Integrating Information Systems In Electric Utilities

Michael S. Moore, Ph.D., Saeed Monemi, Ph.D., and Jianfeng Wang
Vanderbilt Institute for Software Integrated Systems (ISIS)
PO Box 1829, Station B, Nashville, TN 37235

ABSTRACT

This paper presents an integration system ISIS has developed for electric utilities, on top of which decision support tools can be cost-effectively developed and integrated with the other information system commonly present in electric utilities. The system, called the Integrated Distribution Management System (IDMS), provides an easily configurable integration framework, and currently includes one decision support tool, a diagnostics component. The diagnostics component, called the Outage Restoration Management Server (ORMS) is integrated with the various other information systems common in utilities via a flexible, extensible Integration Framework (IF), based on Model Integrated Computing (MIC) technology developed at the Institute for Software Integrated Systems (ISIS). The IF was designed such that 1) the integration between the decision support tools and the utility information system can be easily maintained, and 2) additional decision support tools can be created and integrated into the IDMS quickly and inexpensively. The MIC based IF provides a flexible and extensible integration platform on which can be built a suite of decision support tools that will help utilities run their businesses more effectively and efficiently.

1. INTRODUCTION

Electric utilities are rich in computer based information systems, which are used in operating and marinating the facilities, providing customer support, controlling the substations, and monitoring the health of the electric distribution network. Tasks such as diagnosing faults in the network and planning repairs (outage management), involve the synthesis of information from data collected from these systems. Supporting these tasks with computer based tools requires these information systems to be automatically integrated, meaning that data from the various systems must be accessed and interrelated, then semantically transformed into the information required in the context of the decision support system.

In a project with Joe Wheeler Electric Membership Corporation (JWEMC), a rural electric utility in Alabama, we endeavored to devise a method of cost-effectively integrating their information system, and to develop a framework within which the integration between these information systems could be maintained and evolved by the end users (non-software engineers employed by JWEMC). This integration framework would open the door for the development of a suite of decision support tools that take full advantage of the large amount of data that is available in electric utilities, but currently is not being completely utilized in business activities such as fault diagnosis and repair planning.

The result of that project was a system that addresses the data system integration concerns for electrical utilities, called the Integrated Distribution Management System (IDMS). The IDMS integrates several information systems with a diagnostics component called the Outage Restoration Management Server (ORMS). The ORMS is a diagnostics application that employs an advanced diagnostics reasoning algorithm designed specifically for electrical distribution networks to determine the location of faulty components during electrical outages, and presents the diagnostics results to the user in graphical form to aid in planning repair actions.

The IDMS includes a flexible integration framework, based on Model Integrated Computing (MIC) technology that provides the integration between the ORMS and several standard Commercial Off The Shelf (COTS) systems commonly used in electrical utilities. These components include an ESRI GIS system, a Lucent Technologies Interactive Voice Response system (IVR / trouble call system), a QEI Supervisory Control And Data Acquisition system (SCADA), and a CSA Customer Information System (CIS) database. We will show that 1) the ORMS provides accurate, relevant, and timely diagnostics results and 2) because of the use of MIC technology, the IDMS can be easily adapted to integrate other information system components used in utilities.

2. THE SMALL UTILITY ENVIRONMENT

Small to medium sized utilities tend to have similar concerns with respect to information technology. Most utilities depend upon computer systems for managing their maps (GIS or CAD). Many have SCADA systems for remotely managing sub-stations and main switches. Most have Interactive Voice Recognitions systems (IVR), which automatically log the calls of customers reporting outages. The difficulties come when these systems have to work together, for example in the control room during an outage. A dispatcher watches the trouble call and SCADA systems, addresses trouble calls, and coordinates the repair actions of linemen. The dispatcher is actually performing much of the work of integrating and fusing information together, and manually synthesizing the solutions. It is possible to support these tasks with appropriate decision support tools that perform the integration and fusion automatically. However, small utilities do not have the resources available to develop such systems internally. Hiring companies to develop custom solutions to solve these problems is extremely expensive. Not only is the initial cost high, but also the cost of maintaining, upgrading, and evolving custom software is out of the reach of many small utilities. The result is that many of the processes, such as fault diagnosis, repair coordination, and resource allocation are done manually by experienced staff.

