International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.2, pp : 124 - 129 1 Feb 2014

An Approach to Integrate Geographic Information Systems to the proposed Smart Grid for Dhaka, Bangladesh

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Abstract: ***Smart Grid is an innovative perception which refers to the conversion of the conventional electric power grid to a modern grid. Geographic Information Systems* (GIS) *can be used as a significantly useful tool to* solve *the power crisis and meet the electricity demand, through a better utility management system. The spotlight of this paper is to analyze the necessity of GIS for establishing Smart Grid in Dhaka, Bangladesh.***

Keywords: Smart Grid, Geographic Information Systems, Electric Power System Network, Solar PV, Utility

I. Introduction

Power system engineering is a fast growing area with tremendous potential for research. Application of information technology into power system is providing an excellent opportunity to take this research work to a new height. To improve the system efficiency and utilize the energy sources precisely, new concepts have evolved considering the demands of the people as well as use of energy in most efficient way. 'Smart Grid' is one of the most remarkable and sustainable concepts nowadays to provide secured, reliable, clean and high quality electricity supply. As patterns of customer demands vary , the utilities need to provide better quality, more reliable electricity at a fair cost. The U.S. Department of Energy defines the Smart Grid as the digital technology that allows two-way communication between the utility and its customers, and the sensing along the transmission lines.

Electric power system needs to be well planned for more accurate and efficient operation with more simplicity for maintenance by the operators and users. In order to perform efficient operation and control of this huge network, use of Geographic Information Systems (GIS) is an added advantage for planning. GIS is a smart technology which can be used as an important element of smart electricity network. This technology facilitates electricity network planning along with improved system operation, maintenance and efficiency. The ability of GIS to look for databases and carry out geographic queries has been found as an economically efficient solution for power utilities. GIS have been used in electric power applications for network planning, future expansion forecasting, rapid automatic decision making, proper management of system, keeping the profile of the system upto date with less possible changes into system, integration to SCADA system, solar and biomass energy resources, wind energy evaluation, optimal siting of wind and solar farms and their integration to the grid etc. [i].

II. GIS and Smart Grid

Geographic Information Systems (GIS) are a computer-based tool for mapping and analyzing things that exist and events that happen on earth. This technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These capabilities distinguish GIS from other information systems and make it valuable to a wide range of public and private ventures for explaining events, predicting outcomes, and planning strategies [ii]. Dueker & Kjerne (1989) developed one of the most accepted definitions of GIS, "A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth". GIS give the power to create maps, integrate the information, visualize the scenarios, save the data, plan the system with innovative ideas and solve the difficult problems to develop solutions. GIS relate different information in a spatial context and then reaches a conclusion about the relationship. It stores information as a set of thematic layers those can be linked together by geography. This powerful and versatile concept is very useful for solving many power system related problems such as recording the details of planning activities, network expansion program, load forecasting, land usage for tower establishment, economical and efficient routing, contingency analysis etc. It can disclose new information that leads to better planning and decision making.

Smart Grid consists of controls, computers, automation, and new technologies and equipment working together with the

electrical grid to respond digitally to our quickly changing electric demand [iii]. Comparing with the traditional grid, a Smart Grid includes advanced metering and billing techniques, system automation, dynamic pricing techniques, demand side management, congestion management, advanced sensing, electric vehicle charging, energy storage, integrated communication systems, modern technologies to support the distributed generation, complete decision support, forecast and human interfaces etc. Smart Grid makes the power system secure and reliable, economical in operation, encorporated with clean and green energy sources, optimized of assets and costs, interactive and real-time responsive, self-healing, flexible and compatible, integrated, accommodated with storage options, to provide power quality for the range of needs in a digital economy, to operate resiliently against physical and cyber-attacks and natural disasters, to capable of active participation by consumers, more efficient in transmission and distribution of electricity, quicker restoration of electricity after power disturbances, to help reduce operations and management costs for utilities and ultimately lower power costs for consumers, to help reduce peak demand which will also help lower electricity rates, better integration of customer-owner power generation systems, including renewable energy systems etc. [iii].

