Support of Energy Supply in Yemen by GIS

Jitka Komarkova, Institute of System Engineering and Informatics
Faculty of Economics and Administration, University Of Pardubice, Studentska 95, Pardubice, Czech Republic, Jitka.Komarkova@upce.cz

Ahmed Ba Hakim, Institute of System Engineering and Informatics
Faculty of Economics and Administration, University Of Pardubice, Studentska 95, Pardubice, Czech Republic, as.bahakim@gmail.com

Abstract

Geographic information systems (GIS) are increasingly used to manage various utilities, e.g. gas, water or electricity supply chain. Utilization of GIS by various utilities located in different geographic regions is briefly described at first. Operation of a selected electric utility in Yemen before and after implementing GIS is compared to identify changes in productivity, network monitoring and customer services. Benefits of GIS implementation and future work are described in the end.

Keywords: GIS, electric utility, electricity distribution.

Introduction

Access of citizens to electric energy belongs to important current development goals in many countries, including countries owing oil and gas reserves, like Yemen. According to El-Katiri (2014), access to electricity in Yemen still remains incomplete, especially in rural areas. Geographic information systems (GIS) have currently been implemented by many utilities because they have been proven to be one of the best means for facilities, equipment and personnel management. Inclusion of location and graphical visualization represent main advantages and benefits of GIS implementation. Costs reduction follows proper resources management, as stated by Kwan et al (2014). Utilization of GIS supports management of business processes in company. According to Šimonová (2012) management of business processes significantly helps to fulfil business goals.

A computational system based on geo-referenced data and Google Maps technology has been recently developed in Brazil to support planning of electrical network expansion, as described by Netto (2015). GIS is a very frequently used tool to support planning, utilization and management of renewable energy, i.e. wind energy in Africa (Mentis et al, 2015) or renewable energy in general in Brazil (Tiba et al, 2010) or Turkey (Gungor-Demirci, 2015). GIS is used to efficiently manage electricity transmission networks as well (Bayliss and Hardy, 2012). A disadvantage of GIS is their complexness, so users must learn how to use them. Suitable mobile learning methods may help to solve the problem (Kopáčková, 2014).

Yemen belongs to countries who have implemented GIS to increase an efficiency of electricity supply. Aim of the paper is to evaluate the first experience and benefits of GIS implementation by the Yemeni Public Electricity Corporation.

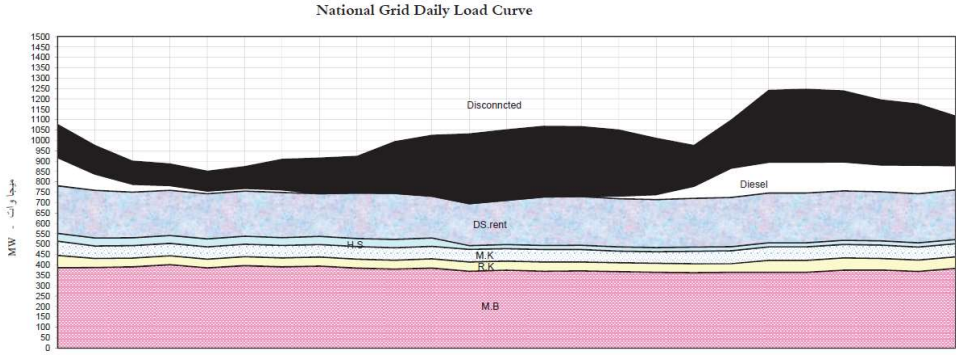
Electric Energy Distribution in Yemen

Situation in Yemen can be described by the following numbers for year 2010 stated by El-Katiri (2014): total production was 7 757 TWh for 24 million of inhabitants, electricity consumption was 249 KWh per capita (the lowest value in the region) and electrification rate was 39.6 % - mostly in urban areas (in 2009). Situation in all other Gulf countries was significantly better from all points of view, including 100 % of electrification rate in Kuwait and UAE. Other countries followed with 98 – 99 %. The only

exception was Iraq with 86 %. This fact required improvement of situation in Yemen, starting with improving services and efficiency of energy distribution.

In Yemen, there is a sole national public utility with a mandate for the generation, transmission, distribution and sale of electricity in the country, named Public Electricity Corporation (PEC-Yemen). Traditionally, electric energy distribution companies run local offices to manage network and to support customers in the region.

In early years, PEC-Yemen experienced many problems with electricity generation, transmission network and operation of the whole supply chain. It resulted in difficulties with ensuring electricity supply for growing Yemen population. In addition, decentralized population pattern is most typical for Yemen. It represents another significant factor which influences electricity supply chain design and performance. Increasing household demand and connected economic analyses (including prices evaluation) were calculated by World Bank (Wilson et al, 2010). The study showed that many households had to use small generators, dry cells and kerosene lighting when electricity supply network was not available. These sources were expensive and negatively influenced environment. Optimization of supply network and efficiency increase were necessary, alongside with involvement of renewable energy (namely solar and wind energy) because of air pollution caused by fuel combustion, as stated by Al-Shamiry (2014). Application of the slow Coherency Decomposition Method was proposed by Badeeb and Hazza (2004) and it clearly showed that performance improvement of the Yemeni network is possible after an adequate analysis by Badeeb and Hazza (2004). The network covers traditional fuel power plants, hydroelectric and geothermal energy and other renewable energy sources. **Chyba! Nenalezen zdroj odkazů.** clearly shows changing load during a day and disconnected customers.



