New Trends for Automated Fault and Disturbance Analysis

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This paper summarizes a TB that discusses automated fault and disturbance analysis in power systems. It is assumed that utilities have intelligent electronic devices (IEDs) installed in most of their substations and that data corresponding to the faults or disturbances is recorded when the events occur. The automated analysis is a step beyond automatic data gathering. Automated analysis includes automated extraction of data, as well as the required processing to identify properties of the events: time, type, duration, location (for faults), impact, etc. The analysis also provides the understanding of cause-effect relationships between the events and automated reaction of the equipment. As an example, the analysis points out whether the event is a fault or not, and if it is a fault, whether the corresponding relays and circuit breakers operated correctly.

Why automation?

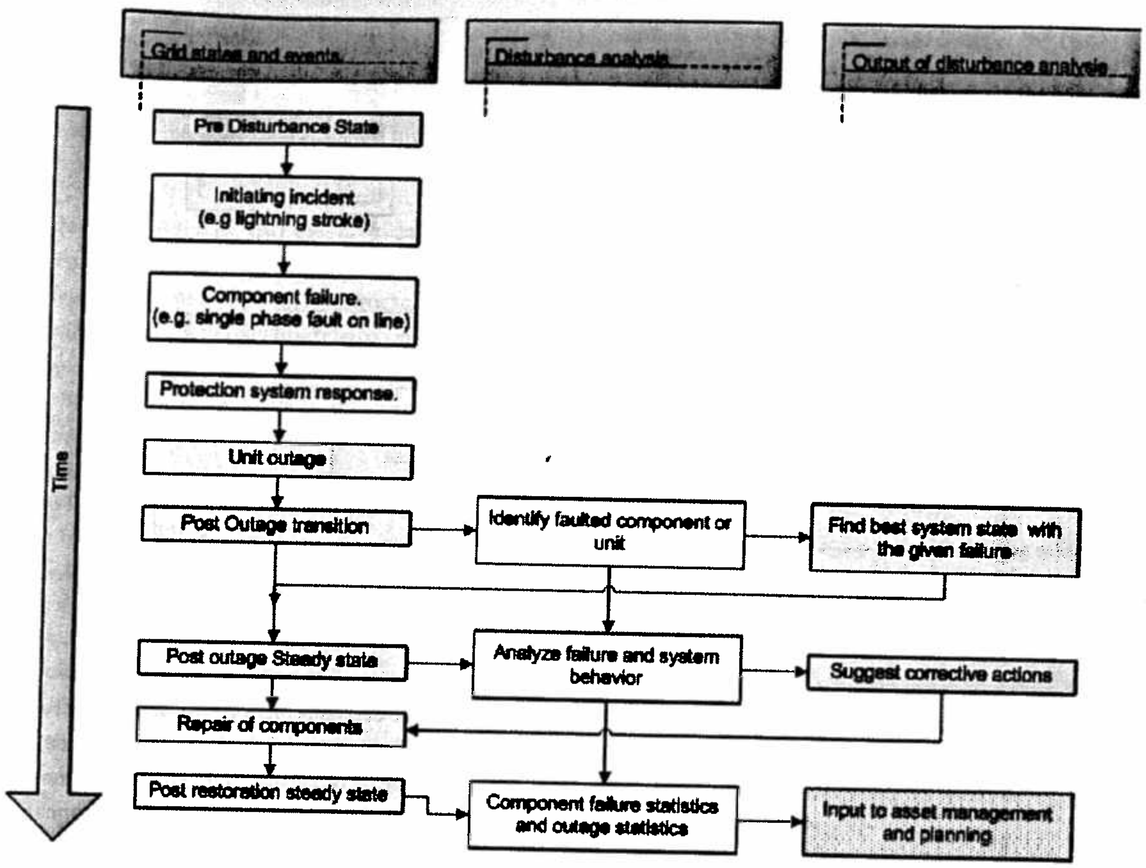
Adoption of automated fault and disturbance analysis is driven by economic and regulatory needs for the following reasons:

- It improves system reliability due to better assessment of system performance
- It enhances staff productivity though reduction of analysis time
- It enables a fast and accurate determination of the fault cause due to automated means.
- It helps more efficient handling of data through integration
- It facilitates developing a better knowledge of the system through collection of statistical data
- It meets regulatory requirements concerning capture and explanation of field-recorded data
- It increases the return on investment in recording equipment due to multiple uses of data
- It emphasizes a need for cooperation of different personnel groups for joint uses of the solution

Adoption of such systems comes with costs that must be realistically evaluated against the many benefits.