III. Integration of Geographic Information Systems to the Smart Grid for Bangladesh

If a Smart Grid can be constructed, Bangladesh will enjoy all the benefits of a modern day power system infrastructure. During peak time in summer in Bangladesh , total demand crosses the maximum generation limit, so planned load shedding is a common phenomenon. Utility engineers and experts say that, the demand deficiencies can be met up in urban areas with peak load shaving and proper systematic usage of present supplied power. Establishing Smart Grid in Bangladesh will facilitate the power system with modern day technologies, thus the country by:

- Faster industrialization and economic growth through a stable, reliable, efficient power supply
- Secured and self-healing network
- Installation of automated metering infrastructure
- Improving generation and distribution p rotection system
- Introducing integration of d istributed energy resources
- Automatic load−shifting and switching
- Creating a deregulated market
- Making economic benefit
- Faster digitization
- Helping planning for the future expansion
- Protecting the environment

GIS' ability to look for databases and carry out geographic queries could be an economical solution for the power utilities in Bangladesh . Integrated GIS will help to reduce costs by reformation of customer service, reducing land acquisition and maintenance costs for establishment of towers, better logistics analyzing data etc. Basically electric power industry is itself a huge industry anywhere. Implementation of GIS in this industry has ensured the benefits of improved management of the organization and its resources. The way this system helps to link all the data sets and share the database, it eases the control and operation of many difficult and time consuming works. For example, the power utility can integrate the customer and its infrastructure database while planning for expansion and maintenance. For decision making in the power utility, GIS helps by querying, analyzing and mapping of data. Decision makers or planners could take the information from GIS very briefly and accurately with the help of the needed map with associated reports and thus could take better decision.

In Bangladesh, t he electricity generation, transmission and distribution system is quite old, back dated and complex in nature and hence the intention of introducing Smart Grid is to up-to date the power system network with the help of the information technolgy network . GIS will help the utilities discover newer thing in investments and risks, reduce the costs of manual labor and allow simultaneous assessment of technical, financial and environmental factors. The database of billing, material account, distribution analysis, outage reporting can be done through this system. The routing of network can now be chosen by the help of GIS. The electrical map can be suitably fit over the base map and with the help of software the changes in the network can be easily updated in less time with more accuracy. The optimization of electric line routing, selecting suitable sites for locating new feeders, load forecasting, load distribution, best possible design and plan for generation site, distribution substation location and capacity etc. features can be well served using the GIS softwares [iv]. Implementation of the optimization methods such as automated optimal routing by dynamic programming for the new power lines and optimizing substation's location and capacity can reduce the time required in design and thus improve the quality of the system [iv]. Geographic and technical constraints should be taken into account for transmission and distribution network planning caried out by Bangladesh Power Development Board, Dhaka Power Distribution Company Ltd , Dhaka Electric Supply Complany Ltd, Rural Electrification Board. Efficient planning method could be chosen which can automatically select the

appropriate size and location of substation, appropriate sizes for the conductors and routing of the feeders considering all the technical and geographical constraints which provide minimum total cost. Sequential quadratic programming and minimum path algorithm could be used to solve these problems [v].

This work looks into the integration of Smart Grid concept and GIS for better power system planning in Dhaka, Bangladesh. Distributed Generation (DG) is one of the components of Smart Grid. GIS geo-information, geo-computation, geo-visualization and geo-analysis abilities can be used for optimal planning of distributed generation facilities. How GIS can be used as a suitable tool for evaluating technical, economic and environmental factors for establishing DG facilities is described in the article [i] . The processing capabilities to use geo-referenced data in different models and formats have made geographic information systems suitable for planning and optimal sitting of the location of DGs. The circuit analysis data can't be stored as geospatial variables and attributes of fixed physical elements, thus GIS toolkit can not be used for power system load flow studies [vi] . System contingency may take place in the distribution system as a result of any fault or congestion or overloading. Thus when these problems occur, electrical switches have to be operated to ensure the reduction of load losses and thus shorten the power outage time for customers. A novel approach has been suggested where GIS can be applied to perform the distribution load transfer operation [vii].

