IMPLEMENTING RESEARCH FOR IEC 61850-BASED FAULT ANALYSIS SYSTEM

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With the maturing of the IEC 61850, utilities are beginning to implement substation automation systems (SAS) that are based on this new international standard. This paper describes such an implementing research for Power Fault Analysis System on East China Electric Power Group in China. In particular, it presents the idea of applying object-oriented methodology to architecture design and providing an open interface of IEC 61850 in the substation layer. Based on the idea and technique, some benefits are brought.

INTRODUCTION

It is not sufficient to develop distributed generation systems that only produce electric power. The automated fault information processing is of interest to the electric power utilities for several reasons. The most compelling one is the need to restore the system as soon as possible after the occurrence of a fault. Automated and integrated fault diagnosis facilitates quick assessment of the fault clearing and location, thereby enabling more timely and correct restorative action.

Power Fault Analysis (PoFA) systems, therefore, should provide not only functionality such as status monitoring and event handling, but also advanced functions like intelligent fault analysis. Actually Intelligent Electronic Devices (IEDs) including Digital Fault Recorders (DFRs) and Digital Relays (DRs) have provided us with the detailed information about transient waveforms and contact changes. Using equipment technology, high-speed data communication infrastructure and advanced software techniques, the Power Fault Analysis (PoFA) system can be built.

In this paper, the application of the object-oriented methodology UML (Unified Modeling Language), as well as IEC 61850, the future international standard for communication networks and systems in substations, to the PoFA architecture design is presented.

Software reuse is a key issue to improve performance in software design and development. It can be summarized as the ability to reuse parts of software (components) in different applications without source-code modification. COM component technologies are becoming popular and they provide the infrastructure to wire up software components. They allow software written in different programming languages to work together, and partially solve the versioning problem.

However this does not completely solve the interface problem. It is necessary to define the semantics of the interface before it becomes practical to use. Therefore this paper also explores which kinds of data are necessary to be acquired and suggests standardized interface technologies for these kinds of data based on COM/DCOM. A future step should be the standardization of meaning like it is done in the coming IEC 61850 standard for seamless communication within substations and control center [1-3]. Standard IEC 61850, combined with the technologies of the Internet and Object-oriented domains will usher in a new era of substation automation. It develops a universal platform that will allow a "plug-and-play" technology to replace today's proprietary devices by providing an integrated, open-system protocol for real-time information exchange seamlessly and transparently.

This project is cooperated with East China Electrical Power Dispatching Center. Primary results are achieved and satisfied.

POWER FAULT ANALYSIS (PoFA) SYSTEM

For the purposes that when the power system fault occurs the present power system situation and the action of protective relays can be quickly mastered by the dispatchers and the reliable basis can be offered to the dispatching department in time to analyze and treat the fault and to ensure the security of power system, it is necessary to establish a Power Fault Analysis (PoFA) System.

Functions of PoFA system

In general, the PoFA System integrates the following functions:
Navigation: Graphic user interface for navigation in the power network structure.
Parameter Setting: Parameters related to protection and protection and control functions provided by substation IEDs are read, modified and updated in the unit. System wide parameter sets should be administrated and archived.
Devices Monitoring: Operation status of all IEDs is

supervised, including the PoFA computer and the communication links.
Event Handling: Time stamped events generated by substation units are transferred for being displayed, evaluated and archived.
Fault Analysis: COMTRADE files uploaded from substation are analyzed, on the basis of which fault location and fault diagnosis can be done.

Problems in existing PoFA system

A PoFA System is generally composed of the following units: fault information acquisition, transmission and processing. It is necessary for fault information acquisition unit to process the information from different manufacturers and equipped with different communication protocols. In fact absence of a unified standard in the field of substation networks, for which a huge amount of conversion work must be done, became the bottleneck restricting the development of PoFA System.

Moving toward IEC 61850 solution

IEC 61850 is an upcoming standard for communication systems and networks in substation, on the basis of which the seamless connection among the devices produced by different manufacturers can be implemented.

IEC 61850 STANDARD

The new standard IEC 61850 - Communication networks and systems in substations - developed by Working Groups 10, 11 and 12 of IEC Technical Committee 57 (Power system control and associated communications) provides a seamless communication solution for intelligent devices comprising the following applications: protection and control; standardized models like circuit-breaker, transformer, and so forth; integration of innovative sensor and actuator technology; metering; supervisory control and data acquisition (SCADA); unified system configuration and device online self-description; remote monitoring and fault diagnosis; automated dispatch and control; asset management; condition monitoring and diagnosis.