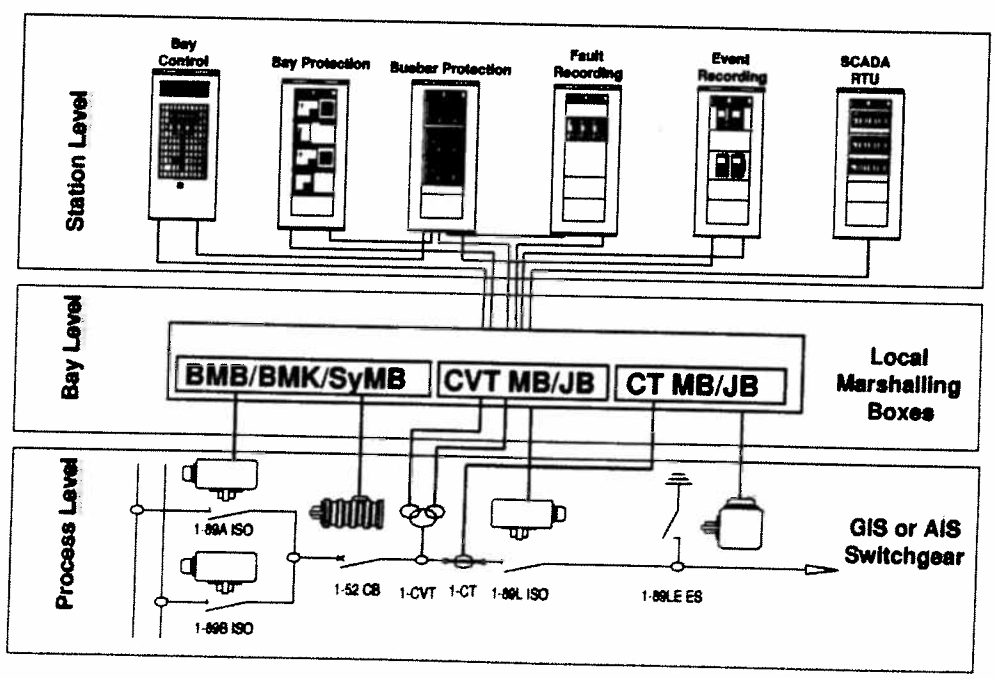
Present Status

In general, the current manual analysis process may be defined as shown in the Figure. This paper discusses the means of enhancing the analysis by performing automate cause-effect process. • • •



The Levels of Automated Analysis

Fault analysis has different levels of aggregation: From analyzing the individual component behavior to analyzing overall system performance. With the level of aggregation the focus of attention shifts. Both the "nuts and bolts" at the component level and total system response have to be analyzed before one can decide if everything was working correctly. The hierarchical nature of fault analysis is shown below using an example of solution architecture. • • •



Future Needs

The future needs for automated fault and disturbance analysis are to integrate data and have multiple uses of extracted information by different utility groups.

Protection analysis with existing data

For the protection staff, it is important to know if the protection system equipment has worked properly in correctly isolating all the fault related problems in the network. That's why the first items to be reviewed are whether or not:

- Opened bays are the minimum needed to isolate the problem
- Relays that have acted are all the ones that had to do it (neither more nor less)
- Reclosing has worked properly

In the case of a more detailed analysis, the other items to be checked are whether or not:

- The protection functions that have acted are the proper ones (no unintended operations)
- Breakers have opened when the trip was received (neither stuck nor slow breaker)
- CT and VT performance was adequate (impacts of saturation and ferroresonance)
- Communication channels worked properly (carrier transmission duration)
- Theoretical and real current and voltages match (consistency check)

With an automatic system, the analysis staff should have a quick and automated way of receiving the following protection related information without a need for human intervention:

- Identification of disturbances that have taken place in the network.
- Indication of which devices should be reviewed because of a malfunction or a questionable behavior.
- Determination of fault duration used in analyzing relay and breaker performance.
- Duration of the clearing time (all phases) used in determining breaker pole opening and fault clearing

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• Calculation of fault location or magnitude of the fault current used in determining which relays should have operated

• Classification of fault type (single phase, multi-phase, evolving) used in analyzing faults, which depends on knowing how faults evolved,

• Selection of phases involved in the fault used in locating faults and analyzing relay system performance

• Assessment of protection behavior used in analyzing duration of fault clearing, including automatic reclosing,

• Characterization of system condition prior to fault: used in analyzing fault causes

• Detection of VT and CT malfunctions, DFR malfunction, or loose contacts used to determine problems with equipment connections

Protection analysis with enhanced data

When protection data is correlated with data from other sources, it is possible to get more benefits from the protection system data:

• Control center data: It is possible to develop a system that automatically detects the disturbances in the network and captures the data from the different devices involved in the disturbance to extract useful.

• Planning data: It is possible to get an accurate fault location distance by comparing the fault impedance and the impedance of the sections of the line used to obtain it.

• Maintenance data: It could be useful for the maintenance department.

• Climate and fire data: Data about lightning, weather and ground fire can help in the analysis to clarify the causes of the disturbances, and can provide information to aid the operators' decisions.

