Integration of GIS with Survey Data for Electrical Asset Mapping in Robertsganj town of India

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ABSTRACT: GIS based consumer indexing and electrical network mapping delivers a tool for consumer, asset and electrical load management for actual decision making in the power sector and its database applications can increase the utility's efficiency if appropriately integrated with other business developments. In India, the power submission department continuously wishes to update their consumer data and the related electric asset features. The consumer's data source has to be recorded and show the pertinent linkages with the distribution transformer (DTR), feeder and substation. The present paper mainly focus on the application of geographic information system (GIS) integrated with high resolution remote sensing data and field survey data for mapping of various electrical asset elements of Roberstganj town of Uttar Pradesh, India. The electrical assets like high tension line (HT), low tension lines (LT), distribution transformers (DTRs), various types of electrical poles, feeders, substations etc. of Robertsganj town are extensively surveyed using the high resolution remote sensing data and then updated on GIS platforms using ARC GIS10.3 software. The exact location of each electrical asset elements of the study area is captured using GPS and same has been plotted on the remote sensing data. In the study area electrification rate is low which approximately 50-60% is and quality power supply is still a faraway. It is identified that the total HT and LT pole in 2011 is 959 and 1421 respectively while it is 1733 and 1899 in 2015. Electric data base prepared though GIS is very useful for decision making, future planning and study such as locations of dangerous poles, load on a specific transformer or location of loose jumpers of HT/LT lines.

KEYWORDS: GIS, electrical assets, remote sensing data, ARC GIS-10.3, surveying, mapping

1. Introduction

An electric distribution utility uses a network of physical services to deliver electric power and energy to daily consumers to those facilities throughout any geographical region. Electric power shortage is one of the main culprits in hindering the overall development in these countries and also a cause of societal disparity (Shekhar et.al., 2008). Each component of the electrical asset distribution system has a known physical location and related data. A complete, detailed electric asset connectivity survey and data is significant for accurate planning and proper functioning of the electric network in any town. Power is the most important infrastructure for the development of the county. The facilitating policy framework, the regulatory mechanism for analysis in generation, transmission, distribution and other related activities have already been put in place by the government. Power industry consequently has to keep track of numerous poles, circuits, power lines, and transformers. Information of location (Adetoro, 2005; Yadav, 2013), voltage, and distribution of electricity of these facilities seem to be very overwhelming.

In India, electrical network data are not properly updated, the consumer's data are inaccurate and the details of the electrical assets and facilities are not properly available on the map. Technological advancements are taking place much faster in generation and transmission sectors in India (Laxmi and Maguluri, 2006). GIS are now being used extensively for the mapping and modeling of electrical utility network systems and it's updating in very less time and more precise on a short duration and a widespread solution encompassing the whole business value chain in the power distribution sector has been delivered easily using this technology.

GIS is built from a mapping foundation and thus creates a visual interface to the data. In addition to normal database queries, information can be examined through a variety of spatial attributes such as distance, proximity, and elevation (Wang et.al., 2010; Rai and Singh 2016). GIS also helps with network routing which determines the optimal path that has the shortest and the fastest distance and minimum cost (Rezaee et.al.,2009) and it can be used to save consumer data source and graphically illustrating the customer's electric connection on an electric map, using GIS software. The whole electric survey data can be overlapped on a GIS platform or on remote sensing satellite data having appropriate spatial resolution to identify existing electrical asset features and other existing land use land cover like settlement, transportation network etc. in the area. Using the GIS, when a particular DT is selected, then all the LT lines linked with that DT and each consumer connected with respective LT range can be displayed. Using GIS program, all program resources (HT/ LT lines, feeders, DTs, Poles) can be listed with regard to a well-defined alpha-numeric code, which exclusively recognizes the particular program factor.

Conventionally, collection and uses of survey data in the ground is a paper-based and tedious exercise with collection of the various electrical asset elements without retrieving to real-time data. The processes of field survey data collection, editing and error removal have been time taking exercise. Geographic data can be uses field in the form of hard copy maps. Field edits were performed using sketches paper maps and forms and these sketches can be edited while returning back to the office in the GIS platform (Sardadi 2008; Sharma et.al., 2013). GIS technology can contribute meaningfully in power improvements processes such as, revenue management, operations management, energy management, consumer relationship management reduction of ATC losses and also play an vital role for distribution loss reduction system and various steps i.e. GIS based consumer database indexing, GIS based electrical network mapping, metering, billing & collection efficiency, energy audit and accounting practices, supervisory control & data acquisition (SCADA) system & distribution automation, maintenance management system, management information system (MIS), load forecasting and load planning can be implemented for proper development of the power sector (Sinha, 2011).