The problems of improving the fault diagnosis capabilities, and in general integrating the available data systems together in support of important decision making processes need to be solved in a cost-effective and general way. Utilities need be able use and maintain these systems more independently and inexpensively, especially in light of the current more competitive environment.

We have developed a system called the Integrated Distribution Management System that is designed to provide diagnostics support, and eventually other decision support tools, to small to medium sized utilities. This system addresses two of the major concerns being faced by these utilities, effective diagnostics, and maintainable and evolvable integration.

3. INTEGRATED DISTRIBUTION MANAGEMENT SYSTEM (IDMS)

The goal of the IDMS is to provide both decision support tools and the integration required to make them work in small to medium sized utilities. One underlying requirement for the design was that the components and the integration code itself should be developed with standard, published interfaces. This approach should produce so-called *open systems*, which are much less expensive to integrate, maintain, and evolve. Toward this goal, and to avoid re-inventing the wheel, we were obliged to use as many Commercial Off the Shelf (COTS) components as possible, and concentrate on making the integration code independent of which components were chosen, so that a utility would not become locked into using a particular vendor's solutions. The first type of decision support tool we found to be most needed and relevant was a diagnostic system that would provide queues to the operators about where the faulted components are in the electrical network during outages.

The requirements of a diagnostics algorithm to be used for utilities are: 1) It must function well using reasonable resources (a standard PC or workstation). 2) It should have the ability to detect multiple non-interacting faults within a sub-station circuit within reasonable response time (10s of seconds). 3) It should be able to take advantage of any instrumentation available (SCADA, trouble calls, etc). 4) It should provide accurate results (few false alarms). 5) It

