Abstract:

Natural Gas is the preferred fuel due to its cost competitiveness and environmental advantages. Distribution of natural gas to domestic consumers is expected to significantly reduce Government’s subsidy on LPG. Reliance Industries has discovered large natural gas reserves with potential of 80 MMSCMD. City Gas Distribution (CGD) is one of the target markets for this gas.

CGD business has witnessed rapid growth in India recently. GIS technology and data are invaluable tools in CGD business processes from planning, engineering to O&M of network. GIS brings added value to CGD business by facilitating integration with other business systems. Integrating GIS in mainstream CGD business process leads to improved analysis, visualization, network planning and informed decisions.

This paper discusses the relevance of GIS in CGD business and describes how GIS technology can be used in CGD network planning process. Various analyses such as Gas demand calculation, DPRS Analysis and pipeline network can be performed in ESRI’s ArcGIS framework in conjunction with Advantica’s SynerGEE to meet the business requirements.
Introduction:

As per June 2008 report of EIA [1], natural gas accounts for 8% of total energy mix in India as against global average of 24%. However, with increased availability and spurt in T&D infrastructure, share of natural gas in is set to rise, primarily driven by power & industrial sectors, CNG and CGD. Industry estimate put net natural gas production in India at 72 MMSCMD for 2007-08, while consumption is estimated at 86 MMSCMD. In 2010, the consumption is expected to go up by nearly 60 MMSCMD to over 140 MMSCMD with corresponding increase in production, thanks to the large finds by private players like Reliance. It is estimated that CGD and road transportation sectors will consume 5% or 7 MMSCMD, with and estimated demand growth of 100% in next 10 years.

The Gas transportation network in India spans over 6,800 KM while another 9,000 KM gas grid is being planned. Based on the distribution network laid down by the existing players, it is expected that 2,500 kM of steel and 25,000 KM of PE piping network will have be installed by all distribution players. This is a huge task and presents tremendous opportunity for cost and schedule optimization by use of geo-spatial technology. The cost of deploying the geo-spatial solution is a small fraction of the savings it will entail.

Business Process

The CGD pipeline network is characterized by large investment, less flexibility, difficult constructability issues and high safety requirements during operation. Power and telecom networks are also laid along the city streets but are far easier to construct and operate owing to absence of above issues.

Goals and constraints:

Work process of CGD network planning & design should meet these challenges by:

- Planning for demand growth over a decade to avoid frequent network upgrade by adequate spare capacity.
- Optimize definition of service area of the City Gas Station and District Pressure Regulator Station (DPRS) and minimise number of DPRS at optimum locations.
- Route ensuring maximum reach with minimum length.
- Network sized critically to ensure supply pressure at consumer & intermediate points without over/ under sizing any element.
- Ability to manually adjust the automatically calculated locations / routes.
- Ability to evaluate design alternatives based on different assumptions.
- Produce calculations, maps and BoM showing various design parameters at all nodes and lines.
- Reduce the network design time to less than a week per city.

GIS in main stream business process: Reviewing above Business Requirement, it is clear that the CGD application has a vast scope characterized by:

- Demography based complex demand calculation with growth projection
- Spatial optimisation for service area and DPRS location
- Routing optimisation based on preferred street network
- Ability to edit calculated data and manage different case studies
- Bi-directional integration with Network sizing application like SynerGEE
- ESRI ArcGIS offering seamless data store for both spatial and non-spatial data is an ideal platform for such analyses. Due to its rich, high level language APIs, ArcGIS based application can be easily embedded in the business workflow. GIS application can also integrate with external engineering applications for line sizing, ERP and EDMS platforms.

Ability to edit the automatically calculated data and design is an important user requirement. Similarly, managing multiple case studies leading to final design and the design changes during and after construction is vital. Both these requirements call for a multi-version GDB and full functionality of ArcEditor. However, considering the fact that the routing functionality...
Implementation

Data Requirement
The application needs following categories of data:
- Generic spatial data like building footprint, street network, landmark etc.
- Application specific spatial and non-spatial data like location and demand of large consumers, census demography attached to city service area, perception of the business group regarding energy consumption potential of population in the residential area, growth rate over next decade etc.

Application Process Flow
The CGD application consists of a toolbar (Figure-1) with 18 functions. While the application runs on ArcMap client, Generate Route function uses Network Analyst Extension / ArcGIS Server web service ensuring standard network solver parameters & reduces in Network Analyst client licenses.