Smart Grid requires a spatial database (GIS) which supports location specific, real-time actionable data and also provides access to historic measurement data for the network components [viii] . Single line diagrams could be made automatically from GIS through the methodology given by Li et al. (2008). In a distribution system facility the network buses, branches, switches and transformers could be represented. An intelligent routing algorithm has been presented for the power system graph. This algorithm allows different facilities such as the elimination of intersection and overlap of buses [ix].

Thus, a pplication of GIS, one of the components of Smart Grid will ease the procedure of decision making for a network planner. GIS can be used to improve the ability to keep the records of customers and other assets geographically. Though it's not been started yet, but GIS can be used in Bangladesh power sector in the electricity routing network for several purposes such as automated route selection for the construction of new power lines, asset management, proper land use, future expansion planning, decision making on new establishments etc.

IV. Case Study: Dhaka, Bangladesh

The daily power demand is increasing day by day in Bangladesh. Thus to cope up the power shortage situation and to continue with the customer satisfaction level, the utilities are forced to add many new generation facilities of small capacities to its power grid. The case study area has been selected in the city of Dhaka, the capital city of Bangladesh. Presently it is the 9th largest city in the world. Electricity in Dhaka is supplied by two entities, Dhaka Power Distribution Company Limited (DPDC) and Dhaka Electric Supply Company Limited (DESCO). For the research , area under DPDC has been chosen. Of all the 132/33kV substations of DPDC, the Dhanmondi 132/33kV substation and its associated networks have been chosen as the main study area of this work.

Distributed generation (DG) is a very widespread and well known topic today for power generation and increasingly is becoming popular. In Bangladesh the growing trend of awareness for generating power from solar PV among the people has already been observed. In the rural areas there are millions of solar home systems already existing, but are not grid connected. The grid connected systems will surely reduce the pressure from the fossil fuels and national grid. DG is becoming popular mainly because of loss reduction, cost saving from transmission & distribution network expansion as it is located near the load centers and scarcity of conventional energy resources. Bangladesh government has set up various rules for the DGs, since November 2010 mandated the installation of roof-top solar panels on all new high-rise buildings [x]. To meet the power crisis and resource scarcity, applications of either stand-alone or grid connected PV systems would be very effective and realistic for power addition. Near about 300MW of power can easily be generated from solar energy to feed the national grid if solar PV systems are installed on rooftops of 20,000 multistoried buildings in capital city, Dhaka [xi].

There has been significant amount of works investigating the evaluation of rooftop area for solar PV applications and urban electrification through rooftop solar PV. GIS tools have been applied by several researchers using different algorithms and methods to estimate the potential area for photovoltaic cells to be set up on building roofs in the urban areas [xii-xiv]. Our aim in this work is to evaluate the potential rooftop area for solar PV installation for urban electrification in Dhaka city with the help of GIS and also map the electricity distribution network. The software used for the analysis is ArcGIS. It is a

system for working with maps and geographic information. ArcGIS is a suite consisting of a group of geographic information systems (GIS) software products produced by Environmental Systems Research Institute (ESRI) [ii].

In this work, the calculation of bright rooftop for the solar PV installation is limited to the study area only. The service areas under the four 33/11kV substations of Dhanmondi 132/33kV substation (could be named as Dhanmondi Grid), have been located in Google Earth software where the earth images are captured from satellites, aerial photography and GIS 3D globe. The areas have been selected not only from the theoretical and conceptual data but also from the field observation and survey. After geographically locating the areas, the map of the potential bright rooftops has been generated. The potential rooftops have been selected by hand digitization method to ensure more accuracy. ArcGIS can also compile the geographic data, analyze the mapped information, share and discover geographic information. ArcGIS is able to manage geographic information in a database. Using the functions of this software, all the informations related to the selected areas and the potential bright rooftop areas have been analyzed. Several limitations and conditions have been considered while analyzing and calculating the total rooftop amount in the areas having the potential for PV installation.

