Enabling GIS in Distribution Utility for Energy Audit and Load flow analysis

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Abstract:

In the nationwide implementation of IT-enabled power reforms in state distribution utilities, under the prestigious R-APDRP project, Geographical Information System (GIS) has gained importance as an effective tool for improving customer services, enhancing operational and energy efficiency and optimizing costs.

Lot of emphasis is given by the state utilities on the leveraging GIS for creating an energy balance sheet and take effective measures to plug the revenue leakages. The geo-referenced electrical network overlaid on area base map is handy for the utility not only for managing assets and their maintenance, but also being used for mapping the electrical consumers to its source of supply for energy audit applications. Moreover, by integrating electrical GIS with network analysis application, various analytical studies are possible for load flow analysis, short circuit analysis, efficiency calculations and load planning.

This paper describes how GIS is being leveraged in power utilities for energy audit and network analysis, and emerging as a powerful tool for load planning and management with the aim to improve the quality of electricity supply and related services.

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He is Working on R-APDRP projects and implementing IT solutions in electrical distribution utilities. He has over 26 years of experience in executing large IT projects, involving end-to-end business automation and system integration, in both power generation and distribution systems. He has earlier worked in senior positions in NTPC and as Head of IT in Uttarakhand Power Corporation Ltd on key projects like SCADA/ DMS, AMR, MBC, GIS and E-Governance for Utilities.
An Engineering graduate from BITS, Pilani, he is also a Post-graduate in Business Management and an Accredited Management Teacher in Information Technology. He has lectured on IT applications in Power sector in reputed academic/ professional institutions like IIT (Roorkee), Power Management Institute, IMT, ICFAI, etc. and presented papers in conferences in India and abroad. His papers have been published in several reputed national and international journals.

Introduction

Energy Audit and Load Flow Analysis are two vital objectives of the R-APDRP reforms under way in most of the State Electrical Distribution Utilities in India. This is in line with the requirements of reduction in ATC losses and total energy accounting. The reforms are envisaged to be brought about through IT-enablement of utility business processes, in which GIS plays a crucial role. The GIS application helps in maintaining indexed consumer database and electrical assets database. The indexed consumers are mapped to their respective source of supply. This is essential for performing energy accounting Distribution Transformer-wise and Feeder-wise. GIS application integrated with Network Analysis module helps in various calculations like technical losses, load flow analysis, energy audit, network optimization and "what-if" analyses.

Energy Audit and Network Analysis

Energy audit has always been high on the priority among all utility applications. Energy audit module has to be seamlessly integrated with metering, billing and collection with minimal manual intervention. The module has to capture electrical distribution network and energy parameters for feeder-wise and DT-wise loss analysis and identification of sections of revenue leakages. Therefore, 100% metering of consumers, substation feeders and distribution transformers is an essential requirements for total energy accounting. The foremost technical challenge is to effect a *seamless integration of the entire business processes* – both the new systems and current legacy systems, unless the utility chooses to discard the latter altogether.

Energy Audit module has to work closely with Network Analysis. There are special tools available to provide graphical analysis of distribution network with schematics highlighting attribute data for every substation, connected feeders, DTs, circuit breakers, sectionalizers and auto-reclosures. The network analysis tool uses advance algorithms for calculating phase imbalances, identifying low-voltage or overloaded sections, calculating section-wise loss levels and taking decisions on system optimization through network reconfiguration, capacitor placements and other system improvements measures as per energy audit requirements.

GIS is being leveraged in power utilities for energy audit and network analysis, and emerging as a powerful tool for load planning and management with the aim to improve the quality of electricity supply and related services. The geo-referenced electrical network overlaid on area base map is handy for the utility in not only managing assets and their maintenance, but also for mapping the electrical consumers to its source of supply for energy audit applications. By integrating electrical GIS with network analysis application, various analytical studies are possible for load flow analysis, short circuit analysis, efficiency calculations and optimization.

GIS requirements of Distribution Utility

GIS application for Distribution Utility is a multi-modular application whose components is integrated with core distribution processes like new connection management, meter data management (MDM), billing and collections, customer care, network analysis and energy audit. For better manageability, the GIS application should be configured with parameterized business rules with service-oriented architecture (SOA). The GIS application should be able to cater to the following business process requirements:

1. GIS based consumer indexing and asset mapping based on DGPS survey, digitization and superposition of geospatial map and data on satellite imagery

2. Integrated with other utility applications for network and load flow analysis, better load management, prevent revenue leakages and improve services

3. Able to conduct simulation studies to evaluate the impact of network reconfiguration, re-conductoring and optimization

4. Have in-built custom library of utility-specific symbols to add various network components with stored attribute data on base map

5. Should have the capability of graphical creation, editing and modeling of distribution network based on GIS data

6. Have the capability of automatic checking and validation of network topology and data based on network design parameters

7. Able to perform load flow calculations to provide power flows in MW, MVAR and current in each section, load at each node, voltage and regulation at each node for low voltage, overloading and loss analysis

8. Provide optimization of network design based on calculations for capacitor placement, switching sequence, protective device coordination and network restorative actions