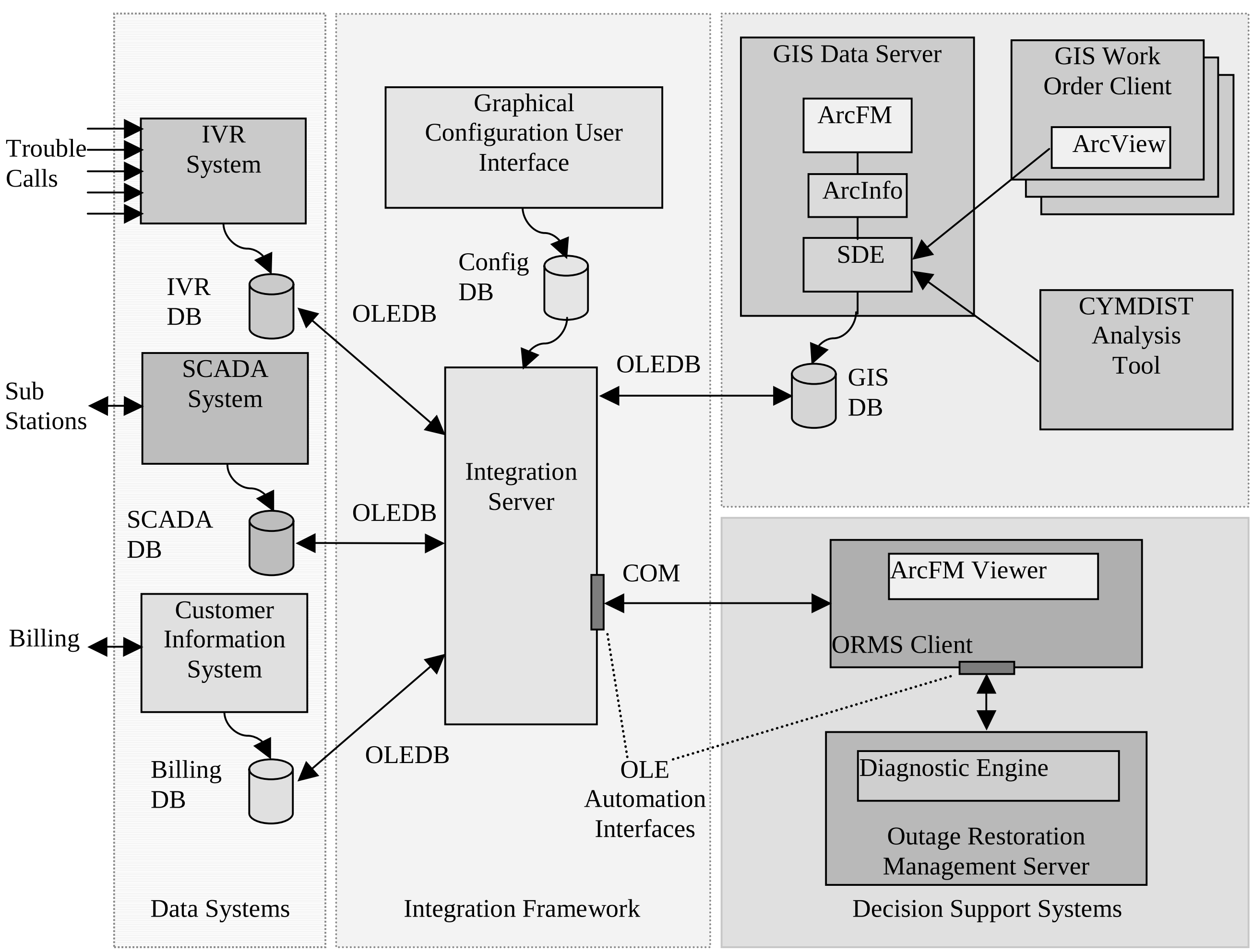

Fig. 1. The Integrated Distribution Management System Architecture

should be able to pinpoint faults at any level in the network (sub-station, feeder, section, lateral, or tap) in any type of component (switch, line, transformer, or fuse).

We found that the algorithms currently in use were lacking in the ability to provide accurate and relevant results. One algorithm we evaluated that was in use in a small utility was a tracing algorithm designed to identify a single fault per sub-station circuit, and was not able to take advantage of SCADA measurements, which can prove extremely useful in utility network diagnosis, as will be shown. No diagnostic systems we found would perform the functionality required with the resources available.

The IDMS was designed around the need for improved diagnostics capabilities, and the flexible, extensible integration to support it.

Overall System Architecture

The IDMS is made up of four major sub-systems, GIS & FM Systems, Data Systems, Decision Support Systems, and the Integration Framework (IF). Refer to Fig. 1.

GIS & FM and Data Systems

These systems are usually present in utilities, in varying forms. A GIS system contains a model of the circuit topology (where components are, how they are inter-connected, and some service, or customer information). Since a major goal was to promote open systems concepts, the IDMS integration framework was designed to work with GIS systems which store the circuit topology information in a standard format, such as a commercially available database (SQL Server, Oracle, Sybase, etc), or in files with either a published format or with standard access drivers available (OLEDB, ODBC, etc). Facility Management (FM) systems are used to design, maintain, control, and generally manage the network. Examples of these are work order management / staking systems, which are used to update the GIS model as the circuit is extended and maintained, and load analysis packages such as CYMDIST.

The Data Systems provide additional information about the network configuration, the customers, and the health and fault status of the circuit. The status information can be thought of as instrumentation of the circuit. For example, a SCADA system will provide remote monitoring of currents, voltages, and switch positions of various remote circuit components (direct measurements). An IVR (trouble call) system will field customer phone calls and log service outages (observations of customers). A customer information database contains address and contact information of customers, service location, and billing information (additional information about the network and customers) that can be used in matching phone numbers of trouble calls to locations in the electrical network.

