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# A time-driven and event-driven approach for substation feeder incident analysis

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ABSTRACT

Feeder incident information is quite useful for evaluating the quality of the electricity distribution system. The improving scheme can be taken based on this information as well. In this paper, an adequate way for gathering this information was developed and the related messages from SCADA historical event log were analyzed by a novel methodology. For correctly and rapidly analyzing the collected messages purpose, this paper developed a time-driven and event-driven approach in order to express the exact feeder incident affairs. The feeder fault information can be fetched precisely and efficiently according to the result of this paper. Furthermore, the outage duration of the fault feeder, excluding the load transferring condition, was computed as well. For the sake of cyber security purpose, this paper developed a low cost and secured file transfer mechanism for transferring the event log from the SCADA system to an intranet web server. Corresponding to the web-based application software based on the result of this paper was consequently developed and installed on the sever of information management department of Taiwan Power Company (Taipower) for all SCADA control centers, and the software is running successfully.



## Introduction

Feeder incident herein is a fault of an electricity distribution system that is caused by the natural disaster, e.g. single phase grounded by hurricane. The number of feeder incident is a measurement of the power quality in electricity distribution realm. In the traditional power dispatch and control center, each incident is recorded manually in the incident report as soon as the incident occurs. However, in case of the occurrence of an incident caused by natural disaster in electrical networks, several hundreds of messages per minute may be presented to the control center operators. Thus the manual incident recording procedure difficultly keeps up with the incident occurrence when the power distribution faults occur frequently. This situation may also cause mistakes in manual incident report. Hence, an intelligent alarm processor (IAP) is required to concentrate on the alarm messages. An automatic incident analyzer is also needed to precisely record the feeder incidents and reduce large quantity of manpower. For the sake of the correctness of incident record as well as the minimum intervention from users, this paper developed a time-driven and event-driven (TDED) approach to automatically analyze the feeder incident via the historical event log. The web-based application system of verifying TDED approach was developed as well.

Several literatures have been studied to investigate the existing feeder incident analyzing approach from the alarm messages library, i.e. historical event log. The reviewing result of these literatures is that most current researches are based on IAP. Though IAP is applied in the current supervisory control and data acquisition (SCADA) system with various degrees of success [1], the substation feeder incident analysis via SCADA historical event log, however, is still underdeveloped. Additionally, analyzing the feeder incident is not easy by means of reviewing the tremendous event log. The cybernation methodology should be therefore realistic for this purpose.

The feeder incident analysis procedure described in this paper depends on the processing of the event, or alarm log. IAP is therefore the main research target for evaluating whether it is adequate for feeder incident analysis. Apparently, the existing IAP researches are mainly based on the expert system and focus on alarm messages concentration. For examples, Hasan et al. described a project on the use of an artificial intelligence system for alarm processing and fault diagnosis [2]. Dijk discussed new AI-based alarm reduction techniques in terms of set theory [3]. Haibo et al. used the approaches of case-based reasoning (CBR) and rule-based reasoning (RBR) to analyze the correlation among the equipment abnormal signals [4]. Deconinck et al. presented a more advanced

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algorithm based on the formalism of fuzzy reasoning petri nets (FRPN) [5]. Several hierarchic diagnosis levels that used heuristic rules as well as compiled qualitative models were used by Wagenbouer et al. to design the alarm processing expert system [6]. Kirschen et al. showed several examples that expert system can help control a power system during an emergency [7]. Additionally, Model-Based reasoning methods [8] and Neural Network approach [9] were applied in alarm processing to concentrate the alarm messages as well. Wei et al. used two modules (i.e., the generation of candidate hypotheses and the truth evaluation for the hypotheses) in the developed approach, and these two modules are operating in parallel on online implementation for determining the fault/disturbance cause [10]. Malheiro et al. presented an explanation mechanism, that has been designed and implemented, which is used by SPARSE, an expert system for IAP and power restoration aid which is running on-line in a transmission control center. This explanation mechanism is intended for use in the real-time expert system with minimum of disturbances [11]. A fault diagnosis expert system was described by Minakawa et al. [12]. This system uses the data from fault detection systems that locate fault points within electric stations. However, based on several independent events as well as their occurring sequence and timing, the feeder incident is exactly evaluated. Most of the above researches used expert or fuzzy system for IAP as well as concentrated on alarm filtering and suppressing are not really for the purpose of incident analysis.