Time Hour / Power MW	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	19:30	20:00	21:00	22:00	23:00	Min MW	Avr. MW	Max MW
Prog.disc.	160	138	112	104	95	105	147	172	177	248	293	336	339	340	337	318	271	197	231	346	351	342	313	294	239	95	243	351
Gen.R.	387	388	391	402	386	397	391	395	385	380	385	370	375	370	372	368	365	363	365	365	365	375	376	369	384	363	373	402
Ger.D	166	142	140	140	140	142	141	143	143	143	145	123	124	124	123	119	119	123	124	142	142	144	140	138	139	119	135	166
Gen.Gas.	135	78	38	23	13	13	13									13	24	58	142	149	149	140	130	138	117		51	149
Gen.S	229	230	220	218	218	218	218	206	219	222	202	202	213	234	235	232	231	235	237	240	240	238	236	236	239	202	226	240
Total.Gen	917	838	789	783	756	769	762	743	747	745	732	695	712	728	729	732	739	779	867	895	895	896	882	881	879	695	791	917
Demand	1076	976	901	886	851	874	909	915	923	993	1025	1031	1051	1068	1066	1050	1010	976	1098	1241	1246	1238	1194	1175	1118	851	1034	1246

DAILY ENERGY (MWh)

GENERATED	DISCONNECTED	DEMAND	Generation %	L.F
17,564	5,650	23,214	76	77.6

Fig. 1. National grid daily load curve (PEC-Yemen)

Pre-GIS State in Electricity Distribution

PEC-Yemen supplies electricity across the whole country (urban areas) as the main electricity supplier. In the beginning, the normal operation meant distribution through transmission lines without any form of precise monitoring. The first issue observed in this period was the increased level of vandalism (see Table 1). This vandalism involved the theft of transformers, broken power lines and even posts that had fallen after torrential rain. Vandalism results into electricity blackout (system downtime), lost income of PEC-Yemen and irritated clients who cannot use electric devices (i.e. business losses).

Table 1: PEC-Yemen – Number of Cases of Electricity Supply Network Vandalism (PEC-Yemen)

Year	Number of Attempts	Successful Attempts
2006-2007	814	800
2007-2008	925	925
2008-2009	1027	1000
2009-2010	1090	1051

Fast identification of failures is not easy without any sensor network or any other advanced technique. Typical way of identification of vandalisms and failures in that time was personal inspection of major connection. Another possibility was to obtain information from customers by a phone. This way of monitoring was very time and money demanding and it was quite unreliable. In this situation, there can be significantly slow response to failures caused by vandalism (and all other reasons) without monitoring of the whole supply network. In the case of PEC-Yemen it means that 1 day response occurred only in 5 % of cases, 1 week response occurred in 21 % of cases, 1 month response occurred in 24 % of cases and the rest (50 %) was highly delayed (Source: PEC-Yemen).

Illegal electricity consumption and poor customer services represent other problems, reported by employees and customers of PEC-Yemen in that time which required improvement.

State in Electricity Distribution after Implementation of GIS

All the listed problems resulted into GIS implementation to fully support facility management and network monitoring. The project started in 2006 – 2007 and GIS have been used from 2010 in an adequate extent of implementation. The implementation has allowed more reliable network monitoring. Due to improved monitoring, decreasing number of vandalism cases is the first important positive result (see Table 2).

Table 2: PEC-Yemen – Number of Cases of Electricity Supply Network Vandalism after GIS Implementation (PEC-Yemen)

Year	No. of Attempts	Successful Attempts
2010	1500	400
2011	1200	327
2012	750	110
2013	310	43
2014 – partial data	100	17

Next significant improvement can be observed in the case of response time because of faster recognition of electricity supply failure. 30 % of cases are solved within 1 day, 55 % within 1 week, 12 % within 1 moth and only 3 % of cases are delayed (Source: PEC-Yemen).

Customer satisfaction increased too along with increased quality of services. Table 3 contains results of a random survey, in which 500 customers took part. Main reasons are: faster response to network failures, electronic bills and other information and faster answers from the customer care centre side.

Table 3: PEC-Yemen – Customers Satisfaction before and after Implementing a GIS (PEC-Yemen)

Satisfaction	Respondents (without GIS implementation)	Respondents (with GIS implementation)
Very dissatisfied	150	15
Dissatisfied	110	25
Slightly satisfied	140	50
Satisfied	70	318
Very satisfied	30	102

Cutting illegal connections (and electricity consumption) is very important for PEC-Yemen itself because they can stop high loses due to monitoring of the network. Utilization of a GIS-based facility management represents another benefit because it helps to more efficiently plan maintenance and design of new parts of energy supply network.