Unlike the related works done by various researchers in different research articles , in this work many inputs to GIS software were processed manually. Practical data collection and observation of the research location have facilitated for having improved dataset for the area. Here, the assessment of rooftop area for the solar PV setup has not been proposed using LIDAR technology or FA tool of GIS. The reasons behind the manual processing of data for evaluation in the study area are: a) Uneven distribution of informal settlements in the area, b) Uneven distribution of population density and building density, c) No correlation between the population and building densities among different areas, d) Incompatibility of many structures for rooftop solar PV setup, e) Extrapolation is not possible due to uneven distribution of population and the density of population varies depending on the types of buildings and informal settlements, f) Bangladesh has six different seasons throughout the year. The solar irradiation thus varies and the analysis based on image recognition is difficult due to weather effects of the rooftop.

Considerable amount of area has not been selected as potential area due to the incompatibility characteristics of those areas for the purpose. For calculating the actual rooftop area for solar PV installation several factors have been considered such as construction and design constrains, shades of trees or higher buildings nearby, obstacles on the rooftop, proper facing of the rooftop, slum areas (informal settlements) and others constraints. The fraction of the actual rooftop area has been evaluated from the total bright rooftop area in accordance with the research from Kabir et al. and that amount is 50% [xv]. The following table shows actual rooftop area evaluated using GIS in four different 33/11kV substation areas of Dhanmondi grid for rooftop solar PV installation.
ArcGIS software has been used in this study to represent the geographical areas along with graphical representations of different parameters of the electrical distribution network. The electricity transmission and distribution network technical analysis in GIS softwares is nearly impossible due to lots of complex and technical issues. But GIS softwares are proven to be an excellent solution for the planning, maintenance, construction and management of the physical assets those are essential for the complex electric network analysis.

The following table shows the actual rooftop area evaluated by GIS in different 33/11kV substation areas for roof-top solar PV installation in Dhaka. The geographic locations of the research area have been represented in the figure 1. Figure 2 & 3 represent study area potential roof-top distribution for soar PV electrification and study area domestic customer distribution, respectively . The existing electric distribution system network has been presented in the figure 4. The whole electric network can be designed with a layer by layer approach. The electric poles, transformers, cables, circuit breakers etc. all the elements could be presented in each layers and over imposing the GIS layers, the whole network scenario would be visible. Each of the layers can store enough data of the equipment's history, management and maintenance scenario, servicing schedule etc. in the GIS database. Creation of different layers of the network has been suggested for future work. The different layers would help the planners and the decision makers to create logics and to find the best solution with the GIS analysis toolkit. Further studies can be done on the integration of GIS tools with the utility SCADA system for the efficient system management, asset management and decision making for network expansion.

Table 1: Calculation of potential power generation from rooftop solar PV in Dhanmondi S/S Service Area

Substation of the Service Area	Total Area	Bright Rooftop Area	Actual Rooftop Area for Solar PV Installation
Dhanmondi 33/11kV	3,346,008 m^2	232,721.62 m^2	116,360.81 m^2
Kakrail 33/11kV	1,660,574.089 m^2	398,783.91 m^2	199,391.95 m^2
Kawranbazar 33/11kV	2,539,521.258 m^2	406,852.51 m^2	203,426.25 m^2
New Ramna 33/11kV	2,285,882.631 m^2	466,399.26 m^2	233,199.63 m^2

International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
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Figure 1: Geographical representation of the study area in Dhaka city

