ENTERPRISE-WIDE USES OF DIAGNOSTICS DATA

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Abstract

The paper discusses how the data integration and information exchange concept implemented in an on-going EPRI project may be extended for the enterprise-wide uses. The on-going project has developed several applications for automated analysis of substation data recorded by Intelligent Electronic Devices (IEDs). As a result, data is converted to information and prepared in a form suitable for the uses by different utility groups.

The paper discusses the requirements and implementation approaches considered as a part of the development of user interfaces. For each utility group, an assumption about the useful information is made and specific interface requirements are outlined. Particularly, attention is paid to the tasks of fault analysis, asset management, and real-time control.

The most important feature of this development is that the non-operational diagnostics data collected in on-line mode becomes an equivalent of operational data and may be used to supplement existing SCADA data. Also, it is presented how SCADA data may help the diagnostics tasks. The proposed concept demonstrates how the new approach of data integration and information extraction may enhance many on-line and real-time, as well as off-line and postmortem analysis applications enterprise-wide.

Introduction

The term substation automation applies to the replacement of analog protection and control equipment in the substation with Intelligent Electronic Devices (IEDs) that have communication capabilities and expanded automation means. The IEDs such as digital fault recorders, protective relays and various types of monitors typically are connected to instrument transformers and/or transducers on transmission lines, breakers or transformers. In addition to providing control functionality, IEDs may feed analog measurements and event data back to a master station or SCADA [1].

Early substation automation developments were focusing primarily on providing operational data and enhancing functionality of Intelligent Electronic Devices (IEDs) when providing non-operational data. In the last decade, some advancement have been made in enhancing the communications and data collection infrastructure, but there have been no significant work on using the combined substation data, converting non operational data to useful information and delivering that intelligence to the users that can apply it [1].

While the operational data tells the operators in the control center what happened, non-operational data can explain disturbances causes and reasons why particular equipment operation happened. In the on-going EPRI project the developments deal with automating data analysis from three types of IEDs: Digital Fault Recorders (DFRs), Digital Protective Relays (DPRs) and Circuit Breaker Monitors (CBMs) [2]. For each IED type, software for automated collection of recorded data is developed either by EPRI or others [3],[4]. Once the data is collected, automated analysis software processes the files to extract relevant information. Since the automated analysis and data extraction are new applications, the options what to present to the users are quite versatile. The on-going EPRI project has focused lately on defining interfaces for different utility groups, including control center dispatchers, protection engineers, and maintenance staff. The difference is made between interfaces available for presenting the information extracted from each individual IED type versus interfaces that may be created for presenting combined information obtained by processing data from all the IEDs.

System Architecture

Figure 1 shows system architecture and how the Graphical User Interface applications are integrated. The Automated Event Analysis (AEA) Client software package is installed on the substation PC and it performs only data acquisition from all IEDs while AEA Server installed in the Control Center room does automated functions such as: converting data formats, classifying events, renaming IED data from substations, interfacing custom analysis applications, allowing immediate processing of acquired data, as well as uploading IED raw and processed data into IED database. There are three types of the automated analysis applications: Circuit Breaker Monitor Analysis (CBMA), Digital Protective Relay Analysis (DPRA) and Digital Fault Recorder Analysis (DFRA) [5].