Users and vendors benefit from the standard in a similar manner because IEC 61850: 1) is a global standard; 2) uses mainstream technologies like Ethernet, TCP/IP, Object modeling, and XML; 3) is highly flexible; 4) reduces engineering and maintenance costs; 5) is a seamless solution for cross-application requirements; 6) reduces the diversity of solutions to be supported.

According to the report of IEC TC 57 SPAG [2], IEC 61850 has been chosen to be foundation of the future seamless telecontrol communication architecture and be applied for modeling control center view of substation and for communication between substations and control centers.

The core of IEC 61850 can be concluded to be three layers:

Information Models:
Logical Node (LN) / Data concept;
Definition of Common Data Classes (CDC), Compatible Logical Nodes and Data Classes (CPLN, CPDC)

Abstract Communication Service Interface:
Use of ACSI as an abstract interface between application and communication

Mapping to real Communication Networks:
Specific communication service mapping (SCSM)-mapping to MMS, TCP/IP, or other protocols

SYSTEM ARCHITECTURE

The overview of the system architecture is shown in Fig.1. As can be seen in the figure, PoFA is a distributed system, i.e. it consists of a number of subsystems and components which contain the functionality specified above; some components are running on the Substation Level, some on the Control Centre Level and others on Network Level. PoFA Substation subsystem is a part system for tasks in one substation: data acquisition, data storage, data filter; PoFA Control Center subsystem is a part system for tasks: fault diagnosis, data visualization and data dissemination; Network subsystem is responsible for data transmission.

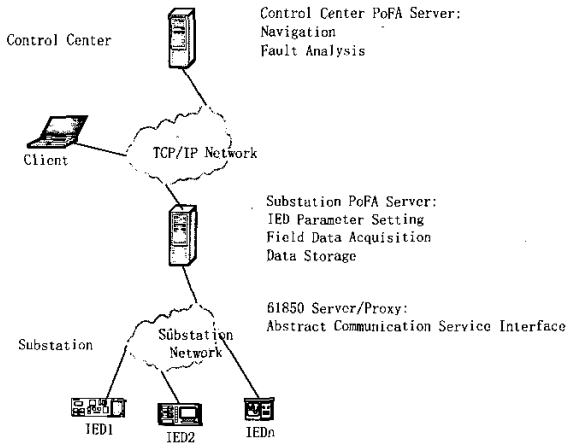

Fig.1. PoFA System Architecture

It is obvious that for each purpose a PoFA system gathers, archives and evaluates data according to the wanted purpose. The base of all this is data acquired from the bay layer and process layer in substation, for which already a lot of sources exist: IEDs like DFRs, DRs, etc. To be able to efficiently gather data with a minimum of engineering, standardized interfaces (IEC 61850 ACSI) should be used, which are discussed below.

IMPLEMENTATION CHARACTERISTICS

COM-based application

To test IEC 61850 solution to PoFA System, we have implemented a prototype, which has basic functions like monitoring and control of IEDs.

Since PoFA System requires building a distributed computer application, the following schemes can be chosen for us: Microsoft's COM/DCOM[1], OMG's CORBA[2], Java RMI[3]. These technologies all can provide architecture and infrastructure for distributed applications. We chose DCOM because component architecture is preferred in this application.

The Microsoft COM is a specification for component interface definition, which is independent from programming languages, such as C, C++, Java, VB. The COM specification describes the interface (binary) syntax standards that should be followed in order to create interoperable COM components. The extension DCOM allows to distribute COM based components within a computer network without additional programming effort.

61850 gateway/proxy

One important issue we have to consider is how to deal with the huge number of legacy IEDs that are currently in-service in today's substations as well as new devices that do not support IEC 61850. In order to integrate these existing IEDs into future IEC 61850 networks, some type of gateway or proxy device is required. In the prototype, we implemented a software proxy that resides in the substation layer and provide IEC 61850 ASCI to out client like PoFA Substation Subsystem.

Subsystem architecture

We have chosen the UML (Unified Modeling Language) as the model representation language, since it has become a de facto modeling standard in software engineering [4]. For our purpose we have only made use of UML's static structure diagram, component diagram etc.

The component diagram for substation subsystem is shown in Fig.2 and for control center subsystem in Fig.3.

