GIS Based Service Oriented Architecture Approach for Electric Distribution

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ABSTRACT

In this age of technological advancements, the electricity distribution operators continuously seek new and innovative ways to create differentiation and increase profits. The customers do not have to wait infinitely to get the service for which they pay, and are ready to switch to service providers who deliver faster. So in order to retain the customer and deliver to the customer efficiently, the best way is to provide highly personalized services. One of the most powerful ways to personalize the energy services is to automate the flow between the different energy components. The electric components are varied and are present in the real world, so in order to automate the working of these components and bring them closer to reality an object oriented approach is required, which captures the properties of these real world entities.

These electric components though independent, work together and its services are utilized by a number of organizational units. Apart from the active electric components, there are a number of administrative components which together form the electric distribution company’s working day in and day out. Since these different systems work independently, there is a delay in the service provided to the customers. By automating the business processes of the different systems and sharing the services of each other through a common integration framework, the delay in the service to the customers is reduced, the efficiency in the service provided is improved and profit to the electric distribution company is maximized.

Thus the present day situation demands the sharing of services between different systems in the electric distribution company, irrespective of the knowledge of who shares what. The communication between these pointless entities enables the flow of information between systems which leads to the faster delivery of services reducing the customer delays and maximizing the service provider profit. Thus an integration framework is the need of the day which will integrate different systems of the electric distribution company from the outage management system, to the workflow management system, to the customer information system, to the feeder management system, to the integrated voice response system (IVRS) etc.

Keywords: GIS, Service Oriented Architecture, Electric Distribution

1. INTRODUCTION

The electric utility industry has numerous departments that work separate and independent. If any process has to be initiated then the process takes ample time to complete just in moving from one department to another. Though all the data is available with all of them, the time taken to process a particular request is very high. So in order to eliminate this discrepancy the services have to be highly personalized. One of the most powerful ways to personalize the energy services is to automate the flow between the different energy components and enabling the flow possible by an integrated unified data model. This automation can be embedded in the GIS environment using a service oriented architecture approach. GIS Technology can support the different spatial and non-spatial queries from various departments and provides efficient responses to queries in return to aid in effective running of day to day operations. Spatial thinking in the integration of the various departments can reduce time considerably and provides faster service to the customers. There is a lack of understanding of what is required and why it is required between the departments. So if what is required and why it is required is understood then the services between the systems can be efficiently handled and automated.

2. AIMS AND OBJECTIVES

- To develop a single integrated data model architecture for the automation of business processes and exchange of data among software applications used in electric utility enterprise.
- The data model is also intended to assist utilities to develop interfaces so that software products from a variety of vendors can incorporate without the need for extensive custom interface development.
- To develop an independent integration structure to integrate different systems such as SCADA, Work Management System, Customer Information System, Outage Management System, Switching System, and Operation and Maintenance system
- Cross integration between all these structural components.
3. DATA USED

The electric distribution data was collected from the field as well as from the Tamil Nadu State Electricity Board for the substations pukkathurai substation. The base map was created by digitizing the survey of India top sheets. The details of the various departments of the Electric Distribution Company were obtained from Tamil Nadu State Electricity Board.

4. GIS DATAMODEL DESIGN

The data model is designed using the object model structure, each objects having unique properties. The objects follow the parent–child hierarchy. Each objects field properties as well as the relationship properties have been specifically designed. The object domain as well as the subtypes have been designed and assigned. The Theme layers were identified based on how each datasets will be used – for editing, GIS modeling and analysis, representing the business flows and mapping. This helps in identifying the key relationships and data integrity rules. The group layers that were identified were as follows:

   a. Devices
   b. Structures
   c. Circuit Segments
   d. Customers and Service
   e. Non Spatial Object Tables

a. Devices

Electric Devices are real world objects that either produces or is powered by electricity. They influence the electricity flow in the conductors. Examples of the electric devices are transformers, over current protective devices, switches etc.

b. Structures

Electrical Structures are devices that are support the network flow without actively taking part in the network electricity flow. Their primary role in the network is to support the devices as well as the conductors. Examples of the electric structures are Pole, Cabinet, Guy, Riser etc.

c. Circuit Segments

These include the conductors that form the part of the network. They are the actual carriers of electric current. The categories may include overhead cables, underground cables and the service cables.

d. Customer and Service

These are the end points or consumers of the electric network flow. They act has sink in the electric network flow. The theme include service points, meter points, generators, street lights etc

e. Object Tables

These are the collections of other attribute that will be related to the themes listed above.