4. THE OUTAGE RESTORATION MANAGEMENT SERVER (ORMS)

Although the diagnostics system is of significant interest, in this paper we will concentrate on the data integration aspects of the system. It suffices to say here that we developed a diagnostics algorithm that could take advantage of all available data, GIS, IVR, SCADA, and customer information, in determining where the faulty circuit components are located. The algorithm is implemented by the ORMS, and interacts with the various

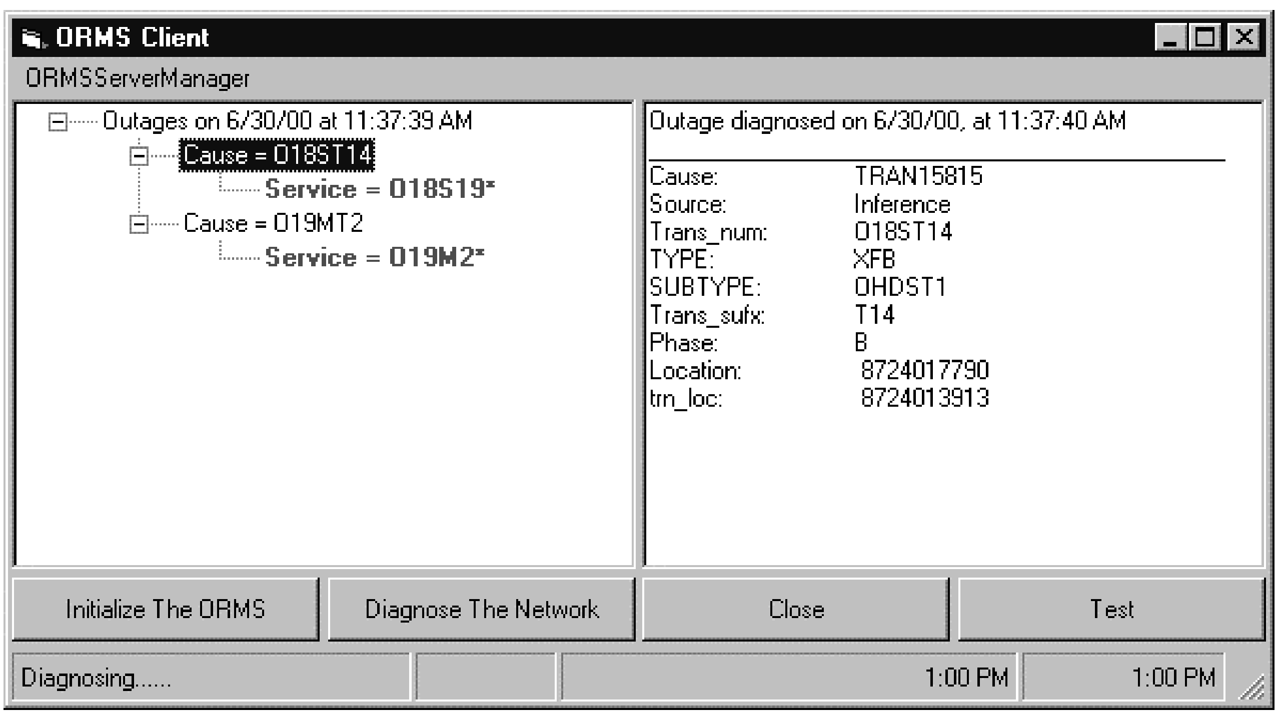

Fig. 2. The ORMS Client

data system via a reconfigurable integration environment. For more information about the ORMS diagnostics algorithm, see [1].

The ORMS Client

The ORMS diagnostics algorithm is implemented by as a Microsoft OLE/DCOM component, and is controlled via a simple graphical user interface called the ORMS Client. The ORMC Client allows the user to initialize and update the ORMS, run the diagnosis algorithm, and view the outages that have been diagnosed. See Fig. 2. In the left pane is a list of outages that have been diagnosed. Each outage is labeled with the Tag of the component that is at fault. Components with a "*" to their right are known to be faulted due to either SCADA measurements or trouble calls. The components without the "*" are implied to be faulted by the ORMS algorithm.

