Automated Fault Analysis in a Smart Grid

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***Abstract*—The latest technology development makes many intelligent electronic devices (IEDs) available in substations today. This brings an opportunity for adding new functionalities that go well beyond what the traditional substation automation solutions have provided. The substation automation role in automated fault analysis may be expanding towards better serving many utility groups: operations, protection and asset management.**

***Index Terms*—substation automation, expert system, genetic algorithm, intelligent electronic device, neural network**

I. Introduction

Various types of users in the utilities may benefit from substation automation: operations, protection, asset management, market operations, etc. In order to achieve such benefits, new concepts of substation automation have to meet the following expectations:

- Local protection concept needs to be enhanced to simultaneously improve dependability and security
- Substations need to be interfaced directly and through coordinating centers for better system-wide protection
- Data from IEDs needs to be merged with data from SCADA to enhance monitoring capabilities
- Condition based data from substation IEDs needs to be utilized for failure rate assessment of assets
- Local automated analysis needs to be coordinated with centralized analysis to cope with N-m cascades
- Control actions need to be defined hierarchically from substations to control centers for best outcome
- Monitoring and reporting of disturbances needs to be automated to meet recent NERC standards

II. Substation Fault Analysis Requirements

To meet the criteria for automated fault analysis in substations, several research efforts were undertaken, many of them still on-going:

- A solution for automated merging of data captured by digital fault recorders (DFRs), digital protective relays (DPRs), and circuit breaker monitors (CBMs) is developed [1-8]
- A concept for detecting, classifying and mitigating cascading events is demonstrated based on local and system-wide monitoring data [9-12].
- An optimal fault location algorithm that uses data from substation IEDs, as well as data from SCADA PI Historian and simulation data from short circuit program is implemented [13-19]
- A risk-based asset management methodology for maintenance scheduling is being developed taking into account condition-based data captured by substation IEDs [20-23]
- An intelligent alarm processor approach is proposed to take advantage of enhanced protective relay data in explaining cause-effect relationships between alarms [24-27]
- A Neural network based protective relaying scheme that enables simultaneous enhancements in dependability and security of transmission line protection is envisioned [28-31]

III. Solution Examples

The new solutions are illustrated through the following figures.

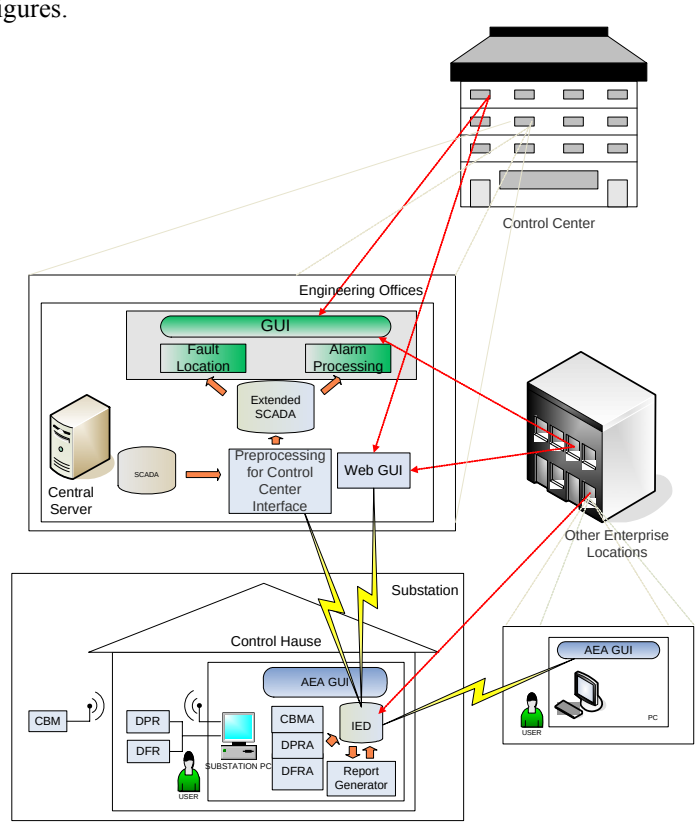

Fig. 1. Automated analysis system architecture

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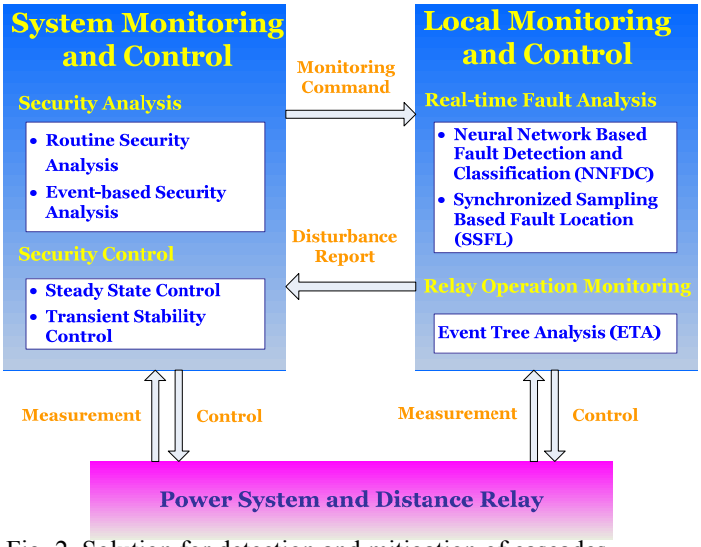