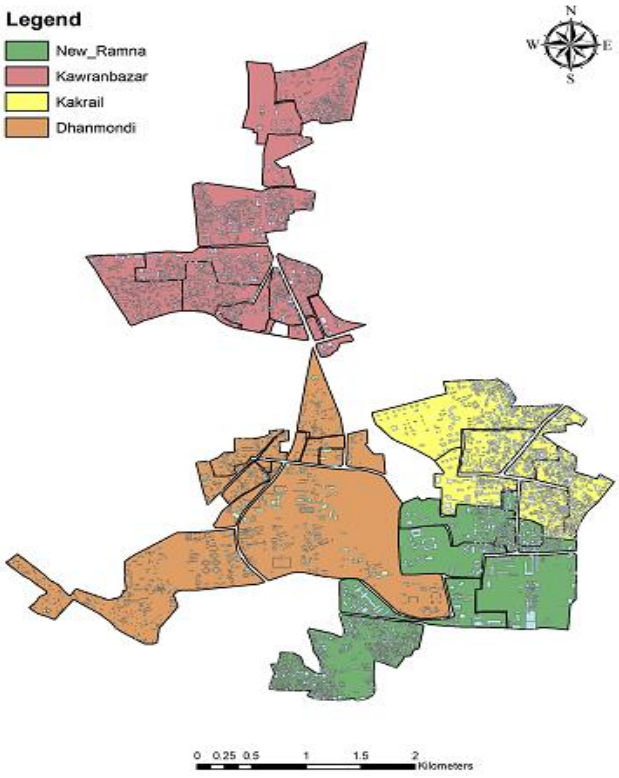

Figure 2: Potential roof-top distribution for solar PV electrification in Dhaka city

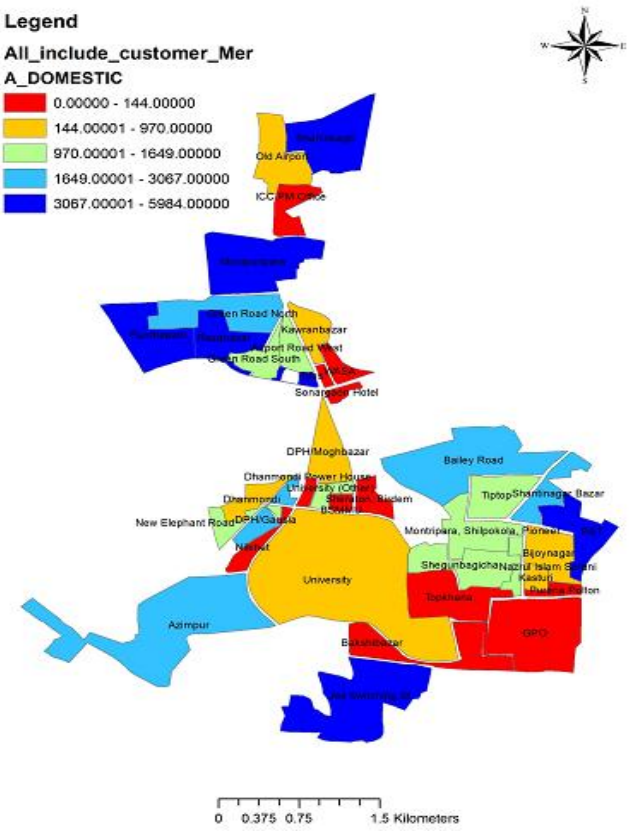

Figure 3: Dhanmondi substation area all domestic customer distribution

Figure 4: Electricity distribution network diagram of the Dhanmondi S/S area

V. Conclusion

Electricity industry has turned out to be one of the biggest businesses and industries now in the world. The utility companies are focusing more on making the maximum profit by serving the people in the best possible way by not hampering the rules and regulations and of course the environment. GIS is a proven component of the Smart Grid that affects the business processes by making the decision making easy. Smart Grid is an obvious option for the attempt to revolutionize the traditional power system in Bangladesh. To ensure the reliability, stability, safety and sustainability of the power supply and economic benefit of the customers, there is no alternative except heading towards the Smart Grid. Inclusion of the GIS technology with other technologies to the proposed system would further enrich the future possibilities.

Acknowledgement

Acknowledgement is due to the Energy Field of Study, Asian Institute of Technology (AIT), Thailand and the Government of Japan for the academic and financial supports. Special thanks to Dhaka Power Distribution Company Limited (DPDC), Bangladesh for the permission for data collection.

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