The identification of key aspect of each theme is done in order to model the behavior and characteristics of each of the themes. It is done in order to arrive at the inter relationships of each of the themes. Discrete features are modeled as feature class of points, lines and polygons. Advanced data types such as the geometric networks, and topologies are used to model the relationships between elements in a layer as well as across the datasets.

The data model designed for the Network Devices Theme is as shown below in the Figure 1.
Once the discrete feature classes are modeled, the attribute field and column types for each of the feature classes were identified and created. It also includes the attribute domains, relationships and subtypes. The prototype design is tested with the application workflows and by performing edit operations. Based on the test results with the application as well as the edit operations the geo database design is reviewed and refined. The design has to be tested for production, performance, scalability and data management workflows.

Based on the above mentioned processes are the feature classes created in the Devices Category were:

- Regulator
- Current Transformer
- Distribution Transformer
- Capacitor
- Over Current Device
- Switch
- Power Transformer
- Generator
- Motor
- Shunt Capacitor
- Substation

The feature classes created for the Structures category were:

- Pole
- Guy
- Primary Cabinet
- Riser
- Secondary Junction Box
- Conduits
- Manhole

The feature classes created for the Circuit Segments category were:

- OH Primary Line
- OH Secondary Line
- UG Primary Line
5. SYSTEM OVERVIEW


- UG Secondary Line

The feature classes created for the Customer Category were:
- Service Point
- Primary Meter

a. SCADA – GIS Integration

The integration of SCADA with GIS will help in automating the breaker outages from the electric substation and let them viewed and analyzed in GIS environment. Also it helps to get the values of the current and outages flowing currently on the field from a click in the system at the office. The integration involves the background database component and the front end GIS component. The integration methodology for the backend database component is as shown in the Figure 2. The background Database environment involves designing the integration architecture and how the data flows between the SCADA systems and the GIS systems and the how the data is needed for the GIS system in the SCADA system database. From the SCADA end there are three tables,

i) The Analog Table – to store the analog data from SCADA such as current, voltage, power factor etc

ii) Digital Table – to store the event based data obtained from SCADA such as the outages.

iii) The Log Table – to hold the timestamps and the breaker id’s to be linked with GIS.

[Diagram: Flowchart showing the methodology of the Background GIS environment]
The Front end GIS continuously listens for the outages in case of the events tracked in the digital tables and reads the analog table in a timed manner to update its own GIS database. The List of all the breakers that are out of power will be listed in the GIS environment and the option is provided to the user to zoom to that particular breaker. This will give the user the area of outage and a list of customers that might be affected because of this outage.

Figure 3 gives the SCADA – GIS integration interface in Arc Map environment. The symbology for the outages is specified accordingly and is shown in Figure 4. The Breaker engaged in the SCADA system is reflected immediately on the map as shown in the Figure 3.

![Fig 3: SCADA – GIS integration interface in Arc Map](image)

![Fig 4: Symbology for the Circuit Breakers](image)

**b. Work Management System – GIS Integration**

The integration of work management system with GIS will help to automate the job handling and assigning of jobs to the field crews in case of outages. The integration has two parts:

- The outages indicated by SCADA
- The outages that are known to the operation and Maintenance team via customer complaints or field visits

For the outages which are indicated through the SCADA environment the WMS team has a framework which is slightly different from the one available for the SCADA team. A frame called jobs is added to the SCADA – GIS user interface shown in Figure 3. The new interface available for the Work Management System team is as shown in the Figure 5.
Once the outage happens and if it is not a scheduled outage the Work Management System team, selects the outage and assigns the job. By clicking on the Assign button, the assign job frame is invoked. The User interface for assigning Jobs is as shown in the Figure 6. The users in this case will be the Work Management System team. They will be assigning a job id and the job type and assign the work to the concerned department.

When the job as been updated to the work management system database, the operation and maintenance team will look into the job and assign the work to the concerned staffs. The User interface for the
Operation and Maintenance team is shown in the Figure 7. The Operation and Maintenance searches for the staffs and if they are free assigns the Job to the concerned staffs. If the staffs were already assigned a work then the job will be queued.

**Fig 7:** User interface for updating the Job

Once the staff is selected and the job is updated the progress of the jobs are seen in the GIS environment of the Operation and Maintenance team. The Symbology of jobs in the GIS map is shown in the Figure 8.

**Fig 8:** Symbology of Jobs in GIS

As and when the staff’s progress with their work can access and update the job status which will updates in the work management system database, which will in turn be updated in the GIS map. The user interface for the job updated by the staffs is as shown in the Figure 9.

