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GIS IN ELECTRICAL ASSET MAPPING: THE CASE OF BHADOHI, INDIA.

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Abstract

With the advancement of GIS technology, electricity asset system in India is going to be much more benefited in power system planning and management. The integration of GIS with electric utilities is tremendously improving the planning and operation of the power system. This paper basically focuses on the application of emerging technologies like GIS (Geographic Information System) and GPS (Global Positioning System) which are capable of carrying out power system analysis like load flow analysis, load movement, electrical line (HT/LT) changes and electric asset management system using the ArcGIS 10.1 platform in Bhadohi city of Uttar Pradesh, India. High resolution remote sensing data is used to prepare various thematic layers i.e. settlement, transportation network map and other land base and performed survey of electrical asset data of Bhadohi, which is finally integrated into GIS platform. Number and types of electric poles, poles ID, distribution transformers (DTRs), the length of HT/LT lines etc. are collected during the field survey. The geographic location of each distribution transformer in the study area has been acquired using GPS and mapped in the hard copies of satellite data. It was that while there were 433 distribution transformers found in 2015 only 336 were recorded in 2011.

Keywords: *GIS, GPS, electrical asset, ARC GIS-10.1, DTRs, HT/LT lines.*

1. INTRODUCTION

Electricity is a vital aspect of the utility sector that is very necessary to the smooth and meaningful development of any city. It is an important part of any person living both in rural and urban region. It has brought many things that definitely have made many marvels and life would seem so hard without it (Govindaraj and Nailwal, 2013). The prime purpose of an electricity distribution system is to meet the customer's demand for energy after receiving the bulk electrical energy from transmission or sub-transmission substation (Kanmani and Suresh Babu, 2014). In India, the electric power industries have been developing power transmission system to follow up with a rapid growth of the power demand due to increasing population pressure on this sector. The electric distribution system is dedicated to delivering electrical energy to end users (Parkpoom, 2013). Electrical Utilities need an efficient way to monitor and maintain their infrastructure that enhances the operations and extend the life of their assets-or notify-them of potential asset failure. For effective asset management, utilities need accurate information feeding of their asset inventory. Power distribution reform is widely considered today as fundamental to the improvement of the commercial and financial viability of India's power sector. The complexity of electrical distribution power system is only a reason for introducing new geospatial technologies as GIS and GPS (Global positioning system) that carries out complex power system analyses e.g. optimization of networks, load forecasting in very less time period as and when required (Parkpoom, 2013). A few utilities and distribution companies have started using GIS or geospatial technologies in order to improve their efficiency levels pertaining to the operations, as well as, customer services (USAID, 2006).

Nowadays, for developing large scale electrical network geodatabases, robust methodologies that integrate traditional data conversion techniques with sophisticated project administration mechanism to enable efficient workflow management and quality control is required. Technological advancement is taking place much faster in generation and transmission sectors. With the radical changes that the electric utility industry is facing, customer choice has become the buzzword for the entire country. Nearly every stage is implementing limited choice programs, choice pilots or at least debating choice. Nowadays, in many developing countries several power utilities are continuing with old conventional manual systems in the distribution sector. The network asset maps in many cities are not properly updated, the customer bills and related data is inaccurate and the details of network assets and facilities are unavailable and not in an appropriate format so that it's proper management are very difficult to the electrical department.

Many companies and electrical departments in India are using GIS techniques for asset mapping and consumer indexing, which explains the concept, the systems' requirements and varied application of this tool in asset management, load predicting, delivery system planning and customer care etc. Use of GIS will simplify easily updatable and manageable database to cable to the needs of monitoring and sustain reliable quality power supply, effectual MBC (Metering, billing and collections), comprehensive energy audit, theft recognition and a decrease of transmission and distribution losses. All these measures will ultimately advance the overall internal effectual and help accelerate attaining commercial feasibility.

A new period of higher implication has arrived for the global positioning system (GPS) and GIS functions at electric utilities mapping. Improved hardware, software, and networking technology have made prospects for the utility industry to form and benefit from more comprehensive and sophisticated GIS. GIS applications have changed from their foundation in map production to advanced analysis tools for planning and operations. To a degree never equaled before, utility managers are looking to their GIS programs, occupied with progressively accurate data collected by global positioning system (GPS) technology, before creating any kind of decisions in the urban and rural areas.