EGIS (Electric network geographic system) in India provides the utility company with the capability to monitor smart grid networks and perform queries about the network health and the system can show the complete network and highlight assets that have altered or that are malfunctioned

(Sharma et.al., 2013). During the previous study by the researcher, it is found that the transmission and distribution losses in India are in the range of 35-40% and it can be slightly reduced by using GIS (Raghav and Sinha, 2006) and it is very helpful for mapping of the various electrical assets elemnts like HT/LT line, DTRs etc. (Kumar and Chandra, 2001, Lgbokwe and Emengini, 2005). Latest technology i.e. GIS in the study area is very helpful for existing related asset mapping and consumer indexing which helps in reducing power losses (ATC losses) for electric distribution utility.

2. Study Area

The study area covers about 30 sq. km. of the Sonbhadra town of Utter Pradesh, India, located at 24.7°N latitude and 83.07°E longitude (Fig.1). Robertsganj is situated in the south eastern corner of the Uttar

Pradesh state. Robertsganj is the administrative headquarters of Sonbhadra district. The Sonbhadra district and Robertsganj as its district headquarters was made by carving off the southern part of the earlier Mirzapur district of Uttar Pradesh.

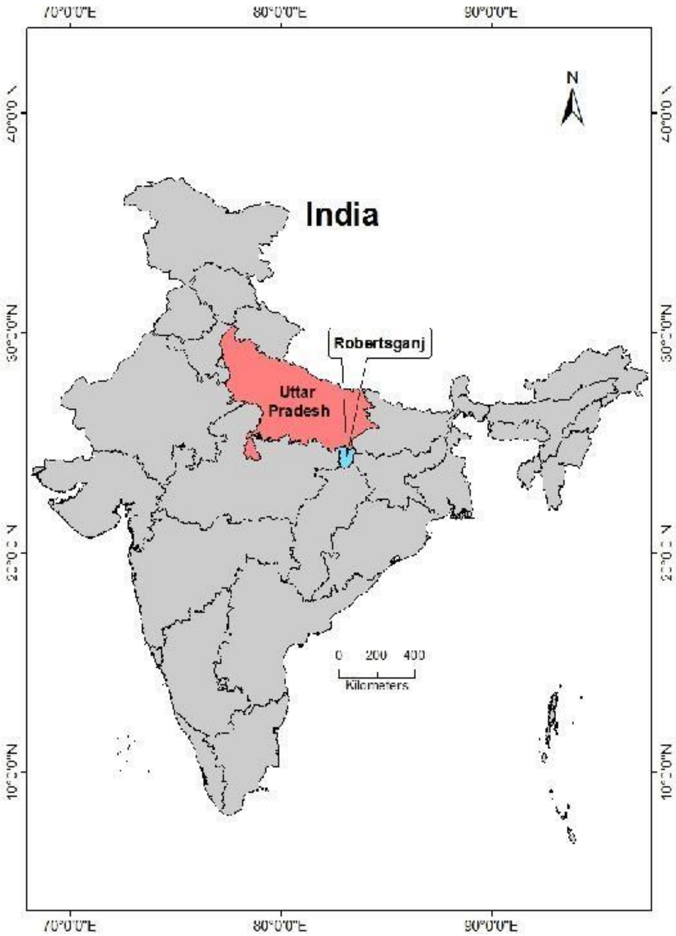

Figure 1 Location of the study area.

It is located at an average elevation of 301 meters and is 90 kilometers away from Varanasi city. As of 2011 India census, Robertsganj is a Nagar Palika Parishad of Sonbhadra district, Uttar Pradesh.

The Sonbhadra city is distributed into 25 municipal wards. The Sonbhadra Nagar Palika Parishad (Robertsganj) has population of 36,689, of which 19,294 are males while 17,395 are females as per report published by Census India 2011.

3. Objective

The main objective of this paper is to prepare a spatial data base of electrical assets of Robertsganj in Uttar Pradesh through field survey data integrated with GIS. In this study changes in the electrical asset elements during 2011 to 2015 on GIS platform are estimated.

4. Data Used and Methodology

Spatial data of electrical assets like HT/LT lines, electrical poles, DTRs feedesr, sub-station etc. are mapped during the field survey. The hardcopy of the study area is used by google earth data to perform the survey activity. Google earth satellite data provides a very high resolution remote sensing data which was very helpful to delineate the feature on the real world. The coordinate point of each electrical assets are recorded acquired with the hand-held GPS, and customers records were linked together and developed into the geodatabase using add xy coordinate in ARC GIS-10.3 environment. Field survey data is updated in the Arc GIS version- 10.3 platform for vector layer generation, maintaining of database and layout preparation which was used for designing of web applications using different controls. These electrical assets data base are very helpful for consumer indexing. For consumer indexing, network mapping and poleto-pole data are calculated during the field survey for spatial data base creation (Govindaraj and Nailwal, 2013).