Fig. 2. Solution for detection and mitigation of cascades

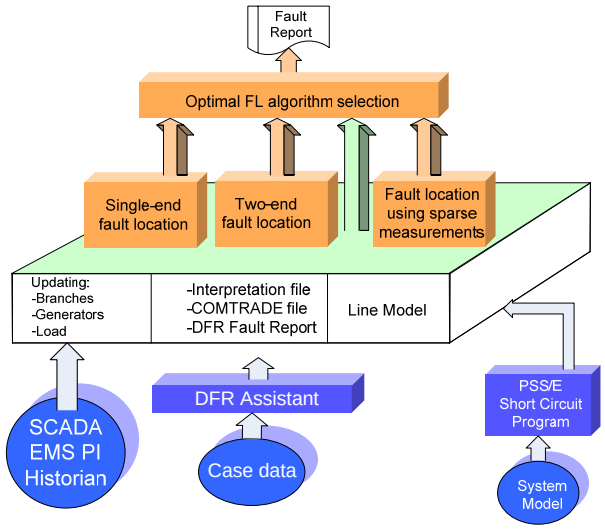

Fig. 3. Optimized fault location

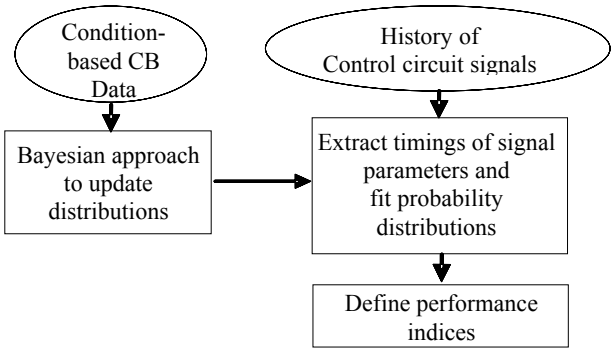

Fig.4. Risk-based circuit breaker maintenance strategy

Figure 1 shows a system for automated analysis of data from substation IEDs [4]. It is located in substations and sends both data and reports to control center, as well as protection and maintenance crews. Figure 2 depicts solution for on-line monitoring of cascading failures [9]. The solution has centralized and local parts. The local part confirms validity of relay operations. Figure 3 illustrates how optimized fault location works [16]. It selects the best algorithm for a given circumstance in the system. To achieve that, it uses direct measurements of phasors, PI historian data and short circuit model. Figure 4 demonstrates how risk-based circuit breaker analysis works [20]. It uses measurements from the control circuit and calculates failure rates. Based on that information, performance indices used in the risk based analysis are computed. Figure 5 gives an outline of an intelligent alarm processor that uses data from substation IEDs to enhance the cause-effect analysis of alarms [25]. Figure 6 gives a neural network clustering algorithm output. This technique is used to detect and classify faults [28].

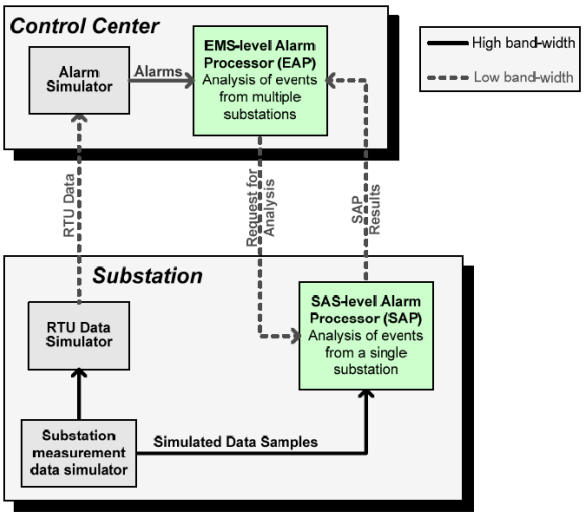

Fig. 5 Intelligent alarm processor

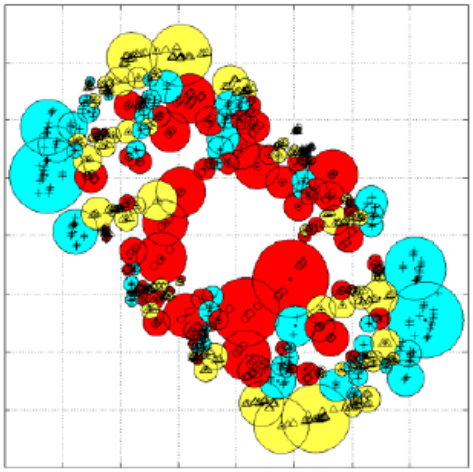

Fig. 6. Neural network based fault detection and classification

IV. Conclusions

The conducted research resulted in several potential and demonstrated requirements brought forward by advanced substation automation and fault analysis solutions:

- Operator efficiency: automated fault analysis of events, which increases speed of drawing conclusions leading to better staff decisions, reduces time of restoration

- Assessment accuracy: fault location and asset management functions will increase quality of conclusions related to maintenance and restoration
- Operator awareness: intelligent alarm processor combined with optimized fault location gives more comprehensive view of the faults and consequences
- Equipment operations: automated analysis of faults and disturbances as well as circuit breaker operation using IED data, can offer better monitoring than SCADA
- Protective relaying: new approaches based on pattern recognition and accurate fault location are more dependable and secure than distance protection
- Regulatory compliance: as NERC standards are becoming more stringent, new solutions provide more details about disturbances than ever before

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VII. Biography

Mladen Kezunovic (S'77-M'80–SM'85–F'99) received the Dipl. Ing., M.S. and Ph.D. degrees in electrical engineering in 1974, 1977 and 1980, respectively. Currently, he is the Eugene E. Webb Professor and Site Director of Power Engineering Research Center (PSerc), an NSF I/UCRC.at Texas A&M University He worked for Westinghouse Electric Corp., Pittsburgh, PA, 1979-1980 and the Energoinvest Company, in Europe 1980-1986. Dr. Kezunovic is a member of CIGRE, Registered Professional Engineer in Texas, and a Fellow of the IEEE.

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