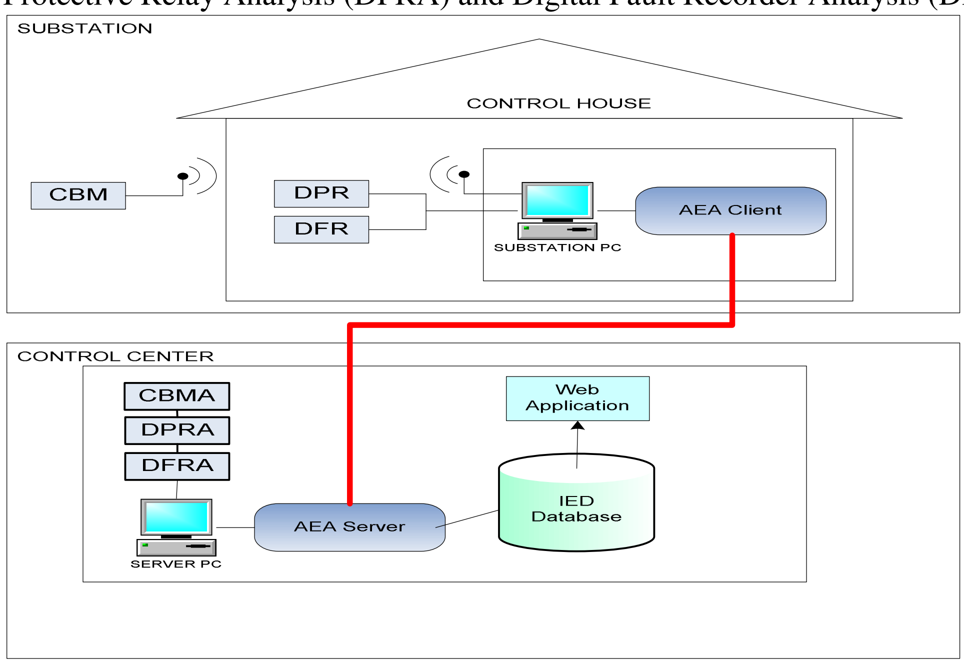

Figure1 System Architecture

The Desktop Graphical User Interface (GUI) is developed on the top of the AEA Client/Server application. AEA Client desktop GUI is capable of displaying only IED raw data, while AEA Server GUI can show both the reports generated as a result of the analysis applications and raw IED data. The Desktop GUI application provides displays for analysis reports, views of COMTRADE files generated by IEDs, as well as substation topology images, and is providing capability for changing AEA Server/Client configuration. In case of testing, adding or removing some devices in substation those devices can be easily integrated in the existing system using Desktop GUI. Figure 2 shows default view of the Desktop GUI.

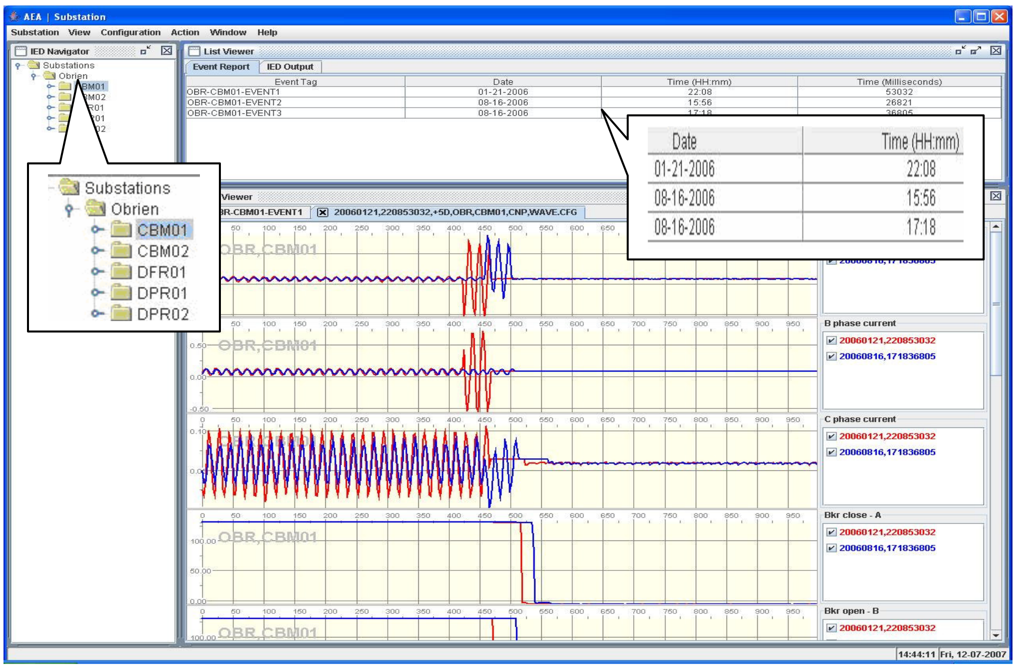

Figure 2 Desktop Graphical User Interface

On the other head, the web application only displays data organized in the list (Figure 3) without any possibility of changing it. When a user logs-in in the web application, the user can visually inspect the data assigned to user's responsibility.