Following step by step process are accomplished during the study i.e.

- Printed high remote sensing data is used to conduct the survey of electrical assets and unique IDs are assigned to each asset with hand held global positioning system (GPS).
- Geographic features like buildings, transportation network, waterbodies etc. are extracted through satellite data in GIS environment and electrical asset network elements are overlaid on these geographic features.
- A single line diagrams (SLD) of each electrical assets network of individual feeder of the Robertsganj town are also drawn in A4 size paper before digitizing electrical assets network (feeders, distribution transformers and electric poles etc.) to verify the mistakes during the field survey, after that electrical networks are digitized in the GIS platform
- Attribute data are collected during field survey and spatial data of electrical assets are linked with each other in ARC GIS-10.3.
- Base map and electrical network data are further validated through field survey data (hardcopy maps, sketches and SLD)
- Data base of electrical assets of 2011 and 2015 are prepared. Changes in electrical assets during 2011 to 2015 are also calculated accordingly.

In the course of the this work, the outcomes acquired can help in the several areas;

- Mapping and monitoring the status of the electrical services in the existing feeder so as to know the status of the existing electrical facilities in the Robertsganj town.
- Retrieval of Geographical Information of the facilities. The spatial information would include coordinates (X and Y), and symbol representation, capacity and location.
- Update the information system in the case whereby new facilities are to be developed. In the near future, when new buildings/consumers are linked to the existing facilities then the electrical information system can be updated in the data base.

The methodology for electrical assets mapping is shown in the fig. 2.