Many utilities have the chance to use base map data created by a local or national government organization, or in exceptional cases, by different utility helping the same area. When digital base maps are not accessible, companies are forced to depend on other sources for base mapping. Many utilities basically digitize base map planimetric features in GIS vector format from present paper facilities maps and others favor to scan the current utility or other paper base map source, and use the resulting raster image as the backdrop for the digital facilities map.

With this competence comes an expectation for GIS/GPS professional to deliver higher levels of planning and management of their data collection process (Maguluri and Lakshmi, 2006). A well-designed GIS-based transmission and distribution network may assistance minimize loss of electricity and allow pooling of supply and demand in order to maximize the efficacy of the electric power system and decrease environmental effects of power generation

(Sekhar et al., 2008). The GIS overlays single line diagrams (SLD) of the distribution network with an efficient customer, meter, and network for distribution planning, data analysis and reporting. The Transmission and Distribution losses in India are in the range of 35-40%. These can be reduced by using GIS-based spatial data and improve the energy competence (Raghav and Sinha, 2006). It is also very helpful for mapping of wide-ranging electrical network including low voltage system or high tension/low tension (HT/LT) network and customer supply points and distribution transformers (DTR) with spatial locations covered on remote sensing high resolution satellite imagery and/or survey maps (Kumar and Chandra, 2001, Lgbokwe and Emengini, 2005). GIS-based buffer zone analysis from spatial informatics can assistance in routing the high tension transmission line nearby to an urban populated area, where spatial buffer zone will keep the residents from strong electric and magnetic field effects (Wang et al., 2010).

GIS layers of information are confined in the map representations which contain a lot of information kept in layers i.e. high tension/low tension (HT/LT) network coverage, roads and buildings etc. The next layer can have useful information on the electrical equipment i.e. LT/HT poles, conductors, distribution transformers etc. (Hassan and Akhtar, 2012). Most of the electrical network/equipment have a geographical location and the full advantage of any network development can be had only if the work is carried out in the geographical context (Sekhar et al., 2008). This paper delivers an impression of how GIS is being used in the utility industry to help meet today's requirements. It begins with a brief discussion of how GIS has evolved in electrical utilities to its current technological state. The present paper describes the survey based GIS method to analyses the changes in the electrical assets network and features during 2011 and 2015.

2. STUDY AREA

The study area covers city area of the Bhadohi, a Lok Sabha constituency and a municipal board in Sant Ravidas Nagar district in Uttar Pradesh state, India. It is also known as the "Carpet City," as it is home to the largest hand-knotted carpet weaving industry hub in South Asia. It is located at 25.42°N 82.57°E. It has an average elevation of 85 metres (278 feet).

This district is situated in the plains of the Ganges River, which forms the south-western border of the district. The Ganges, Varuna and Morva are the main rivers. The district is surrounded by Jaunpur District to the north, Varanasi district to the east, Mirzapur district to the south, and Allahabad district to the west. The district has an area of 1055.99 km². Location map of the study area is shown in Figure 1.

According to the 2011 census, Sant Ravidas Nagar (Bhadohi) district has a population of 1,554,203. The district has a population density of 1,531 inhabitants per square kilometre (3,970/sq mi). Its population growth rate over the decade 2001-2011 was 14.81%.