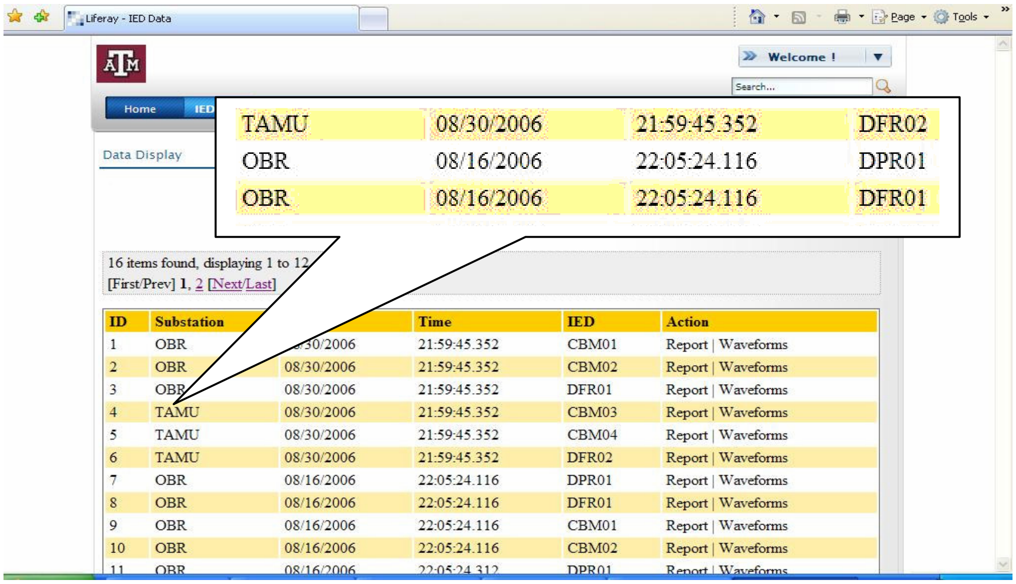

Figure 3 Web Graphical User Interface

Requirements for Data Presentation to the Users

Substation automation brings possibility to implement the fault location analysis and system restoration control in real time by applying specialized processing on the data that are coming from substation devices. The data recorded by IEDs is usually difficult to read. Because of that, automated analysis applications that generate reports for each IED are developed and implemented. The customized reports contain only information relevant to specific tasks within a utility department. Those reports are a necessity because every department in the utility looks at different aspect of system operation. Maintenance, operation, and protection personnel each view events from different perspectives, and therefore, need information tailored to their particular needs. As an example, a report generated for protection engineers is shown in Figure 4.

Before protection engineers are making final decision regarding the cause-effect analysis of faults, they usually visually check data (signal waveforms) recorded by IEDs.This process may take time because every IED records large amount of data and, usually, those data are not well organized. Specialized reports and related tools for waveform analysis and information viewing can make protection enginers work more efficiently. The inspection of signal waveforms is improved by a few additional functionalities allowing easy manipulation and viewing. The visibility of each signal can be enhanced by providing several graphical display features: selection of signals to be viewed including an option to remove some signals from the dispaly, comparison of signal waveforms by displaying them superimposed in the same view with a color code, user ability to move a displayed signal to any other view by dragging its label, and signal zooming to view further details. Some of this functionality is shown in Figure 5.