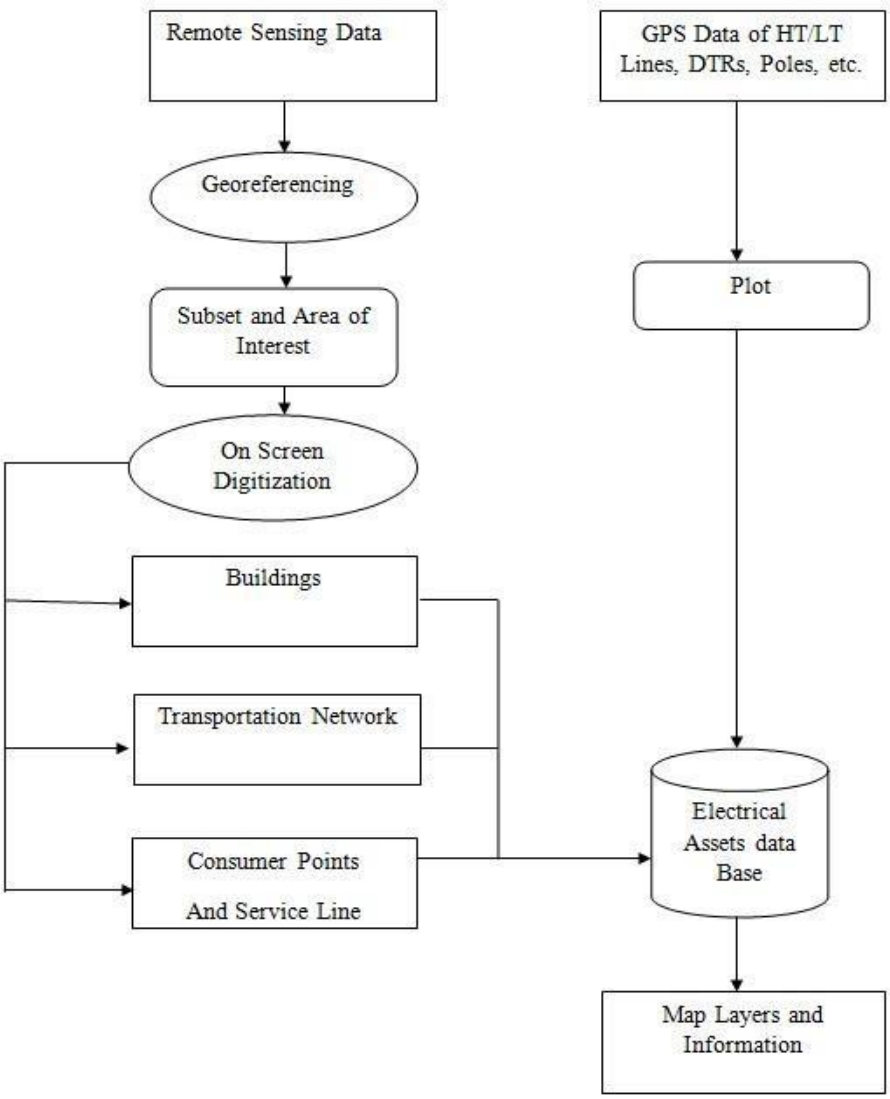

Figure 2. Methodology for Electrical Assets Mapping

5. Results and Dicussion

This study is meant to increase the understanding and networking of electricity power distribution towards effective power distribution. Most significantly, the power industry is anticipated to keep track of the electrical facilities (poles, circuits, power lines and transformers) involved in the distribution of energy to the consumers. With the aid of GIS, variety of information can be well organised on a computer system connecting the database to developed an output map. The main benefit of electrical asset data base is to keep the consumer indexing data which increase the efficacy of distribution system in terms of quality and earn increased incomes by decreasing outages and T & D losses (technical and distribution loss), and to incorporate the functions of different disciplines into the main stream of operational hierarchy through wide networking.

During this study, an electrical data base of each asset elements of Roberstganj of 2011 and 2015 with proper geographical location are are acquired from the field survey using a hand held GPS. Documentation of electrical LT and HT lines, the line length, type and capacity of DTR and types of existing electrical poles are prepared. The sub transmission and distribution network indicating details of 132/33/11 KV Chapk and 33/11 KV hydel colony substation, distribution transformers (DTRs) and the LT/HT lines is very well described and these electrical assets are overlaid on the geographical base map prepared through remote sensing data using ARC GIS-9.3 software. The network documentation prepared in this study provides the facility for tracing the electrical connectivity for any part of the network. That is, it is possible to find out all assets elements electrically linked to any particular LT/HT lines or distribution transformer.

In the present paper, the spatial search operation was carried out through query generation to recover the information stored in the database relating to certain thoroughly demarcated attributes within the database to answer spatially associated questions. This process involved the connection between the database and the map of the selected area of interest. Spatial queries were generated to provide answers to the application use of GIS in developing a model (representation of reality)

During this study, transformer database is also prepared which contain transformer location, pole number, serial number, make, capacity, manufacturing year, installation year. It also shows status and condition of jumpers, etc. Maximum load recorded by transformer has also been included in the databases. Latitude (X) and Longitude of each transformer has also been calculated hand held GPS. HT/LT line's length has been calculated using field calculator in ARC GIS platform. Poles database contains the condition of poles and type of poles etc. Three types of electric poles i.e. HT pole, LT pole and composite pole are identified in the study area. In this study it is identified that the total HT and LT pole in 2011 is 959 and 1421 respectively while it is 1733 and 1899 in 2015. No. of composite pole is also increased from 2011 (200) to 2015 (433). Total number of pole in Robertsganj has been increased from 2580 in 2011 to 4065 in 2015 respectively (Table 1).

Table 1. Changes of electrical asset in the Robertsganj town during 2011 to 2015.

Type of Pole	2011	2015
HT Pole	959	1733
LT Pole	1421	1899
Composite pole	200	433
Total	2580	4065
DTR	175	324

In this study, sub-station wise and feeder wise electrical asset data of Robertsganj are also collected and documented for the analysis. It is clearly seen that the Robertsganj city has two working sub-station i.e. 132/33/11 KV Chapka and 33/11 KV Hydle colony. Currently in these sub-stations, the specifics of assets like electric cables, DTRs, pillar boxes and consumer’s details like consumer number, voltage, consumption, bill date etc., are available in form of tables in a database management system (DBMS). The details of network lines and their description are kept in the form of single line drawings (SLD) and digitally updated in the GIS platform. Capacity wise DTR in each feeder of Robertsganj town during 2011 and 2015 are given in the Table 2 and 3. Sub-station and feeder wise changes of electrical asset in the Robertsganj town during 2011 and 2015 are presented in the Table 4 and 5. Electrical asset location and HT Network in each feeder in Robertsganj town during 2011 and 2015 is shown in the Fig. 3 & 4. Fig. 5 and 6 show the electrical asset location and LT Network in each feeder in Robertsganj town during 2011 and 2015.

At present, total 324 DTRs is identified in the Robertsganj town in 2015 which was 175 in 2011. Substation and feeder wise data was also collected during the field survey and same has been updated in the data base. It is depicted from the Table 2 and 3 that total number of DTRs connected with 132/33/11 KV substation was 145 and 257 in 2011 and 2015 while only 30 and 67 DTRs was linked with 33/11 KV Hydle colony substation in 2011 and 2015 respectively and it is due to increasing load and pressure of new consumers in the city.