9. Provide automatic checking and validation of network topology and data based on network design parameters

10. Perform load flow calculations for low voltage conditions, overloading, loss analysis and voltage regulations

11. Perform "what-if" analysis of distribution network parameters, such as
    a. Capacitor placement and sizing,
    b. Selective reconfiguration & re-conductoring,
    c. Substation sizing and location,
    d. Network augmentation
    e. Network load variation

Utility GIS architecture

To serve the purpose of the Utility in terms of ease of use, interoperability and integration with other modules, the GIS application for the Utility has to be n-tier, web-based application based on Service- Oriented architecture (SOA). The various components of this architecture are:

1. Presentation Layer: This layer is for formatting and delivery of information and services as required by the Utility. This layer renders the content in presentable format to the target client devices e.g. Browser, Laptop, Desktops, etc. As the underlying functionalities will be completely decoupled from the presentation technology, new devices or service delivery channels can be easily adopted without impacting the functional components.
2. Application/ Business Logic Layer: The application tier consists of COTS server application namely ArcGIS Server and ArcFM Server providing the necessary functionalities such as authentication, geo-processing, metadata management, map rendering etc. Customized interfaces and applications will be developed and exposed to the clients using these components. These functionalities include Map navigation, locater tools, query, editing, tracing, SLD's, versioning etc. It breaks large applications into manageable, autonomous and well contained components of business functionality that can be used in a variety of circumstances as defined in the Process Integration layer. The application layer exposes specific components as a service.
3. Process Integration Layer: Process layer provides for modeling of the business processes and their integration. It will enable to all the underlying services to be integrated and orchestrated as per SOA principle. Addition of new processes or changes in existing one can be implemented by orchestrating the changes as per the new requirement, e.g. if the existing collection process requires new payment mode to be incorporated, it would just require new payment service to be integrated with existing process.
4. Enterprise Data layer: The database tier consists of the GIS database including the GIS data Store (containing the complete data for the Land base, Network and Consumers), Operational Data Store and Analytical Data Store. All the databases are integrated to each other using Data integration Services. The GIS Data Store is the provider of the electrical network data to the other systems such as Network analysis, energy audit etc. The database tire also includes data authoring stations for the administration and authoring of map data. Thus, this layer comprises of the data and information aspects within the enterprise.

Data corresponding to each application stack is available in this layer. This layer is also be responsible for transferring operational data to analytical systems.