**Fig 9:** Staff Updates of Jobs

Once the job is completed its status is updated on the map as shown in the Figure 10.
If the administrator wants to see the status of the individual jobs, a user interface was developed in which the administrator can select a particular job and get the status of the job. The administrator can view the time in which the job was allocated and the time since last update. The interface is as shown in the Figure 11. For non circuit breaker devices the jobs are assigned by selecting the Devices and assigning jobs directly in the GIS map.

Fig 10: Job Status in the Map

If the administrator wants to see the status of the individual jobs, a user interface was developed in which the administrator can select a particular job and get the status of the job. The administrator can view the time in which the job was allocated and the time since last update. The interface is as shown in the Figure 11. For non circuit breaker devices the jobs are assigned by selecting the Devices and assigning jobs directly in the GIS map.

Fig 11: Job Status for the administrator

C. GIS – Customer Information System – Work Management System Integration

The integration of customer information system with the GIS environment enables the electric distribution company to spatially locate and retrieve customer information spatially once the customer calls. When a customer call is received, the service operator locates the customer using the locate customer tool as shown in the Figure 12.

Fig 12: Locate Customer Tool

By Clicking on the locate button the location of the customer is selected and zoomed to in the GIS map. The Customer Service Personal can then retrieve the
customer information using the retrieve customer tool shown in Figure 13.

![Retrieve Customer Tool](image1)

**Fig 12:** Retrieve Customer Tool

On Receiving the Customer Complaints the customer can be located based on the locate customer tool and the Assign Job tool is invoked to create a job as shown in Figure 13.

![Assign Job Invoked](image2)

**Fig 13:** Assign Job Invoked

Once the job is created the WMS Process flow is continued and updated as such. Once the customer calls back the WMS status is retrieved and informed to the customer.

d. **Outage Management System – GIS Integration**

When a customer call is received, the service operator locates the customer using the locate customer tool. When the Customer is located on the map, the path to the customer from the source and the devices to be checked for the customer should be determined.

Utility Network Analyst was used to determine the trace from the customer located to the source supplying the customer upstream. The upstream trace from the customer to the source is shown in the Figure 14.
In case of outage in a substation, the affected customers downstream have to be located and valued. Utility Network Analyst was used to determine the trace from the source to the customers fed by the source. The downstream trace from the source is shown in the Figure 15.
Report Generation

- The report of the affected customers is generated by the Outage Management team
- The action for the retrieval of power can be based on the priority customers affected.
- The report also helps the administrator to get a view of how the customers are affected in the area.

e. Switching – GIS Integration

The Switching operation have to be integrated with GIS in order to visualize the total area affected by the outage and the maximum area that can be retrieved by effectively optimizing the Switching Operations. Switching operation is based on the open and closed switch locations and the position of the circuit breakers with respect to the switches. The position of the switches and the circuit breaker is shown in the Figure 16.

Area supplied by one single feeder in the substation is given in the Figure 17.
In Case of a cable cut the area affected by an outage is shown in the Figure 18

Fig 18: Area affected by outage

The connected open and closed switches are found and is shown in the Figure 19

Fig 19: Finding connected open and closed Switches
The switches are opened and closed appropriately as shown in the Figure 20.

**Fig 20:** Open/Close Appropriate Switches

Actual outage are after switching is shown in the Figure 21.

**Fig 21:** Actual Outage Area after Switching
f. GIS for Operation and Maintenance

Inspection Report can be generated for street lights for each Inspector along with the map of the street lights that are to be inspected during an inspection cycle. The inspection report menu is shown in the Figure 22.

![Inspection Report Menu](image)

**Fig 22: Inspection Report Menu**

The report generated is shown in the Figure 23

![Inspection Report](image)

**Fig 23: Inspection Report**

6. CONCLUSIONS AND RECOMMENDATIONS

- The Electric Utility model is developed keeping in mind the real world scenarios and modeling the behavior of the electric components as the work on the field.
- The Categorization of the themes of the data model makes the understanding of the inter-relationship between themes better.
- The Data model assists in automation of the Business process and for better delivery to the customers.
- The Business Processes such as SCADA and WMS are modeled inside GIS environment and it works across the system enabling seamless data flows.

The following are the future enhancements that can be done to the project output:

- The Data model is never final and it should evolve and update itself.
- The Systems such as CIS (Customer Information System) and FMS (Feeder Management System) needs to be incorporated inside the Data model.
Other Cross integration possibilities and integration enhancements between CIS, Outage Management, FMS, SCADA, and GIS have to be identified and integrated.

REFERENCES