It is clearly identified that the 132/33/11 KV substation is a largest substation of the Roberstganj town which supply electric to the city from 04 existing feeders. . In this study, it is also identified that there are so many illegal electric connections and power thefting which might be increased the power load on the transformer (DTRs) during the last 4 years.

It is found that the maximum DTRs (55) was installed in 11KV town No. 2 feeder followed by district head quarter feeder (47) while only 1 DTR was installed in hospital feeder of 132/33/11 KV substation of Robertsganj in 2011 while, 96 DTRs has been connected to both 11KV town No. 2 and district head quarter feeders in 2015 and this is only because of population pressure in the area of 11KV Town No. 2 feeder and district hospital feeder.

Maximum DTRs (39) installation is identified in 11KVA town no.-02 feeder of 33/11 KVA hydle colony substation while 11KV town no.-03 feeder shows only 10 installed DTRs load in 2015 (Table 2 and 3). Capacity wise DTRs of each feeder of Robertsganj are also recorded in the data base and it is observed that the only one high capacity DTR of 63 KVA was installed in 132/33/11 KV Chapka sub-station in 2011 though it is now 2 in 2015. The small capacity 10 KVA, 25KVA and 63KVA DTRs in Robertsganj has been increased during 2011 to 2015. It is found that the maximum 100 KVA DTRs is installed (18 to 54) during the last four years (Table 2 and 3).

During 2011-15, overhead and underground HT and LT network length have been increased in all the two substations of the Robertsganj town. It is detected that the total overhead HT network length in 2015 is 94.80 km in 2015 while it is 55.57 km. in 2011 whereas the overhead LT network length are 60.85 km. and 82.37 km. in 2011 and 2015 respectively.

Maximum overhead HT network is increased (approximate 30 km) in 132/33/11 KV Chapka substation in comparison to the other sub-stations during 2011 to 2015. District head quarter feeder is recorded maximum development in the HT and LT overhead lines. It is noticeable that the nominal increase of LT overhead lines in 33/11 KN Hydel colony sub-station and also electric department is not supplying electricity in town by underground LT network while underground HT network in Roberstganj town has been increased from 1.59 km to 2.45 km.

It is clearly seen from the Table 4 and 5 that the overhead HT network length in each feeder is continuously extending due to continuous population growth, extension of town and demand of new electrical connections in the study area. Many new colonies have been developed in the Robertsganj town which increase the demand of new electric connection and overburden of electric load. Due to this, the concerned department is continuously trying to improve the electric facilities and installed many new DTRs in the Chapka feeder according to the demand and development in the town.

In Robertsganj, the electrification rate is low which approximately 50-60% is and quality power supply is still a faraway. Problems contain many aged infrastructures, high system losses, delays in completion of new plants, low plant efficiencies, erratic power supply, electricity theft, overloading of system components, inefficient planning, corruption and shortages of funds for power plant process and maintenance etc. These lead to extensive load shedding subsequent in severe disruption in all significant and economic activities.