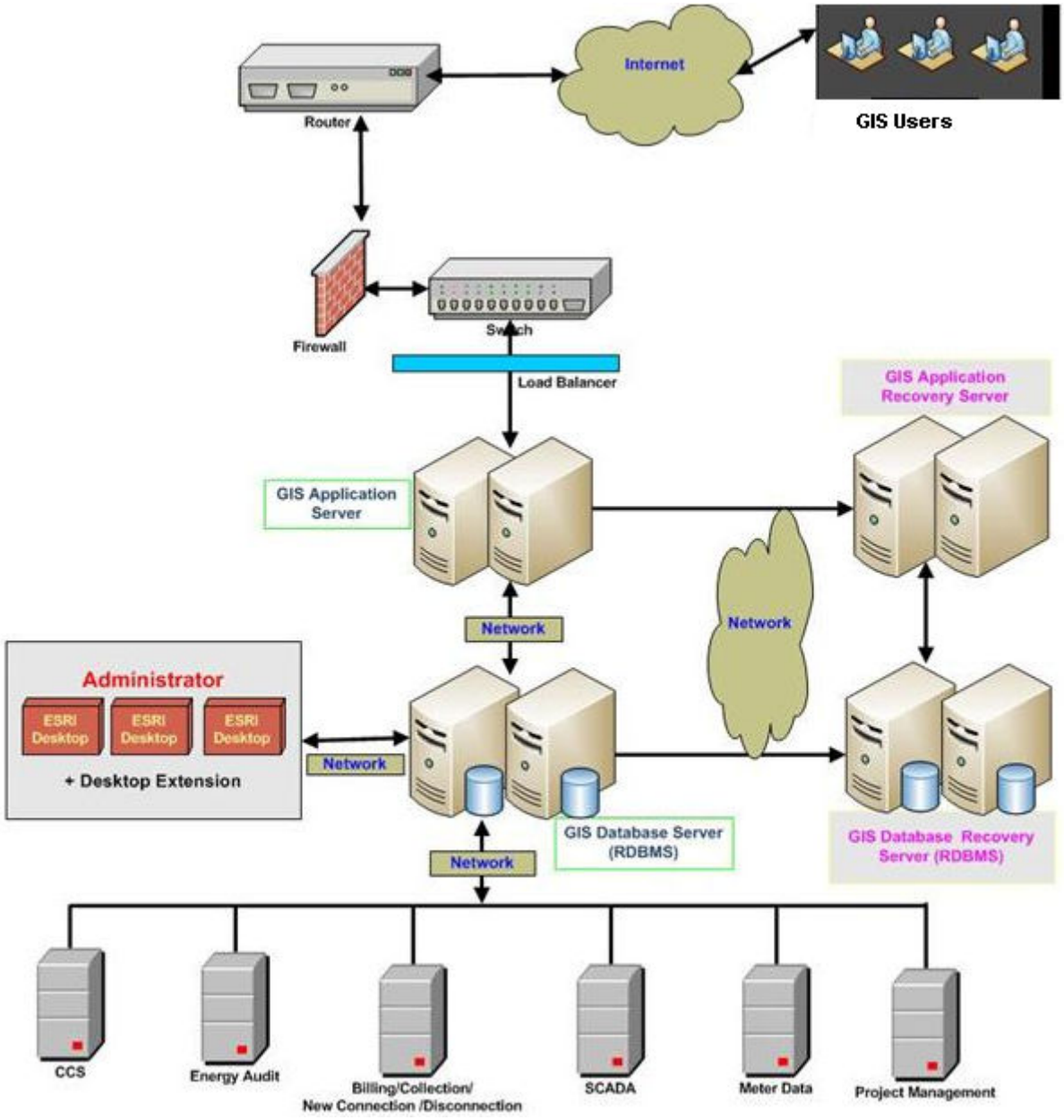

Fig: 1 – Utility GIS architecture

Utility GIS Technology requirements

The GIS platform should support generic GIS components and conform with Open GIS data standards e.g. Open Geospatial Consortium (OGC). The solution must support the latest Web 2.0 and SOA technologies. This will ensure that the Utility GIS solution can be easily integrated with any SOA-compliant third-party applications. Moreover, the application should be highly scalable and easily configurable solution to meet current and future business needs. SOA-compliance empowers the GIS application to deliver geospatial content and capabilities via Web services. Web services correspond to recognizable business functions and offer a set of protocols by which they can be published, discovered, and used in a standard form. Web services are the building blocks of service oriented architecture (SOA), the backbone of service-level integration.
Embracing GIS technology within the context of an SOA enriches the organization's service offerings and improves overall efficiency, accuracy, and accessibility to organizational business processes. These services can be utilized in a variety of client applications on a middleware integration platform, such as Enterprise Service Bus, essentially to meet the following objectives:

1. Integration Capability – The application architecture should provide standards-based integration, without the need for proprietary programming tools.
2. Enterprise Scalability – Use of open standards ensures scalability of the application as per Utility's requirements, and optimizing both deployment and maintenance costs of integrated systems.
3. Customizability – Industry standard solution will ensure customization with minimal efforts and ease of deployment of newer version.

Utility GIS Solution on ArcGIS/ ArcFM platform

The GIS software selected for developing Utility applications should be capable of centrally managing geo data, providing better data security and integrity of the vast utility database of distribution network assets and electrical consumers. It should provide access to large volumes of data resources, while reducing storage costs and data processing overheads. It should extend GIS capabilities for mobile workforce management, increasing the accuracy and value of field data collection and asset monitoring. The GIS software should be scalable and robust, designed to meet the Utility's requirements.

The ArcGIS platform conforms to open standards and enterprise IT frameworks that allow users to incorporate GIS into any application on a variety of computing and mobile devices. ArcGIS supports Utility's workflows and business requirements, supports spatial data management, editing, analysis, and display. The interoperability across various business modules is achieved through open IT standards:

1. Web standards, through SOAP, XML, JavaScript, etc.
2. OGC compliance, through GML, WFS, WMS, WCS
3. Enterprise Integration, through SOAP, XML, EJB, SQL, etc.

ArcGIS Data Interoperability eliminates barriers to data sharing by providing state-of-the-art direct data access; data translation tools; and the ability to build complex spatial extraction, transformation and loading (ETL) processes. It allows the use any standard GIS data, regardless of format for mapping, visualization, and analysis. ArcGIS Server exposes the geospatial capabilities using open, standards-based application program interfaces (APIs). This standards-based approach provides geospatial capabilities for various applications. In addition, ArcGIS allows distribution data and services on the Internet and ArcSDE gateway, an interface for managing geo databases in a database management system (DBMS).

ArcFM is a pre-integrated tool on ArcGIS software for modeling, editing, maintaining, and managing electrical asset data in an enterprise system. It provides extensions for feeder management and network analysis. It includes tracing tasks to automate utility operations and an extensive set of editing tools. It facilitates geographic data creation, network mapping and network analysis. It allows integration of multiple calculations such as voltage drop, load flow, fault current, load management, network optimization, etc.

Conclusion:

In Electricity Distribution Utility, it is a fundamental requirement to have a proper energy accounting and auditing system, aided by distribution network analysis on GIS platform. This can be achieved by automating the distribution value chain using open-standards architecture and appropriate technology. A high level of integration is required using enabling features and web services for timely and accurately recording, processing and mining of data for energy audit and analysis. The process integration envisages the solution to be designed in a multi-tier, web-based and service-oriented architecture (SOA) model. Enabled by GIS, Energy Audit and Network Analysis modules can be seamless integrated with meter data management, billing and collections, asset management, indexed consumer database and electrical network mapping on a middleware enterprise service bus. Standard plug-ins, business APIs and inter-operability standards like WSDL, UDDI, XML and SOAP facilitates this integration process.