The ORMS Client is also capable of displaying the faulted components and the affected customers on the GIS map. Currently, the implementation supports this functionality only for the ESRI ArcFM GIS software. However, extending this capability is straightforward.

5. THE IDMS INTEGRATION FRAMEWORK

The IDMS employs Model Integrated Computing (MIC) technology, namely the Mutigraph Architecture (MGA) to create a flexible, reconfigurable, and extensible framework with which the data from the GIS system and the Data Sources are integrated with the ORMS. The Integration Framework can also provide integration for other decision support tools.

Model Integrated Computing

Model-Integrated Computing (MIC) is an approach to developing systems that directly addresses the problems of system integration and evolution by providing rich, domain-specific modeling environments including model analysis and model-based program synthesis tools [5]. This technology is used to create and evolve integrated, multiple-aspect models using concepts, relations, and model composition principles routinely used in the specific field, to facilitate systems/software engineering analysis of the models, and to automatically synthesize applications from the models.

The Multigraph Architecture

The Multigraph Architecture (MGA) is an MIC technology that has evolved during the last decade as a software framework and infrastructure for system integration and synthesis [6]. MGA includes generic, customizable tools for constructing domain specific modeling, analysis, and program synthesis environments. The technology has matured in major applications developed for the government and private industry, including fault detection, isolation and recovery systems for aerospace applications, on-line problem solving environments for the chemical manufacturing industry, high-performance parallel instrumentation systems, embedded simulators for turbine and rocket engine testing, and manufacturing execution systems.

The GME Model Editor

The MGA includes a configuration Graphical Model Editor (GME) that includes facilities for model building and transformation [2]. For the Integration Framework, we configured the GME to build models in a language we designed and called IDMS.

The IDMS Modeling Paradigm

The role of the IDMS models in the Integration Framework is to act as a repository for meta-information describing all available data source in the system, how they can be inter-related, and the transformation between these inter-relations and the semantics required by the context of the decision support tools in the system, namely the ORMS. For this reason, the IDMS modeling paradigm, or language, contains "Data Source" models, which describe all available data sources, how to connect to them, their tables, fields, and keys. Note that one assumption the Integration Framework makes about the data sources it can communicate with is that they are relational, and can be accessed via Microsoft's OLEDB technology. This class of data sources includes most commercially available database (SQL Server, Oracle, Sybase, Informix, Access, etc), as well as simple sources such as formatted text files, Excel spreadsheets, etc.

In addition to data source models, the IDMS paradigm contains "IDMS Configuration Models", which contain "Query Models". The query models describe how the various data from the data sources can be composed to implement the data accesses, complying with the semantics required by the ORMS. See Fig. 3 for examples of data source, table, and IDMS configuration models.

The graphical representation of the query models follows that of industry standard application such as Access. The differences between these models and Access query specification is 1) these models also represent the mapping between the data which will be returned by the queries and the semantics of the data consumer (the ORMS), and 2) the IDMS models are transformed into the configuration of a component which will implements the inter-database queries – the queries are not executed within the modeling environment.

To ease the task of building the IDMS data source models, we implemented a special model interpreter that can automatically import the database schema information from any OLEDB compliant database. This interpreter imports the tables, fields, and foreign key information. Thus, the models themselves are almost completely automatically generated.