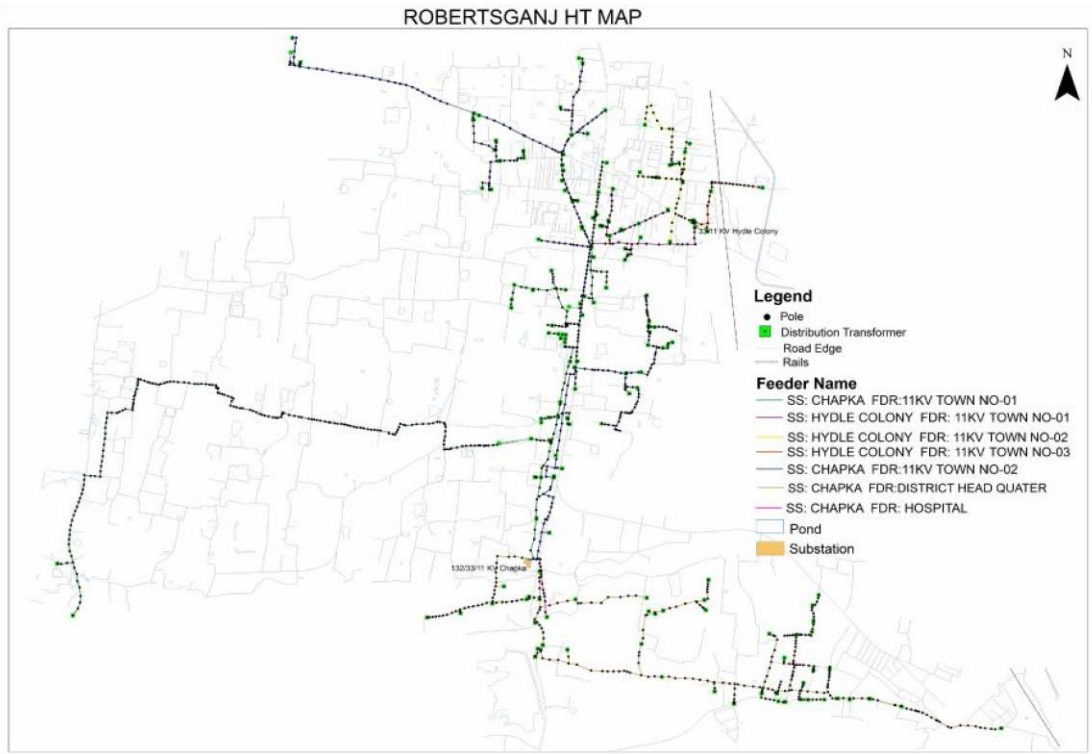

Figure 3 Electrical asset location and HT Network in each feeder in Robertsganj town in 2011.

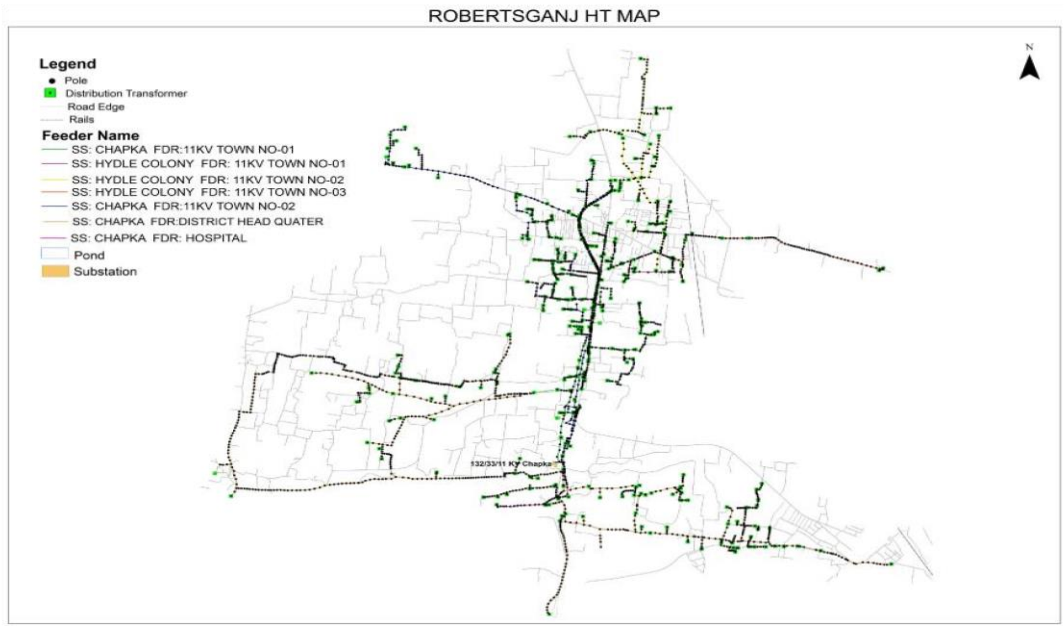

Figure 4 Electrical asset location and HT Network in each feeder in Robertsganj town in 2015.