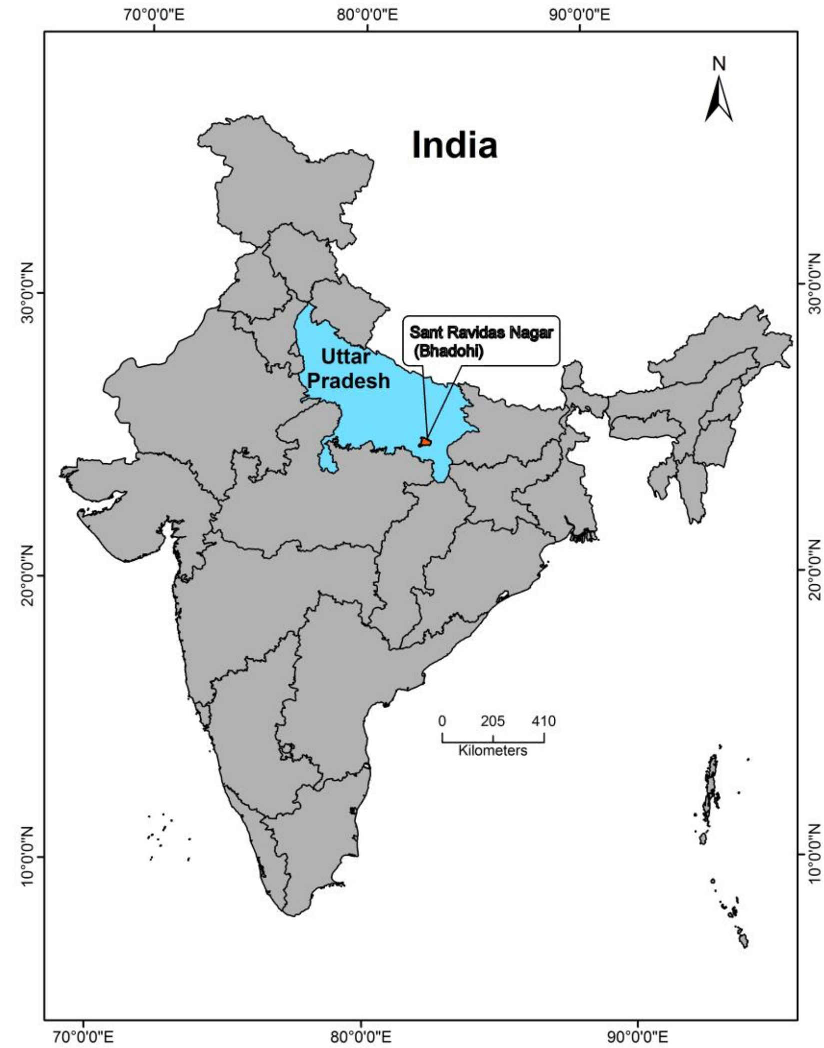

Figure 1. Location of the study area (Bhadohi) in India

Sant Ravidas Nagar has a sex ratio of 950 females for every 1000 males, and a literacy rate of 89.14%. Bhadohi has an average literacy rate of 90%, higher than the national average of 69.5%; with 94% of the males and 86% of females are literate. 18% of the population is under 6 years of age. Gyanpur is the headquarters of Bhadohi district. Carpet weaving in Bhadohi-Mirzapur region dates back to the 16th century, during the reign of Mughal Emperor, Akbar and is believed to have established when centuries ago, some Iranian master weavers stopped at Madhosingh village, near Khamaria, in Bhadohi while travelling in India, and subsequently set up looms here.

The present day Bhadohi district is biggest carpet manufacturing centres in India, most known for its hand-knotted carpet. Bhadohi is known as "Carpet City". While the Mirzapur-Bhadohi region has the largest number of weavers involved in handmade carpet weaving cluster, engaging around 3.2 million people in the industry, Bhadohi alone employs 2.2 million rural artisans in its 100 percent export-oriented industry. Bhadohi based organisations account for about 75%t of the Rs. 44 billion of total carpet exports from India.

3. OBJECTIVE

The main purpose of this paper is to develop an electric-GIS application which supports a functionality such as to create a network of electric utility. Its main objective is to analyse the changes in the electrical asset features from year 2011 to 2015 using field-based data collected through GPS integrated with GIS.

4. DATA USED AND METHODOLOGY

Electrical asset databases are very useful when connected with spatial information in the GIS platform. Spatial databases for electric poles, high tension/low tension (HT/LT) line, and distribution transformers have been created in ARC GIS-10.1, describing spatial locations of all the electrical assets. Distribution transformers database contain transformer location, its unique id., make, capacity, installation year if any, number of connections. Maximum load on the transformer recorded by transformer has also been fed in the databases. Latitude (X) and Longitude (Y) of each transformer and HT/LT line's length has also been calculated using field calculator. Poles database contains the condition of poles and type of poles

In this study, a number of GIS and remote sensing software packages are used for data processing i.e. ERDAS imagine software version-10.1 for geo-referencing of high resolution satellite data and ARC GIS-10.3 for on-screen digitizing of the electrical asset and ground base natural (water bodies and vegetation) and man-made features (transportation network and settlement) interpreted through the satellite data. High-resolution remote sensing data downloaded from Google earth. The individual data pieces are properly mosaicked and georeferenced so that the feature e. The methodology for several inputs for GIS model on power electrical planning network model is shown in Figure 2.