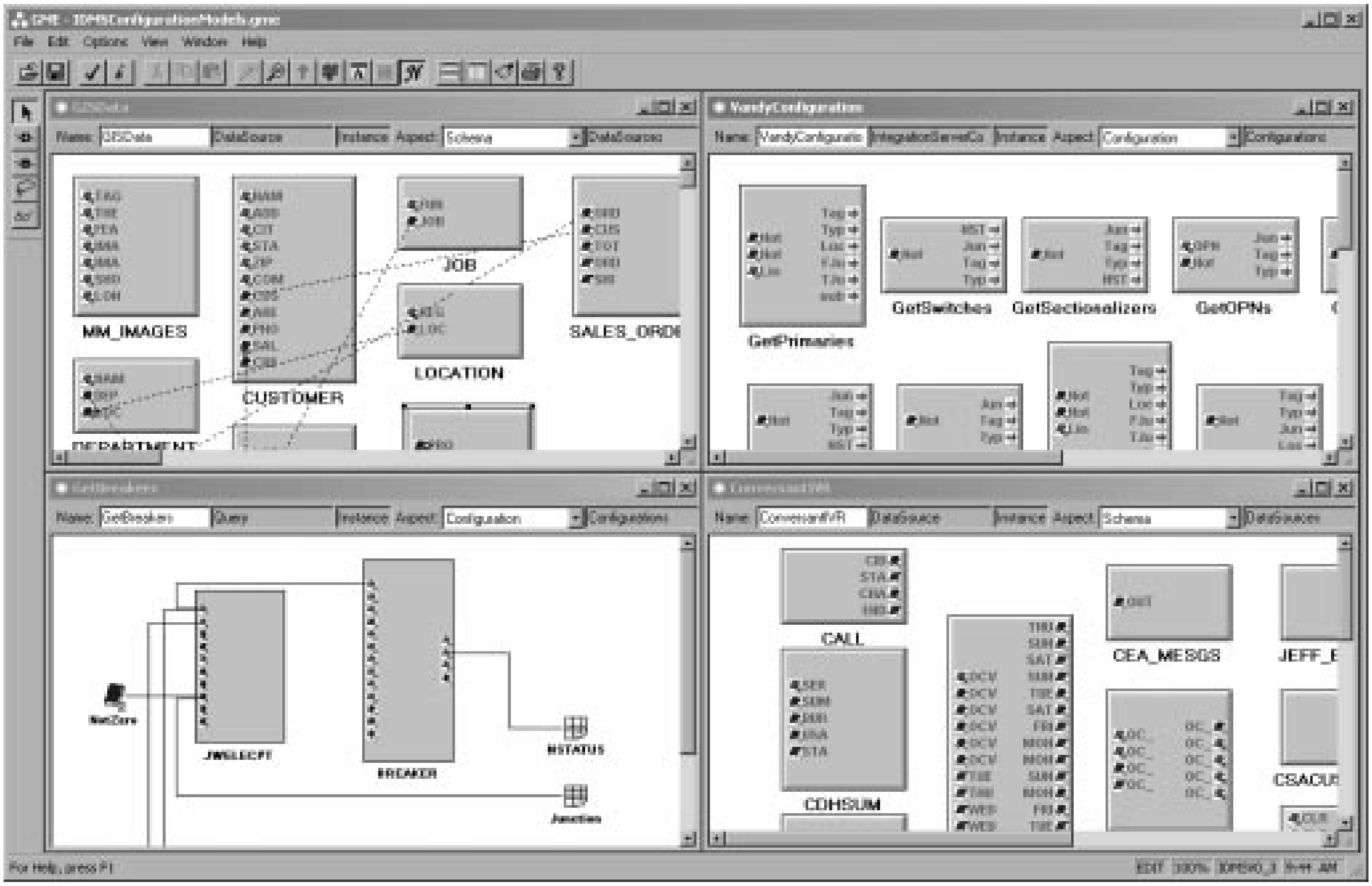

Fig. 3. An Example IDMS Configuration Model

The IDMS Integration Engine

The IDMS Integration Engine is the component that actually performs the requests for data to the individual data sources, interrelates the data, and forms the records required by the ORMS client, in the format in which it requires the data. It thus implements the integration between ORMS and other information system components.

For instance, the ORMS client must obtain trouble calls from the Integration Framework to update the ORMS and diagnose an outage. The ORMS client calls an OLE/DCOM interface function of the Integration Engine with the identifier “GetTroubleCalls”, which returns the data as an OLEDB record set object. The actual query performed by the Integration Engine will join the *outages* table from the IVR system, which includes phone numbers, with the *customers* table from the CIS, which contains transformer numbers, with the *transformers* table in the GIS database, which contains transformer identifiers and map locations. The ORMS client uses the information returned by the call to the Integration Framework to identify the customer trouble calls in the circuit. However, the ORMS client code is absolutely independent of the data location, source, or format.

