Designing and Populating Geospatial Systems to Support Advanced Applications for Field Automation

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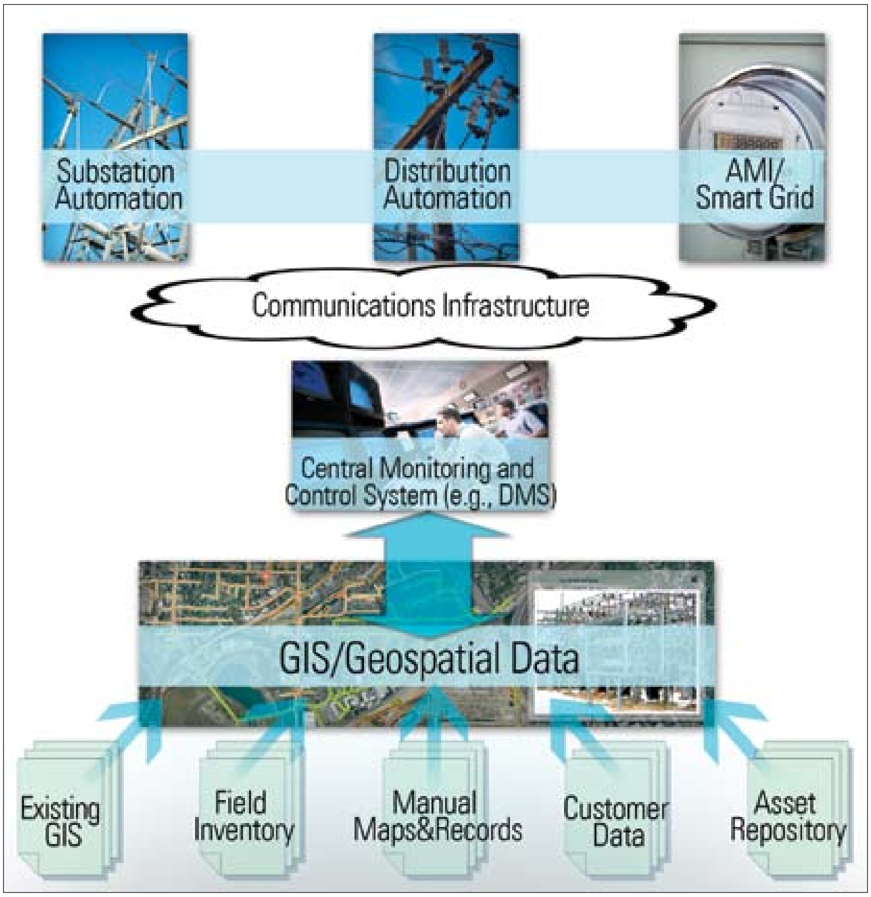
Introduction

Electric utility companies are typically using aspects of GIS to support the various business processes involved in managing the electric system and providing service to customers, such as feeding outage management and power flow analysis systems. As more and more new field automation technologies — including Distribution Automation (DA), Substation Automation (SA), Advanced Metering Infrastructure (AMI), and Smart Grid applications (SG) — become mainstream, GIS plays an even more critical role.



Evolution of GIS

Early GIS systems have their roots in automated mapping with some facilities management capabilities. Current GIS technologies for utilities provide not only support for spatial data, i.e. the ability to see where facilities are and to manage the relationships with other spatial features, but also provide for managing network topology of the electrical system components.

GIS in electric utilities began in the late 1970s primarily as a tool to automate a company's manual mapping functions. There was a strong focus on presentation of facilities data, to ensure that symbols, line work, and annotation were legible; and the ability to generate multiple map products at various scales. Some products (among them IBM's GFIS), however, did put an emphasis on developing a model behind the graphical representations of the electric facilities with the idea of managing these facilities. In addition to typical attribute information (dates, material, manufacturer, model, ratings) the models also dealt with relationships including electrical connectivity.

As GIS has evolved over the past thirty years, there has been an increasing emphasis on the model of the electric system and growing reliance on the model behind the map to provide information to users and integrated systems rather than focusing on multi-purpose presentations of map-type data. Moreover, many electric utilities are using their GIS to provide network connectivity models to system analysis and planning tools to perform power flow analyses of various types, and now, commonly to outage management systems.