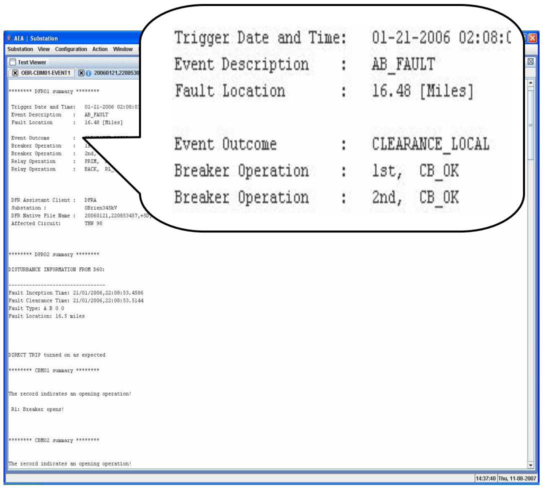

Figure 4. Report for protection engineers

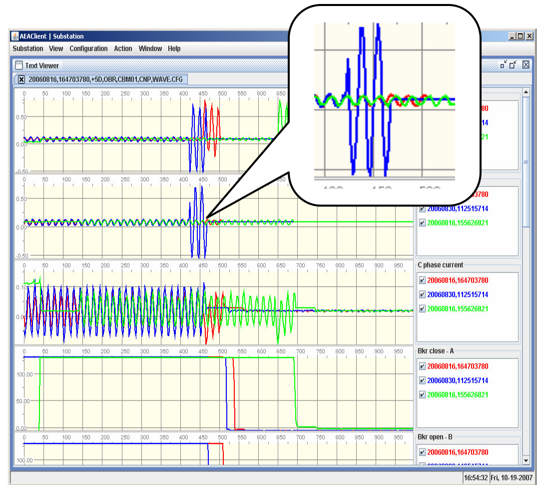

Figure 5. Signal waveforms display

On the other head, customized reports for dispatchers present where or what the problem is, did the line re-close and stay in, what is the equipment that operated, did everything work correctly, and if so can the part of the system be returned to service, if not, what has to be isolated [6].

Maintenance personnel require information concerning damage to the equipment or operating outside the designed parameters. The maintenance personnel can then be dispatched to correct any problems (i.e. downed conductors, failed lightning arrestors, stuck breakers, or stressed transformers) [6].

Data Transfer between Substations and Control Center

Data from individual substation IEDs such as Digital Protective Relays (DPRs), Digital Fault Recorders (DFRs) and Circuit Breaker Monitors (CBMs) already provide useful information associated with stand alone IED data capture. The bulk of data recorded by the devices can be combined and streamlined to provide a more relevant and versatile source of information to serve control center applications such as Fault location, Topology Processor for State Estimator and Alarm Processor. An interface to each IED makes those data accessible to the remote Control Center applications. This together with power system component models will provide a powerful tool not only for substation-level, but also for system-level disturbance monitoring and analysis. Figure 6 shows an Applications Hierarchy.

Every substation IED supplies each utility group with data of interest to that selected group. For example, the protection engineers may use dedicated fault locators (FLs), digital protective relays (DPRs), and digital fault recorders (DFRs) to capture data and extract information to analyze faults and performance of related fault-clearing equipment. The substation operation personnel uses sequence of event recorders (SERs), and lately the integrated systems (ISs), to capture operating conditions of a substation and to execute local control and monitoring functions through dedicated substation control (SC) solutions [7].

The redundancy of the data is very important in data analyzing and decision making process. Because of that, there is attempt to use non operational data as an enhancement to SCADA data. It may be recognized that the topology data and associated measurements are changing dynamically as the substation operation takes place and that IEDs record pre- post- and in time of the fault condition. To correlate those data and make it accessible to the applications located at the Control Center level, new data processing should be implemented. The new data processing should use standardized data formats.