The Integration Engine has the capability to access data from any OLEDB compliant data source, and can perform relational operations on data from disparate data sources (e.g. it can perform a relational join operation between data stored in SQL Server and data stored in a text file). Again, these inter-database operations are configured from the models, so there is no coding (no SQL, VB, C++) required in defining and executing such operations.

Model Transformation

The IDMS models are transformed into the IDMS configuration database, which includes configuration tables read in by the Integration Engine, and other system components.

When data sources change (system components are removed, replaced, or added, or data formats change) the models can be updated and the integration configuration is “resynthesized” from the models automatically [3,4].

6. CONCLUSIONS

The IDMS provides a platform on which can be built a flexible and cost-effectively extensible suite of decision support tools for electric utilities. The diagnostics component, the ORMS, is capable of efficiently identifying faulty components during power outages. The ORMS algorithm is implemented as an OLE/DCOM component, and has been integrated with several standard COTS systems commonly used in electrical utilities.

Diagnostic Capabilities

Although the ORMS diagnostics component is not the focus of this paper, there are a few notable comments that can be made to show its relevance to the electric utility domain. The ORMS diagnostic engine is capable of efficiently diagnosing faults in energy distribution networks. The following capabilities make this system unique: It can locate not only a single fault, but also multiple faults (non-interacting faults within a single feeder). It is able to locate and identify any faulty electrical components, including conductors. The diagnosis is fast and accurate, and takes advantage of any available data. The ORMS has been received well among engineers in the energy distribution industry.

Integration

The use of MIC in the Integration Framework has produced a flexible, extensible, and easy to manage integration between decision support tools and the various data system in utilities. The approach has proven to achieve almost effortless integration, and reconfiguration. Although currently the IF has been used only with the ORMS, it is capable of supporting the data integration needs of many decision support applications.

7. FUTURE WORK

We plan to take advantage of the flexibility of the IF, and extend the IDMS to include other decision support tools. One example is a repair-planning tool, which could use GPS data to track the locations of repair crews, and efficiently schedule repairs. Another is a feeder reconfiguration support tool, which would suggest switching actions to reconfigure feeders to back-feed sections during massive outages. This tool could take advantage of load analysis software in predicting the effects of various switching plans.

In addition to new decision support tools, we plan to attempt to integrate the ORMS with GIS and mapping system from other vendors to exercise the flexibility of the Integration Framework.

8. REFRENCES

[1] S. Monemi, “Fault Management Systems in Energy Distribution Network Environments”, Ph. D. Dissertation, Vanderbilt University, Dec. 1999.

[2] G. Karsai and A. Ledeczi, “ A Graphical Modeling Environment for the Multigraph Architecture”, ISIS, Vanderbilt University, Manual ver. 0.5, Nashville, TN, 1998.

[3] M. Moore, et al, “Diagnostics and Integration in Electric Utilities,” Proceedings of the IEEE 2000 Rural Electric Power Conference, Louisville, KY, pp C2-1-C2-10, May 2000.

[4] M. Moore, et al, “Integrated Diagnostics for Electric Utilities,” Proceeding of the 4th World Multiconference on Systemics, Cybernetics, and Informatics (SCI’2000), Orlando, FL, July 2000 (In Press).

[5] Sztipanovits J., Karsai G.: "Model-Integrated Computing", IEEE Computer, pp. 110-112, April, 1997.

[6] Ledeczi A., Maroti M., Karsai G., Nordstrom G.: "Metaprogrammable Toolkit for Model-Integrated Computing", Proceedings of the Engineering of Computer Based Systems (ECBS) Conference, pp. 311-317, Nashville, TN, March, 1999.