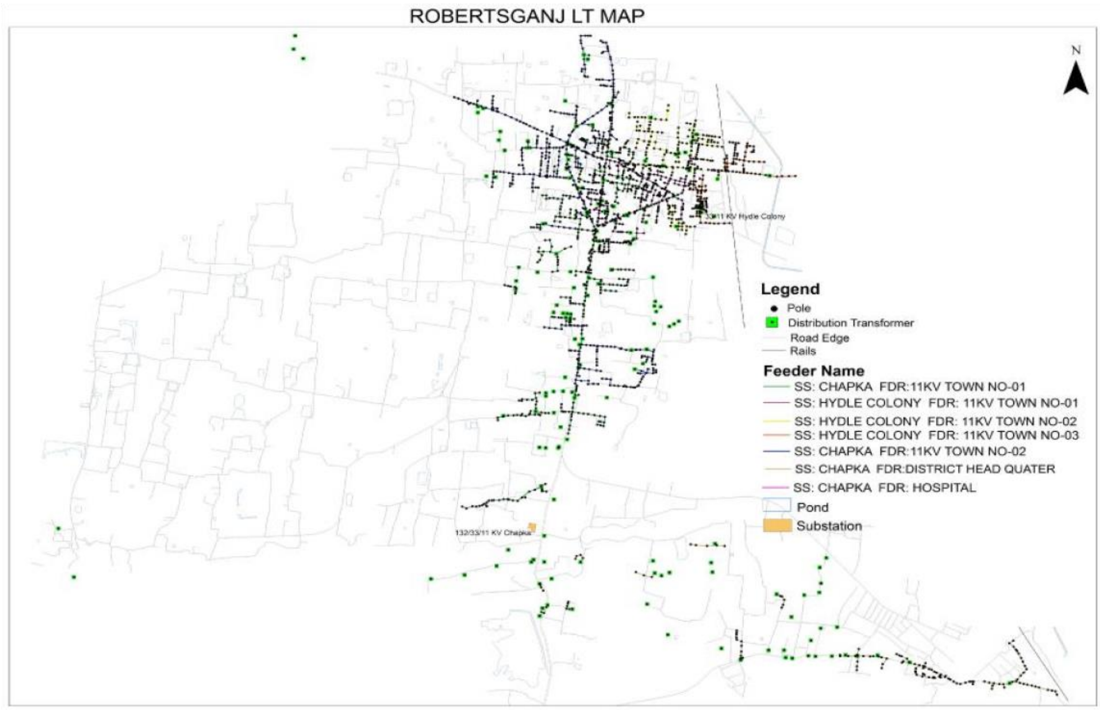

Figure 5 Electrical asset location and LT Network in each feeder in Robertsganj town in 2011.

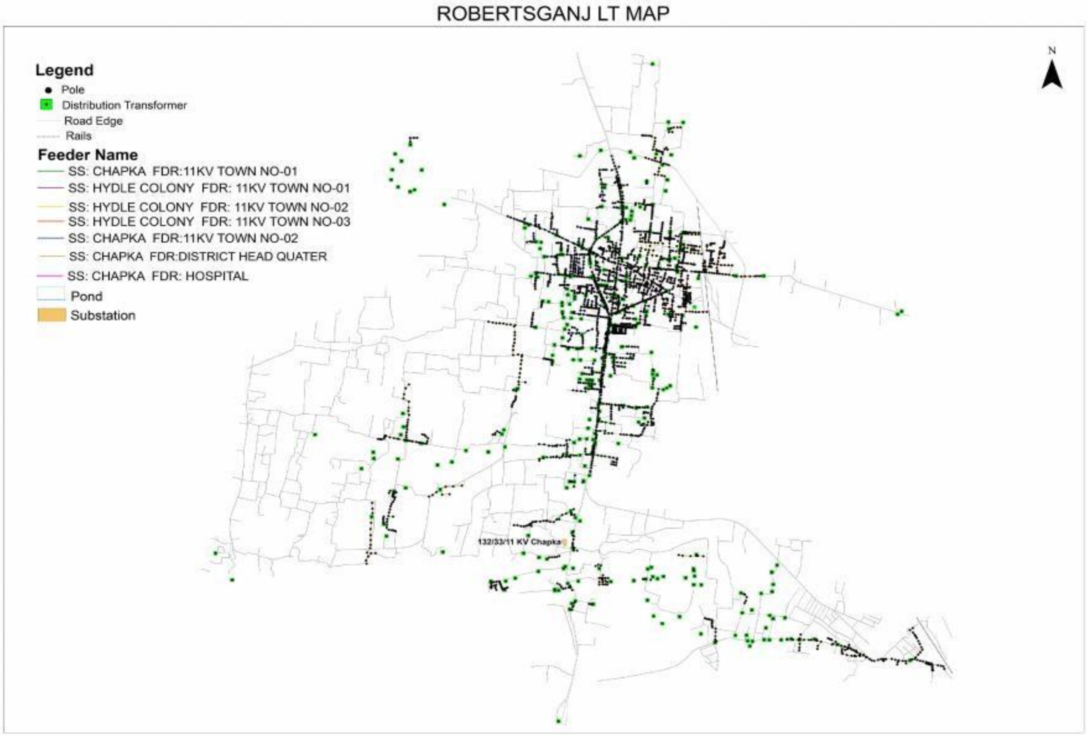

Figure 6 Electrical asset location and LT Network in each feeder in Robertsganj town in 2015.

Table 2 Capacity wise DTR in each Feeder of Robertsganj town, 2011.

