPS clocks are being used for accurate time information.

Data Resolution

Event data channels should have response characteristics suitable for resolving information to at least the nearest millisecond.

Analog data channels should have a frequency response extending to 1500 Hz to capture all significant waveform data and the record length should be about 45 cycles of 60 Hz data to include the high speed reclose. A sampling rate of approximately 6000 Hz is required to achieve a frequency response of 1500 Hz with practical anti-aliasing filters.

An analog-to-digital converter (A/D) will resolve analog data to one part in 2^N where "N" is the bit resolution of the converter. This may be used to show that a 12-bit converter (±2048 bits) would provide a resolution of 1% at 5.0 amperes for a full scale calibration of 100 amperes.

Time Synchronization

For general comparison of data from various recorders located throughout the electrical system, the master station operator should be able to set and control all recorder clocks throughout the system to a resolution of about one second.

If data from two or more sources are to be merged for analysis purposes, the time information must have an accuracy of one millisecond or better.

If data from different sources are to be merged to make calculations such as phase angle between sources, it is necessary that time information have an accuracy of 50 microseconds (1 degree of 60 Hz) or better.

Acquisition Triggering

Data acquisition systems need to be triggered to acquire data. Recording then continues for a preset interval to capture data throughout the entire clearing operation. Various types of sensing algorithms, Boolean expressions, and external events may be employed to detect the occurrence of a fault for triggering purposes. Some examples of sensing algorithms are: overcurrent, over/undervoltage, negative sequence, phase angle shift, and rate of change of current.

Pre-Disturbance and Event Duration

It should be possible to record several cycles of pre-disturbance data. The pre-event interval is required to prevent any loss of fault waveform data and to establish pre-fault levels and relay memory quantities. The recorder should acquire pre-event data and continue to collect data throughout the clearing operation, or event duration.

Data to be Available for Transmission

All data required for analysis should be available for high speed transmission to a master station. A minimum set of data includes:

- All station bus potentials (all phases). Residuals may be derived from phase quantities.
- All three phase currents and neutral. It is best to record the neutral current and derive it from phase quantities as well. If they are different, a short exists in the neutral.
- Time information throughout the recording period.
- Critical event and contact status data.

CONCLUSIONS

The Power System Relaying Committee believes that the publication provides helpful information for use by manufacturers and users of fault and disturbance recorders.

REFERENCE

1. Fault and Disturbance Data Requirements for Automated Computer Analysis, IEEE Power System Relaying Committee Report, Special Publication No. 95TP107 (1995).

Papers may be ordered from:
IEEE Service Center
445 Hoes Lane
Piscataway, NJ 08854-4150
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