The main benefits of GIS utilization are:

- Workflow automation or improvement
- Monitoring of existing network and equipment
- Decision-making improvement during zoning, routing and planning new networks
- Spatially-oriented management
- Improvement of planning and resource allocation (facility management)
- Improvement of communication between company and citizens and company and between departments themselves
- Improvement of data recording and maintenance
- Improvement of different data (e.g. remote sensing imagery, sonar, LIDAR data) integration

The obtained result is represented by a network of well monitored lines whose breakage is immediately noted. Customer care in terms of repairs and sorting out outages is also done faster than in their previous system. This influences the company's revenues and operations improve with time.

Future work

The first benefits of implementation of GIS are clearly visible. Because of the lack of financial data, it is difficult to precisely calculate return on the investment and other economic indicators. Contemporary political situation causes some complications in more detailed data collection and utilization. The future research can be split into two main directions:

a) Utilization of GIS. GIS can be used to support planning and design of new parts of the network and optimization of the network and its capacity: network analyses and digital terrain models are suitable tools. Remote sensing can be easily used to collect data from rural areas with complicated (or dangerous) access. Different scanners can be used to measure terrain, network and other conditions. Obtained data can be imported into GIS and used to improve planning.
b) Economical assessment of costs and benefits. This evaluation requires detailed data and time series which is difficult to obtain now.

Conclusion

Yemen represents one of developing countries which have shifted from use of paper maps to utilization of the GIS is the field of electricity supply. The country has implemented the GIS system throughout its electrical network, from electricity generation to transmission and distribution to final customers. The new system has reduced the need of stationing engineers in various parts along the transmission lines as the whole grid can be monitored from a central position. An added advantage that comes with the adoption of this system in electric utilities is the increased revenues. These added revenues are due to

reduced cost of operations, as the system takes over most of the duties of monitoring the electrical network. Other benefits come from identification and prevention of illegal energy consumption.

Another important way of GIS utilization is planning of a reasonable network extension into rural areas, as it is recommended in El-Katiri (2014). From global point of view, GIS is one of tools which can support better distribution of electrical energy in Yemen and support development of the whole country.

Acknowledgment

This paper was supported by the SGSFES_2015001 fund provided by the University of Pardubice.

References

Al-Shamiry, F.M.S. (2014), 'The Air Pollution by Fuel Combustion,' [Online]. Proceedings of International Conference on Agriculture, Food and Environmental Engineering (ICAFEE'2014), [Retrieved September 1, 2015], 15-16 January 2014, Kuala Lumpur, Malaysia, 29-31, http://psrcentre.org/images/extraimages/7%20114532.pdf.

Badeeb, O.M.A. and Hazza, G.A.W. (2004), 'Application of the Slow Coherency Decomposition Method to the Yemeni Network,' *International Journal of Electrical Engineering Education* 41 (1), 56-63.

Bayliss, C.R. and Hardy, B.J. (2012), Transmission and distribution electrical engineering, Elsevier/Newnes, Oxford.

El-Katiri, A. (2014), 'The energy poverty nexus in the Middle East and North Africa', *OPEC Energy Review* 38 (3), 296–322.

Gungor-Demirci, G. (2015), 'Spatial analysis of renewable energy potential and use in Turkey,' *Journal of Renewable and Sustainable Energy* 7 (1), 013126, http://dx.doi.org/10.1063/1.4907921.

Kopáčková, H. (2014), 'Preparedness for mobile learning at higher education'. Proceedings of 10th International Conference on Digital Technologies (DT) 2014, ISBN 978-1-4799-3303-7, 9-11 July 2014, Zilina, Slovakia, 146-151.

Kwan, M-P., Richardson, D., Wang, D. and Zhou, C. (2014), Space-time integration in geography and GIScience: research frontiers in the US and China. http://dx.doi.org/10.1007/978-94-017-9205-9.

Mentis, D. et al. (2015), 'Assessing the technical wind energy potential in Africa a GIS-based approach,' *Renewable Energy* 83 (C), 110 – 125.

Netto, V.A. (2015), 'Planning of network system for the distribution and transmission areas of electric energy,' *IEEE Latin America Transactions* 3 (1), 345 – 352.

Šimonová, S. (2012), 'Identification Of Data Content Based On Measurement Of Quality Of Performance,' *E+M Ekonomie and Management* XV (1), 128-138.

Tiba, C. et al. (2010), 'A GIS-based decision support tool for renewable energy management and planning in semi-arid rural environments of northeast of Brazil,' *Renewable Energy* 35 (12), 2921 – 2932.

Wilson, M, Jones, J.B and Audient, P. (2010), A New Slant on Slopes: Measuring the Benefits of Increased Electricity Access in Developing Countries. Report No. 53963-GLB. [On-line]. Energy Sector Management Assistance Program (ESMAP), World Bank. [Retrieved August 30, 2015], http://www.esmap.org/sites/esmap.org/files/ESMAP%20Benefits%20of%20electrification%20Final.pdf.