Subsequently, the literatures of event-driven approach are reviewed for feeder incident analysis purpose. Laliwala et al. proposed an event-driven service oriented architecture (EDSOA) as an extension of SOA to model the event-driven process chains and to achieve event-driven automation of business process [13]. This paper similarly used an automatic event-driven process to analyze the incident information from SCADA event log. Also, Yu et al. studied the output synchronization problem of networked passive systems with event-driven communication, in which the information exchange among the coupled agents is event-based rather than pre-scheduled periodically [14]. This concept is adopted in this paper for passive event-driven system other than searching the specific messages in SCADA event log.

However, the classification of the feeder incident, e.g. temporary or sustaining, is deeply time dependent. As far as the time-driven is concerned, Agrawala described that in time-driven system, time plays the fundamental role and all actions are assigned a time when they must take place. The resources are managed by assigning the required resources to an activity for an appropriate period of time [15]. Referring to this description, the SCADA digital input (DI) scan rate, i.e. 2 s, is adopted to check the relationship between RELAY TRIP and CB OPEN messages. The logic of this checking is that CB OPEN message should appear within 2 s after REALY TRIP event occurrence if both messages are dependent. The SCADA analog input (AI) scan rate, i.e. 10 s, is used to evaluate that if AMP LOW or AMP return to normal (RTN) message is corresponded to the current feeder incident. Furthermore, 60 s time period is used to classify the incident type, i.e. temporary or sustaining. Incident duration time period less than 60 s should be classified to a temporary incident. Finally, a valuable literature is considered. Miao et al. proposed intelligent alarm analyzer (IAA) for handling transmission line, bus bar and transformer faults as well as relay malfunctions [16]. The sequence-of-events records (SER) are also needed by this method for pinpointing the fault location(s) and malfunction device(s) on line. This is an excellent approach for fault analysis in power transmission area. However, TDED approach developed by this paper concentrates on the incident analysis in power distribution realm. Hence, a completed fault analysis mechanism in whole power system can be integrated based on IAA and TDED.

Based on reviewing the above IAP related literature, it is clear that feeder incident analysis cannot be fully accomplished by an expert base IAP approach only. This paper therefore adopted TDED for this analysis as well as developed the corresponding web-based application system on confirming the analysis methodology. The feeder incident message and the significant feeder quality identifier based on outage frequency and duration have been obtained effectively by deploying this web- based application system in the electricity utility for analyzing the feeder incident.

## Time-driven and event-driven model development

Generally, an event-driven mechanism includes three major components: a set of event generators, an event queue that buffers the event in sequence, and event dispatching mechanism that removes the events one at a time from the queue and sends them to the corresponding event handlers [17]. The power system event and alarm processing subsystems in a conventional real-time SCADA system are almost completely built based on this framework. To increase the system performance, these subsystems are always designed in a proprietary and specific operation environment. However, most current SCADA systems are developed based on an open system. The event message is therefore able to be queried from a relational data base via an open query language rather than obtained from the real-time event queue. Consequently, the event generators and queue are easily arranged by querying the relational data base periodically.

One of the efficient ways for finding the incidents in a huge event log is utilizing an event-driven approach [18] to establish a state table for incident outcomes analysis. According to the research result of this paper, each record in this table contains substation name, feeder name, RELAY TRIP, CB OPEN and CLOSE events with their time tags. Additionally, voltage level of each circuit breaker (CB) and several other flags for identifying the possible states are also recorded. Once a RELAY TRIP message is read, the corresponding substation name, feeder name, and the time tag of RELAY TRIP message are recorded in the state table to denote the beginning of a new incident session. In a real incident situation, a CB OPEN message is generally read subsequently to mark the time of which the incident begins. Again, a momentary change detect (MCD) message for CB CLOSE and CB OPEN caused by re-closing relay is probably read under a temporary incident situation. This message can be used to correctly count the times of CB operation for maintenance purpose. The recorded incident is assumed to be a temporary incident [19] and the session is closed if CB state is CLOSE and no other CB OPEN message appears within one minute after incident session begins. On the other hand, a sustained incident occurs if CB state is OPEN and followed by a low current alarm message and no other CB CLOSE message appears within one minute after incident session begins. The sustained incident session will not be closed until a CB CLOSE alarm message and a return to normal (RTN) message of low current alarm message appear.

The core framework of this paper is the event dispatching mechanism. It includes a dispatching routine, an event handler, and an incident report generator. The dispatching routine recognizes numerous events during an incident session. For example, a sustained incident, i.e. the outage duration greater than 1 min, starts from a RELAY TRIP event and stops at the occurrence of AMP RTN (feeder current returns to normal) event. Every incident can be categorized into temporary or sustaining type. A temporary incident is one that the feeder circuit breaker (CB) re-closed successfully in one minute after the incident occurs while a sustained incident is one that the CB is failed to be re-closed in one minute after the incident occurs [18]. Once an incident corresponding