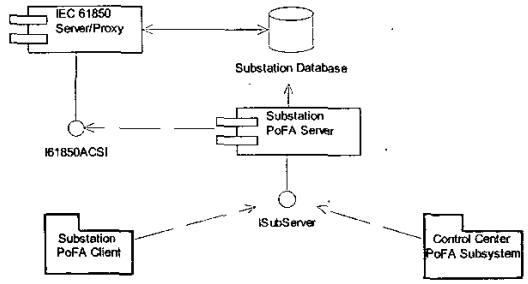

Fig.2. Component diagram for Substation PoFA Subsystem

In Fig.2, Substation PoFA consists of the components implementing the core system functionality. The following functional components can be distinguished in this subsystem: 61850 Server/Proxy, PoFA Server and Database. The exterior system includes Substation PoFA Client and Control Center PoFA Subsystem.

The following typical scenario describes the functions of individual components:

·61850 Server/Proxy constantly provides services according to IEC 61850 for PoFA Server.

·PoFA Server constantly provides services for PoFA Clients and Control Center Subsystem.

·Substation Database is historical data storage.

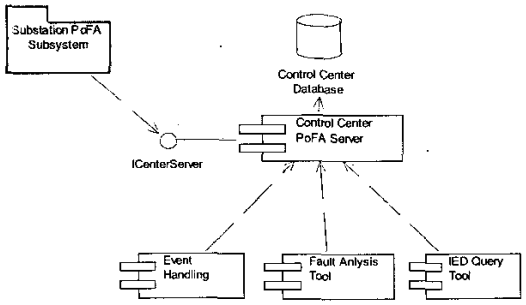

Fig.3. Component diagram for Control Center PoFA Subsystem

In Fig.3, the control center subsystem is similar to substation subsystem. The COM-based component is PoFA Server. The functional tools consist of the following modules: Event handling, Fault Analysis and IED Query,

[1] COM Component Object Model
DCOM Distributed COM
[2] CORBA Common Object Request Broker Architecture
[3] Java RMI Java Remote Method Invocation

etc.

Through the use of technologies above, the PoFA system will be more scalable, extendable, upgradeable, flexible, maintainable and reliable. Project specific adaptation can be performed partly automatically. Furthermore, both local and remote monitoring should be possible.

Interface implementations

The COM component called IEC 61850 Server/Proxy implements the interface I61850ACSI. I61850ACSI provides almost all kinds of services defined in IEC 61850 standard.

The interface definition of I61850ACSI is extracted from the IDL[4] file and only an example of Dataset that is a class model defined in IEC 61850 is given:

```
[   object,
    uuid(88B4D02C-C0C9-4FD4-BD68-3F4279889071),
    helpstring("I61850ASCI Interface"),
    pointer_default(unique)
]
interface I61850ASCI : IUnknown
{
...
// Sample of DataSet Serveice
[helpstring("method CreatDataSet")] HRESULT
CreatDataSet([in, string]wchar_t* pwszDataSetRef, [in,
string] wchar_t *pwszDAVlaue);
[helpstring("method GetDataSetValues")] HRESULT
GetDataSetValues([in,string]wchar_t
*pwszDataSetRef,[out, string]wchar_t **ppwszDAValue);
[helpstring("method SetDataSetValues")] HRESULT
SetDataSetValues([in,string]wchar_t *pwszDataSetRef,[in,
string]wchar_t *pwszDAValue);
...
}
```

The IEC 61850 Server/Proxy has been implemented with C++. It realized the I61850ACSI interface to allow transparent access real-time information from field devices.

This interface can be used locally or remotely via DCOM from another COM component called PoFA Server, which implements PoFA core functionality. PoFA Server realizes the interface of ISubServer (in substation) or ICenterServer (in control center).

CONCLUSION

Power Fault Analysis (PoFA) system should be an open distributed application, i.e. different data sources, devices and software components should be easily integrated into the system; legacy systems can be replaced by new components without much effort.

This paper illustrates that the application of object-oriented methodology UML (Unified Modeling Language), IEC 61850 Standard (communication systems and networks in substation), as well as the Microsoft COM (Component Object Model) technology are feasible to reach the goals.

From the PoFA functionality presented in this paper, which is based on the IED's data integration, the benefits of using PoFA can be summarized as follows:

(1) Fast and accurate fault diagnosis ensures the security of power grid.

(2) Component design gives high re-usability and sets the stage for future expansion and upgrades.

(3) Lower cost of data integration is achieved by using IEC 61850.

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[4] IDL Interface Definition Language