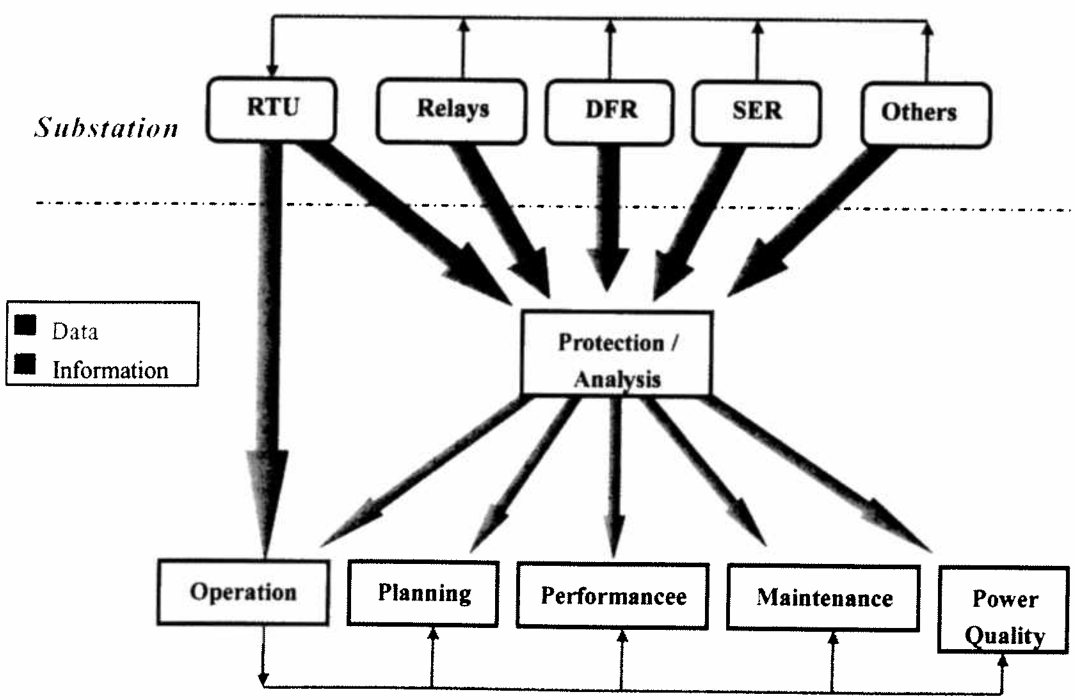
New User and Functional Requirements

The protection staff is not the only one that can benefit from the automated fault and disturbance analysis. The analysis can provide information of interest to many other utility groups as shown.

The report also gives detailed listing of the functional requirement for future solutions for automated analysis of field-recorded data coming from Intelligent Electronic Devices (IEDs) located in substations. The functional requirements are organized by the following categories: Intra-station, Inter-stations, Utility-wide and Inter-utility.

Implementation Issues

Implementation issues are important for successful development and deployment of an automated analysis system. Recognizing the criticality of some of the implementation issues, one may prevent failures or may eliminate unnecessary burdens of a deployment.



Implementation constraints

• Personnel constraints: Personnel that are performing manual analysis may not find the reason for urgency of deployment of an automated system that will eliminate their manual tasks, and may create a passive resistance to the implementation process.

• Equipment and infrastructure constraints: A typical infrastructure constraint is the availability of the communication resources and database designs to support data integration required for the automated analysis.

• Project management expectation constraints: Existing business models where each utility group develops its own infrastructure for system monitoring may not be conducive to developing data integration projects that will benefit many groups simultaneously.

Deployment strategy

• Time tagging and synchronized sampling of data: Knowing which event happened first is vital when trying to identify the cause and effect sequences. Another important, and yet not fully recognized issue, is data sampling synchronization. This does not have anything to do with time tagging but has everything to do with the way the sampled data may be aligned.

• Automatic collection of data from data sources: Collection of data from IED's can be a time consuming task. The automated data "gatherer" should also check if the IED is available at certain intervals, and give notice if equipment is out of service.

• Automation of analysis tasks: both the level of aggregation and the focus of attention shift for different parts of the analysis. To get payback on the analysis, the most time consuming parts (i.e. bay level analysis) should be automated first.

The role of standards

• Existing standards: At present, lacking of good standards for implementation of automated analysis systems is an issue that needs to be resolved before such systems become everyday practice. The following are examples of standards issues that need to be addressed in the future:

1) Three slightly different implementations of COMTRADE (1991, 1999, 2001).
2) IEC 60870-5-103.
3) IEEE C37.232.
4) Harmonization between IEC 61850 and IEC 61970.
5) Extension of Synchrophasor standard IEEEC37.118

• Internal utility conventions: The convention used to designate configuration data within a utility can simplify or complicate the work. Time tagging may be in GMT, local time with or without automatic DST changeover, so that time tags must be adjusted in order to correctly correlate events. To successfully integrate this data, the naming convention within the utility must be well defined, and chances are that every system has its own internal format. Integration of data from different utilities is also a challenging task because of the different conventions for naming the same object. ■