Sub Station	**Feeder**	**2011**								
		DTR Capacity								
		10KVA	**25KVA**	**63KVA**	**100KVA**	**160KVA**	**250KVA**	**400KVA**	**630KVA**	**TOTAL**
132/33/11 KV Chapka	11KV Town No-01	17	9	4	4	-	3	5	-	**42**
	11KV Town No 02	11	15	7	10	-	9	2	1	**55**
	District Head Quarter	12	25	4	1	-	5	-	-	**47**
	Hospital	-	-	-	-	-	1	-	-	**1**
33/11 KV Hydle Colony	11KV Town No-01	2	2	2	2	-	4	2	-	**14**
	11KV Town No 02	1	3	-	1	-	5	-	1	**11**
	11KV Town No 03	-	-	-	-	-	4	-	1	**5**
Grand Total		**43**	**54**	**17**	**18**	**0**	**31**	**9**	**3**	-

Table 3 Capacity wise DTR in each Feeder of Robertsganj town, 2015.

Sub - Station	Feeder	2015 DTR Capacity 10KVA	25KVA	63KVA	100KVA	160KVA	250KVA	400KVA	630KVA	TOTAL
132/33/11 KV Chapka	11KV Town No-01	17	11	8	15	1	7	2	2	**63**
	11KV Town No -02	31	22	8	21	-	9	5		**96**
	District Head Quarter	32	42	12	3	-	7	-	-	**96**
	Hospital	-	1	-	-	-	1	-	-	**2**
33/11 KV Hydle Colony	11KV Town No-01	2	1	3	4	-	6	2	-	**18**
	11KV Town No 02	6	10	5	9	-	6	2	1	**39**
	11KV Town No -03	-	1	1	2	1	3	-	2	**10**
	Grand Total	**88**	**88**	**37**	**54**	**2**	**39**	**11**	**5**	

Table 4. Sub-station wise changes of electrical asset in the Robertsganj town during 2011-15

Sub station	Feeder	DTR		HT Underground (Km.)		HT Overhead (Km.)		LT Overhead (Km.)		LT Underground (Km.)	
		2011	2015	2011	2015	2011	2015	2011	2015	2011	2015
132/33/11 KV Chapka	Hospital District Head Quarter 11KV Town No-02 11KV Town No.01	145	256	1.448	2.241	48.114	77.16	39.93	56.37	0.00	0.00
33/11 KV Hydle colony	11KV Town No.-01 11KV Town No.-02 11KV Town No.03	30	68	0.143	0.225	7.458	17.63	20.92	26.00	0.00	0.00
	TOTAL	175	324	1.59	2.46	55.57	94.800	60.85	82.37	0	0

Table 5. Feeder wise changes of electrical asset in the Robertsganj town during 2011-15

Sub station	**Feeder**	DTR		HT Underground (Km.)		HT Overhead (Km.)		LT Overhead (Km.)		LT Underground (Km.)	
		2011	2015	2011	2015	2011	2015	2011	2015	2011	2015
132/33/11 KV Chapka	Hospital	1	2	0.118	0.118	0.651	1.794	0.28	0.78	0	0
	District Head Quarter	47	96	0.054	0.506	15.315	41.214	5.647	14.62	0	0
	11KV Town No-02	55	96	0.518	0.571	16.34	21.250	19.16	17.81	0	0
	11KV Town No.-01	42	62	0.756	1.045	15.78	12.870	15.12	23.92	0	0
33/11 KV Hydle Colony	11KV Town No.-01	14	19	0.032	0.044	3.096	3.001	8.23	9.16	0	0
	11KV Town No.-02	11	39	0.039	0.039	3.098	10.553	7.879	11.71	0	0
	11KV Town No.-03	5	10	0.072	0.141	1.26	4.102	4.88	5.12	0	0
TOTAL		175	324	1.59	2.44	55.57	94.78	61.19	83.15	0	0

Conclusions

From this case study undertaken, it can be concluded that the GIS applications have not reached the optimal investigation and there is still room for further study and addition in the field as far as utility service delivery like in the case of electricity distribution is concerned. It can helps in to maintain the electrical asset, better consumer services, reduction of technical losses, energy audit and accounting, real time operation of distribution network, better revenue protection, long term distribution planning etc in the Roberstganj town.

With this study, future proposed location of DTRs has been easily identified so that with the expansion of the town and development of the area, consumer demands for the electricity will increases then those new DTRs help to meet the demands of consumer and new consumers will not face electricity problem. GIS based Consumer indexing helps to decrease electricity theft and reduce electric losses. By executing electric asset mapping and consumer indexing, it is easy to get all the asset data about electric poles, DTRs & Consumer in the data base and this data base can be used for electrical planning and development by electric department of the Roberstganj town.

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