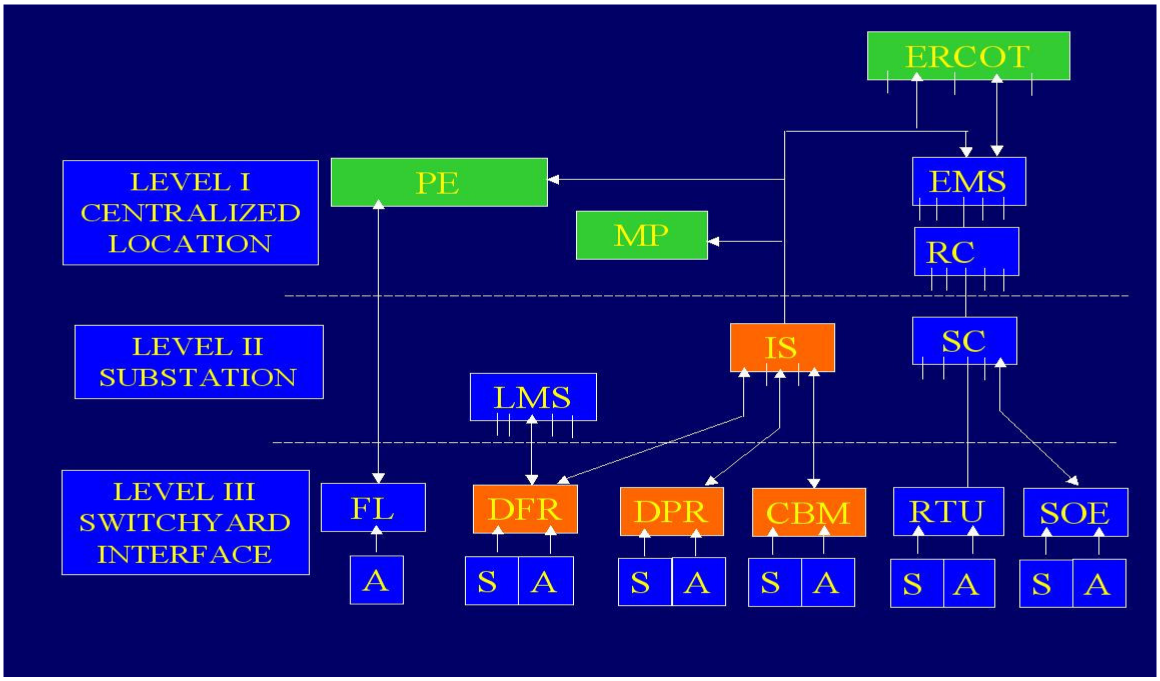

Figure 6. Applications Hierarchy

The analysis and control may be viewed in a hierarchical way (Figure 7) where some actions are initiated at a substation while some more centralized actions are initiated at a control center. There is need for interfacing data from the substation system to the control center. Having a strong processing capability in a substation will lead to different data processing and data extracting strategies: performing substation-wide applications, executing preprocessing for the centralized system functions, allocating centralized functions to substations using distributed processing. In all of these instances the substation equipment data interchange standard (for example, IEC61850) will have to be harmonized with EMS database interface standards (for example, IEC 61970)[8].