Table 1 delineates the four major levels of utility automation, from stand-alone deployments to integration of near real-time field automation. Each level represents increasingly sophisticated spatial data usage, and the expansion of advanced applications and integrations. And each level allows the utility to realize increasing benefits and efficiencies in the energy delivery process. As GIS evolves, it can help move utilities to Level 4 by becoming a key source and repository for integration of real-time, location based data

Utility Automation Level of Adoption	Key Characteristics
Level One - Standalone Deployments for Mapping, Facilities Management and Workforce Automation.	Localized application; value-added tools such as graphic work design leverage geospatial technology, but other non-spatial tools such as work management do not and miss opportunities. Data redundancy and multiple maintenance results in many conflicts.
Level Two - Integration of Energy Delivery Systems for Workforce Optimization (GIS, CIS, OMS, WMS, GWD, CMMS)	Integrated applications leverage spatially enhanced functionality; the value of non-spatial applications is extended through location-based awareness. Integration through enterprise integration technology. Business processes are still largely departmental.
Level Three - Integration of Energy Delivery Data Marts for Asset Optimization	Integration occurs at the business process level; definition of enterprise workflows. Instead of spatially enabling applications, core data are spatially enabled — attaching a location to each asset optimizes the asset management process. GIS is enabling technology and the correlation engine for analysis.
Level Four - Integration of Near Real-time Field Automation	Real-time, location based data from substation and distribution automation, SCADA, advanced meters and other field automata are integrated, enabling near real-time analysis and decision-making.

Table 1 - Field Personnel Functions

from substation and distribution automation, SCADA, advanced meters and other field automation devices, enabling near real-time analysis and decision-making.

Field Automation Data Requirements

Field automation entails the installation of various types of monitoring and operating devices at the electric substation and potentially including devices within the customer premise. These can be meters, automated switches, monitored reclosers or sectionalizers. They will either be autonomous devices that perform specific actions based on specific monitored location conditions or, communicate with a central monitoring and control system, such as a Distribution Management System (DMS), to provide status information and/or accept commands. A DMS is a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system, specifically to minimize impact of outages to customers and to protect the system from damage due to failures.

Communication between the field automation device and the central monitoring and control system can be over the electric network itself via BPL (Broadband over Power Lines), a dedicated communications network (such as fiber), cellular communications or radio frequency (RF) media. In any case, in order for the DMS to correctly interpret the information being fed to it and to make the correct decisions about actions to take, an accurate representation of the distribution system is required. This accuracy is not necessarily from a spatial perspective, but from the aspect of electrical connectivity.

Modern DMS applications perform near real-time power flow calculations to either provide information to operators about whether switching operations can or cannot be safely performed or to allow those decisions to be made automatically. This representation (or model) must be such that for every location where an Intelligent Electronic Device (IED) is installed, the system needs to know the characteristics of the circuit downstream of that device in terms of customers, loads, peaks, conductors, generators, and other devices.

The GIS model that would feed such a system therefore needs to have a complete, accurate, connectivity model from the substation through to the customer at the individual phase level. The model must provide for the ability to represent internally the individual phases (conductors, units within a bank, customer connections) of all electrically conducting features. This includes the conductors, switches, fuses, transformers, capacitors, reclosers, and sectionalizers. Particularly, complex devices such as pad mounted switchgear need to be accurately depicted in terms of their internal configurations. This requires modeling the internal bus, switches, fuses, and elbows that make up that equipment.

With these new field automation applications in mind, a utility can proactively enhance its GIS and related databases to provide the required data structure and content to support field automation. This requires planning, design and conversion activities to bring data organization, contents and quality on par with field automation requirements.

Current State Assessment of Data

The first task to be undertaken is to develop a thorough understanding of the current GIS database as well as other related datasets that provide additional information about the electric system. These would include the utility's customer information system (CIS), possibly a work management system that contains asset or equipment data, and standalone equipment configuration and maintenance databases.

It is very common in GIS (as well as many other databases and systems) that the initial data model design includes attributes and relationships based on the many user and application requirements. But for various reasons during initial database population (conversion) or through ongoing updates through related business processes, this information was either not populated, or was populated inconsistently. In addition, as business requirements change, there is often a need to start capturing additional information about database entities. In many cases it may not be possible, practical, or cost effective to modify the database schemas and/or applications software to record this new information. In these instances, the fall back tactic is to place this information into the comments or another unused field in a coded fashion. In many cases this is information that needs to be structured correctly in a database so that it can be made available to various applications and end users.

Typical Conditions to Address for GIS to Support Field Automation

The following are a number of typical situations that may need to be addressed:

- **Customer to transformer/device connectivity** – Customer connectivity to a distribution transformer (in most cases), or alternately to a primary metering device. Typically this information is managed in a CIS or Meter Data Management System, but if not, or if the quality of the data is questionable, then this relationship needs to be established and business processes need to be implemented to ensure that the relationship is created correctly for new customers, and updated when connections in the field are modified. This relationship can be established in various ways, depending on the individual case. Options include:
  - Geocoding service addresses (computing a map coordinate from street addresses using an street center line network) and performing a spatial proximity search to associate customers with transformers based on distance, type, voltage, phasing, and class of service.
  - If available, analyzing or tracing secondary and service conductors between transformer and the customer premises
  - Field inventory
  - If the utility is planning to install an advanced metering infrastructure, then all meter locations can be GPS-located when the meter upgrades are performed and the serving transformer identified.
- **Underground systems not complete** – Very often underground systems within manhole/vault/duct systems are either not modeled or not populated correctly due to the complexity and detail of the existing records. This class of data needs to be researched either from existing detail drawings (manual or CAD), physical field inspection, or a combination of the two.
- **Pad-mounted Switch Gear at High Level Only** – If complex devices are only modeled as the structure itself, showing terminating conductors only, then additional detail on the internal configuration will need to be captured. This requires the correct representation in the GIS model depicting bus connections, individual switches, fuses and elbows by phase. This representation may be able to be determined from examination of operating maps or schematics, by physical field inspection, or a combination of the two.
- **No Phasing information** – For many utilities whose initial emphasis was on automated mapping, phasing information is represented only by annotation, and then, often only on selected device classes with users interpreting the symbology and annotation to infer phasing information when needed. By contrast, modern GIS models require this data explicitly on all electrically connected features. If this data is available for certain subsets of features, it may be possible to develop software to propagate this to connected features, being careful to enforce certain connectivity rules (i.e., a single phase feature cannot feed a multiphase feature). Typically, operating maps or schematics will contain sufficient information to be able to infer phasing, but ambiguous situations may still require field inspection.

The analysis of the existing GIS and related datasets needs to determine the usability of the data. For each feature (entity) and attribute the following types of characteristics must be understood:

- How many of the records have null data values?
- How many have illegal or non-plausible values?
- If there are interdependencies between fields or special business rules, are these valid?
- Is there valuable information in comments fields or other unstructured formats?
- Is the unstructured data in a form that can potentially be parsed with software?
- Do records in other datasets contain identifiers that can be used to correlate with the GIS?
- What is the correlation rate across records in different datasets?

This analysis should yield a type of "health and wealth" assessment of the utility's GIS and related databases. This will provide the kind of information necessary to plan how the existing databases can be processed to provide the required data structure and content to support field automation.

The **sidebar**, *Typical Conditions to Address for GIS to Support Field Automation*, highlights typical situations that may need to be addressed based on the outcome of the current state assessment. Depending on the overall assessment of data completeness and quality, a field inventory may be required for the system as a whole, or hopefully for only a subset of the network (i.e. overhead only, or underground manhole/duct).

Action Plan

The current state assessment is followed by the development of an action plan for the work needed to achieve the data organization, content and quality required to support the field automation devices and applications.

While the end state in terms of a GIS database design will be fairly uniform across the industry, the important issue here is that each individual organization will have a unique set of pre-existing conditions to deal with. Therefore, the specific steps and activities that need to be taken will be unique for each company. For each class of data being addressed, some combination of the following activities will need to occur:

- Combining two (or more) record sets into one, removing redundancy, and resolving ambiguities
- Developing software to parse or decode unstructured data elements into a structured format (i.e. address or comments fields)
- Setting up software and processes for human beings to analyze exceptions and efficiently enter correct data into the database
- Locating and analyzing legacy manual maps, drawings, or records to extract additional information needed to supplement automated data
- Developing software and processes to convert completely manual datasets into the GIS

- Establishing specifications to be issued to external data conversion companies to provide any combination of the above mentioned activities
- Developing quality assurance and quality control specifications, software, and procedures to ensure that the data being produced (internally or externally) meets requirements

Another necessary activity is to ensure that the interface from the GIS to the central monitoring and control system (such as a DMS) is transferring all required device classes, attribution, and relationships completely and accurately. In the initial stages of testing and deployment the central system is likely to identify many erroneous or ambiguous conditions. These need to be corrected in the GIS source system so that subsequent updates will be more accurate. In addition, business processes surrounding the GIS update process may need to be improved to ensure the timely update of the network database with proposed, energized, and as-built data.

Conclusion

With the advance of utility field automation comes the critical need for geospatial systems to become a key source and repository for integration of real-time, location based data from AMI and Smart Grid, substation and distribution automation, and other devices, thus enabling near real-time analysis and decision-making. The GIS model that can feed such a system must, therefore, have a complete, accurate, connectivity model from the substation through to the customer at the individual phase level.

With these new field automation applications in mind, a utility can proactively enhance its GIS and related databases to provide the required data structure and content to support field automation. This requires a "health and wealth" assessment of the utility's GIS and related databases, followed by development of an action plan to define the work needed to achieve the data organization, content and quality needed to support the field automation devices and applications. ■

About the Author

Gene Kindrachuk *is a systems design and analysis expert with more than 25 years of experience in GIS and utility applications. His expertise includes data conversion and migration; system design, development, and integration; business process and data analysis; database design, and development of specifications for hardware, software, and communications for AM/FM/GIS, WMS, MWFM, OMS, and related technology solutions. He holds a B.S. in Computer Science from the University of Alberta.*