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

- Survey of electrical assets to allow unique id to each asset using printed hardcopy of satellite data with a hand held global positioning system (GPS). GPS was used to get the exact latitude (X) and longitude (Y) of each electrical asset.
- Base map (building, transportation network, and water bodies) is prepared from high-resolution satellite image to overlay asset network features over it.
- Before digitizing assets network (feeders, distribution transformers and electric poles etc.), a single line diagrams (SLD) of each electrical assets network of each feeder of the Bhadohi town are also prepared on A4 size paper to check the errors if any during the field survey then after the networks are digitized in the GIS platform
- Field-based data (attribute) and spatial data of electrical assets are integrated with each other in GIS domain. All network elements are identified and their technical Attributes are recorded in ARC GIS-10.1.
- Validation through field survey (land base & electrical Network Data) through hardcopy maps.
- Spatial data of electrical assets of 2011 and 2015 are compared accordingly to calculate the overall changes in the electrical assets.

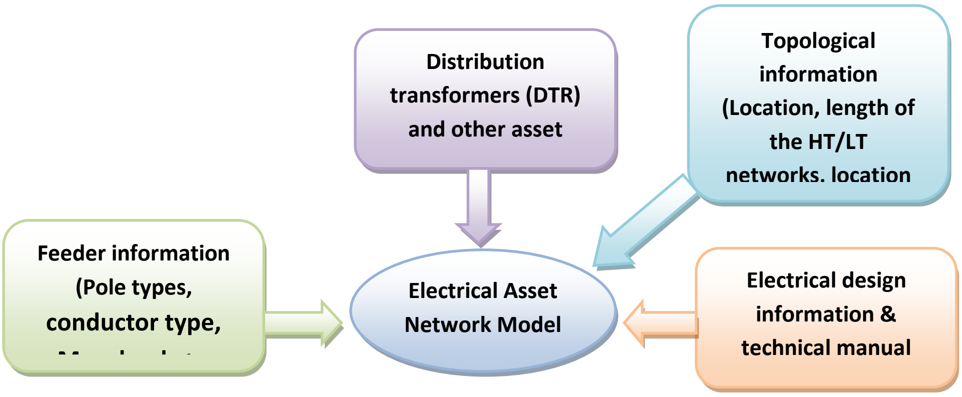

Figure 2. Inputs for GIS model on Power Electrical planning network model

5. RESULT AND DISCUSSION

The main advantage of electrical asset database is to maintain the consumer indexing record and consumer indexing is to enhance the efficiency of distribution system in terms of quality and earn increased revenues by reducing outages and T & D losses (technical and distribution loss), and to encompass the functions of different disciplines into the mainstream of operational hierarchy through wide networking. In this study a database for each asset indication the exact geographical location is created and compared during 2011 and 2015. During a survey of electrical LT and HT lines, the line length, type and type of DTR used and numbers of various types of poles existing are documented. The sub-transmission and distribution network indicating details of 33 KV feeders and 33/11 kV substation, distribution transformers and the LT/HT lines is developed and superimposed on the geographical map prepared through GIS so that the physical position of the electrical lines, substation is known and easily identified on the map. 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 elements electrically connected to any particular LT/HT lines or transformer and distinguishing points are clearly marked.

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 have also been calculated handheld 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 found that the total HT and LT pole in 2011 is 1383 and 2848 respectively while it is 1797 and 3239 in 2015. The number of the composite pole is also increased from 2011 (421) to 2015 (555). Total number of pole in Bhadohi city has been increased from 4652 in 2011 to 5591 2015 respectively (Table 1).

Table 1. Changes of electrical asset in the Bhadohi city during 2011 to 2015

Type of Pole	2011	2015
HT Pole	1383	1797
LT Pole	2848	3239
Composite Pole	421	555
Total Pole	**4652**	**5591**
DTR	336	433