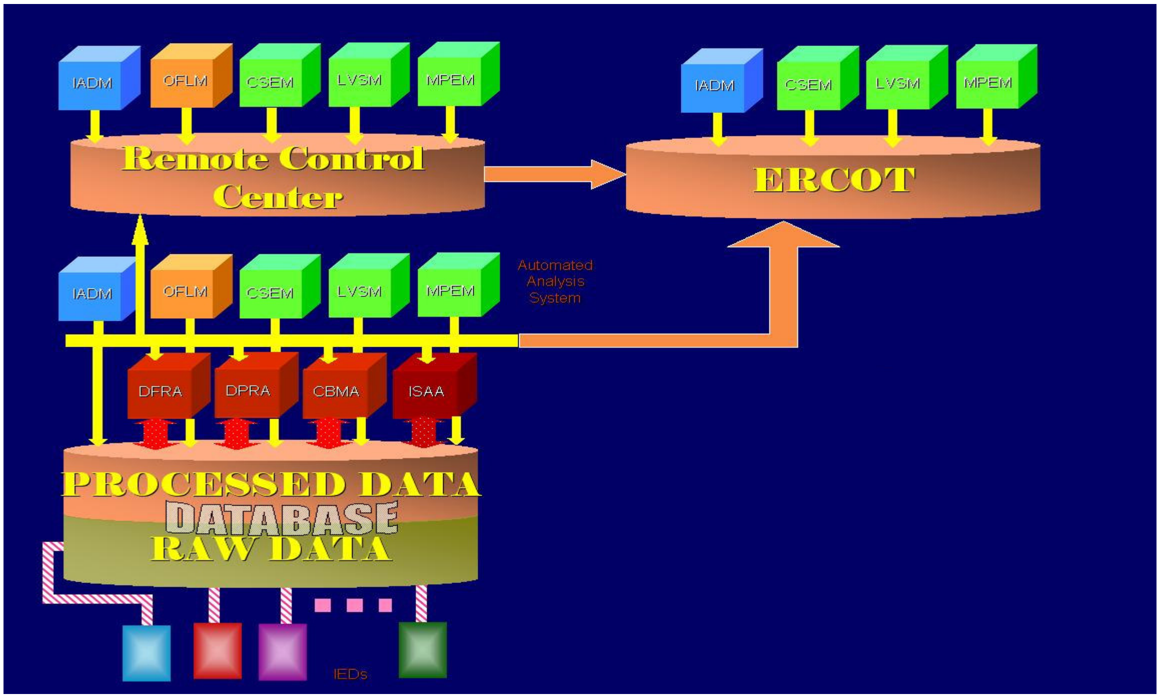

Figure 7. An example of proposed data transfer hierarchy for ERCOT

The Control Center Adapter module shown in Figure 8 preprocesses IED data. It is assumed that CIM IED model is integrated in the existing CIM standard that describes overall power system model [9]. This module matches triggered data from IEDs with scanned data from SCADA by providing correlation regarding the time and topology.

The following two scenarios may be developed:

- The Extended SCADA Database can be automatically populated every time there is new data in the IED database
- The Control Center Adapter can continuously check the SCADA database for updates. If the matching events are found in the IED database, then the Adapter will automatically process the data and upload it to the Extended SCADA database.

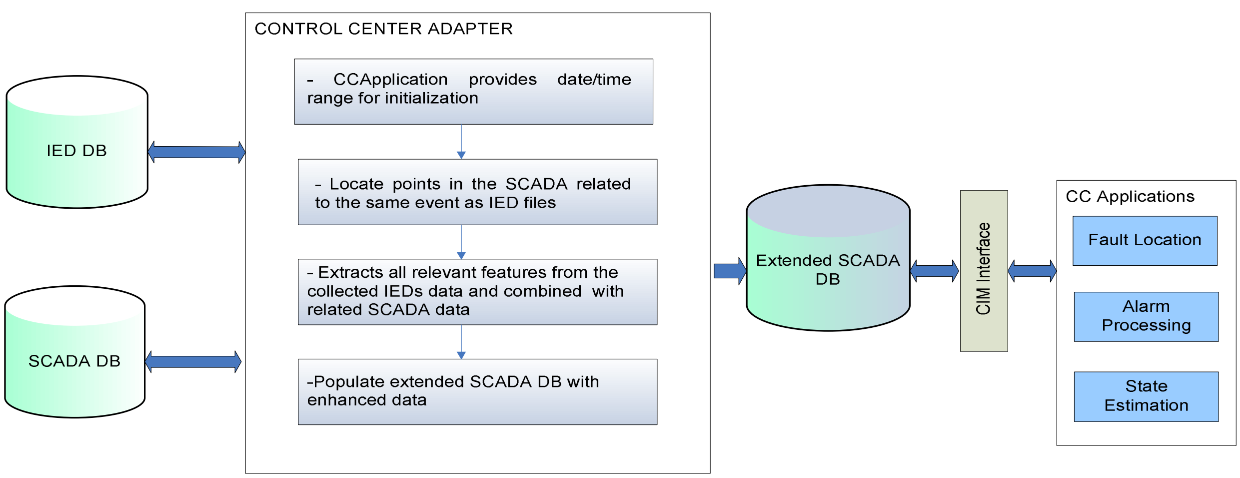

Table 8 Control Centre Adapter

As soon as an event occurs the IED devices record signals including the pre- and post-fault values of the samples. The signals are processed by the analysis applications and reports are generated. The files with raw IED data and generated reports are than uploaded to the IED database. This will automatically initialize the Control Center Adapter to start scanning the SCADA database according to the time and area of the disturbance. After locating all the necessary data, the files will be processed and relevant information will be extracted. This extracted information will be uploaded to the Extended SCADA Database. The output of this process will be stored in the extended SCADA database and can then be directly accessed by the control center analysis applications.