The application process flow is described below
1. As a preparatory step, the User connects to ArcSDE GDB through ArcMap and loads CGD specific layers like CGD Structures, route, DPRS blocks and City Grid in TOC. User then creates and switches to a new version for the city of interest. User also adds the CGD Toolbar mentioned above.
2. User adds new Industrial / Commercial consumers’ location with their address and demand as appropriate.
3. One of the business requirements is to provide ability to perform “what if?” analysis, requiring creation of multiple case studies for each city. Towards this, User initiates a new Case Study. The Case Study number is system generated with User defined Case Description.
The City Grid feature class consists of a 1 sq. kM grid covering entire city. Each grid contains pre-calculated data of number of buildings, households and reference to the case study number. While population growth, terminal year etc. are applicable to the entire city, the calculations are performed at grid level to provide better granularity during subsequent design. The calculations factor in annual growth, terminal year, gas consumption pattern for different income groups, market penetration, customer conversion factor from alternate energy source to PNG for commercial and industrial consumers as well as different income groups of residential consumers. The software computes overall demand of PNG that is used for CGD network and stores the same as attributes of City Grid feature class for CGD network Planning.

CGD Network is a hierarchical network with one City Gas Station feeding several DPRS forming the Steel Piping main within the city. The DPRS equipment is commercially available in certain fixed capacities. As such, they need to be located to service the area around their location to satisfy the projected demand in the area. This calls for optimally:

- Choosing the number of DPRS
- Configuring the service area for each DPRS ensuring 100% coverage

This has been achieved using an algorithm to solve Capacitated Facility Location Problem (CFLP) from the fields of computational geometry and Operations Research. The CFLP problems are extremely computation intensive. In order to implement this practically, a clustering based approach proposed by Liao and Guo [2] that yields near optimal configurations of facility locations with fast convergence is chosen. The approach can be applied to sufficient and insufficient capacity, providing optimal service area and location of the facility within the service area.

Figure-2 shows the results of this approach using real life data for one of the cities. Computation time is less than one minute.
It is sometime necessary to adjust the automatically calculated blocks based on design, constructability or RoW issues. Various tools are provided for manually performing these activities within ArcEditor session. It is also necessary to precisely locate the DPRS station point (Structure) in specific premises. Since the above algorithm suggests location in a specific 1 SqKM grid, this task is simplified to a great extent.

In the next step, NetworkAnalyst Extension based AGS service is utilized to perform optimal route calculation. Computation time is around 2 minutes due to route passing through large number of points.

Lastly, the route validation tool not only performs the route validation for any unwarranted duplicate segments / miss-outs etc. but also ensures that the demand information is populated at various nodes so that the spatial route data with the structures can be used by SynerGEE. A sample screenshot of completed route network is shown in Figure-3:

Integration of GIS and SynerGEE

- Customised application developed on GIS platform allows users to optimize the number of DPRS, their location, service areas and routing. However, sizing of each network element is equally important to reduce capital cost of CGD network. The spatial network (locations / route) is seamlessly accessed by engineering software like SynerGEE® for network element sizing.
- SynerGEE Model Builder allows query, filter and import of data from all ESRI formats including enterprise geodatabase, to build SynerGEE Network models. It converts GIS point data into SynerGEE facilities like regulator stations and compressor stations. Bidirectional transfer of demand/supply data, polygons and other model-specific information is possible.
- SynerGEE® Gas Automated Design Module (ADM) enables user to assess pipe size options for the network model with specified loading conditions, material cost,
installation cost and location. ADM calculates lowest possible pipe diameter for transporting required quantities of gas to delivery points.

- Users directly access the GIS optimized spatial network for further optimal sizing of each element by creating the SynerGEE network model. The ADM module then iteratively solves the piping network to arrive at the optimal size of each line, storing results in the SynerGEE model.
- In the last step, GIS User imports the data such as line sizes, pressure profile etc., from SynerGEE for printing and issuing Design / Construction drawings through GIS.

Key Benefits

Key benefits of the GIS based CGD network planning and design system are:

- Implementation of planning and design work process defined by business and engineering users resulting standardized and reliable design.
- Complete revision management of all deliverables within the application.
- Controlled spatial / attribute data creation / storage for reliable results.
- Optimal DPRS location, service area & routing for substantial cost saving.
- Flexibility to change the design to suit the site conditions.
- Tight integration with SynerGEE for design calculations.

With the help of this solution, planning of Steel Pipe network of a metro city after evaluating 3-4 alternatives can be completed in 2 days, a significant reduction from current industry benchmark of 2-3 weeks.

Way Ahead

The application meets all, and exceeds most of the user requirements in the design of main Steel network. The application is presently designed around ArcMap client limiting its deployment. It can be converted to a web application, permitting more users to design larger downstream network, even remotely. The downstream PE network and last mile will involve much more amount of manual work with limited further design optimization. Additional functionality will be developed, to tackle the scalability.

References:

2. A Clustering-Based Approach to a Special Capacitated Facility Location Problem by Ke Liao and Diansheng Guo