Use of Common Information Model for representing Intelligent Electronic Devices

CIM data model is an approach to the management of the system model. It utilizes the basic structuring and conceptualization techniques of the object-oriented programming. The approach uses the uniform modeling to supports the development of an object-oriented scheme across utility organization [10].

Figure 9 shows the IED classes for DFR, DPR and CBM that can be included in the existing Power System CIM standard model.

The IEDs are all subclasses of Intelligent Electronic Device, which is a subclass of Protection Equipment, class that already exists in the CIM Power System Model. The CBM class does, however, have relationship with Circuit Breaker class. The relation is called association. The circuit breaker may be connected to one or none Circuit Breaker Monitors and every Circuit Breaker Monitor may be related to only one Circuit Breaker. The class Intelligent Electronic Device has following attributes:

- Name (internal name for device- CBM1, DFR2...)
- Status (on /off)
- Activation start time (time and date when device is integrated in the system)

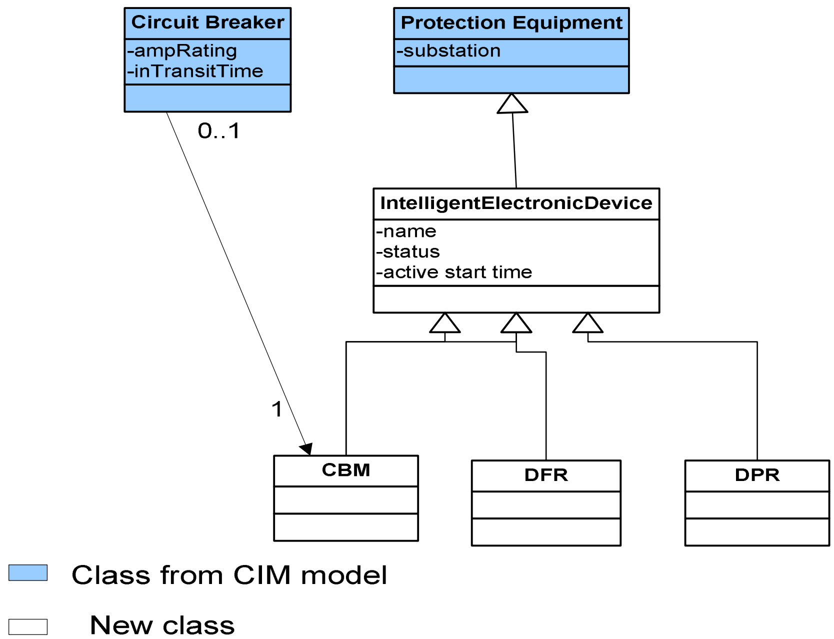

Figure 9 CIM IED model

Features extracted from the data collected by IEDs will be defined as attributes in the CBM, DFR and DPR.

Conclusion

The paper makes several points about importance of customized reports tailored to the needs of different utility groups and good data/information presentation. The utilization of combined SCADA and non-operational IED data, and their integration to make data and information accessible for enterprise wide uses is also outlined.

The major benefits of the applications are:

- Data that is recorded by IEDs is converted to information automatically and can be used by different groups at the enterprise level

- Customized data displays for each utility group minimize the time needed for extracting vital information relevant to their work from IED data and improve the tasks of fault analysis and real time control

- Preprocessed non operational IED data may be an enhancement to SCADA data by providing a more relevant and versatile source of information when serving control center applications such as Fault location, State Estimation and Alarm Processor

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