In this study, substation wise and feeder wise electrical asset data of Bhadohi are also collected and calculated for the analysis. It is found that the Bhadohi city has three working substation i.e. 33/11 KV Bhadohi town, 33/11 KV, Carpet city and 33/11 KV Fattupur. Presently in these substations, the details of assets e.g. cables, transformers, pillar boxes and consumer's details like consumer number, voltage, consumption, bill date etc., are obtainable in the form of tables in a database management system. The details of network routes and their description are maintained in the form of single line drawings (SLD) and updated in GIS platform. Total 234 DTR is identified in the Bhadohi substation followed by Fattupur (131) and Carpet city (68) in 2015 whereas this figure was 194 for Bhadohi substation, 100 for Fattupur and 42 for Carpet city in 2011. Bhadohi substation is the largest substation which provides electric supply to the city from 05 existing feeders. Total DTR installed in Bhadohi town has been increased from 336 (2011) to 433 (2015) and it is due to increase load and pressure of new consumers in the city. In this study, it is also identified that there are so many illegal electric connections and power theft which might be increased the power load on the transformer (DTRs) during these 4 years. It is found that maximum DTRs (16) are installed in Khushiyara industrial feeder in Bhadohi while only 1 DTR is installed in Bhadohi feeder during 4 years. In Carpet city and Fattupur substation, Jamunipur feeder (15) and Maryadpatti feeder shows maximum (16) installation of DTRs respectively. Capacity wise DTRs of each feeder of Bhadohi are also calculated and it is noticed that only one DTR of 630KVA was installed in Bhadohi city while it is now 5 in 2015. The number of 63KVA DTRs installed in Bhadohi is reduced from 92 to 85 while the number of 10 KVA, 25KVA, 63KVA, 160KVA, 250KVA and 400KVA capacity DTRs installed in the area are increased during 2011 to 2015 (Table 2 and 3).

Table 2. Capacity wise DTR in each Feeder of Bhadohi city, 2011.

Feeder	**2011**								
	DTR Capacity								
	10KVA	**25KVA**	**63KVA**	**100KVA**	**160KVA**	**250KVA**	**400KVA**	**630KVA**	**TOTAL**
Bhadohi	2	6	9	7	3	14	9	1	**51**
Carpet city (town)	1	-	-	-	-	3	1	-	**5**
Coloney	-	6	2	2	1	1	-	-	**12**
Indra mill	1	18	11	3	1	11	1	-	**46**
Jamuni pur	13	8	2	5	3	2	4	-	**37**
Khushiyara	6	19	39	11	1	9	-	-	**85**
Maryad patti	9	26	25	11	-	6	1	-	**78**
Nai bazar	-	2	4	1	-	4	2	-	**13**
Sidhvan	-	-	-	4	-	2	3	-	**9**
Grand Total	**32**	**85**	**92**	**44**	**9**	**52**	**21**	**1**	**336**

Table 3. Capacity wise DTR in each Feeder of Bhadohi city, 2015.

Feeder	**2015**								
	DTR Capacity								
	10KVA	**25KVA**	**63KVA**	**100KVA**	**160KVA**	**250KVA**	**400KVA**	**630KVA**	**TOTAL**
Bhadohi	-	11	6	11	2	14	8	-	**52**
Carpet city (town)	-	-	3	4	-	8	-	1	**16**
Coloney	-	5	3	4	-	3	-	-	**15**
Indra mill	4	18	9	12	-	10	7	-	**60**
Jamuni pur	21	9	7	4	-	6	4	1	**52**
Khushiyara	6	23	23	23	4	10	2	-	**91**
Khushiyara Industrial	1	-	2	7	3	2	-	1	**16**
Maryad patti	7	34	23	12	-	13	5	-	**94**
Nai bazar	-	2	3	4	-	8	2	-	**19**
Sidhvan	-	2	1	3	1	7	2	2	**18**
Grand Total	**39**	**104**	**80**	**84**	**10**	**81**	**30**	**5**	**433**

During 4 years HT and LT network length both in overhead and underground have been increased in all the three substations of the Bhadohi. It is surveyed that the total overhead HT network length in 2015 is coming 110.93 km in 2015 while it is 94.66km. in 2011 whereas the overhead LT network length in 2011 and 2015 are 118.44 and 125.72km respectively. Maximum overhead HT network is increased (approximate 8 km) in Bhadohi substation in comparison to the other two substations during 2011 to 2015 while overhead LT network is reduced (approximate 2 km) in the Bhadohi substation and it might be due to time to time changes of electrical network from one substation to the other station by electric department. Due to this Fattupur substation shows a maximum increase of overhead LT network during 2011 to 2015 (approximate 9km.). Capacity wise DTR in each feeder of Bhadohi city in 2011 and 2015 are provided in Table 2 and 3. Substation and feeder wise changes of an electrical asset in the Bhadohi city during the 2011-15 show in table 4 and 5 respectively.

Table 4. Substation wise changes of electrical asset in the Bhadohi city during 2011-15

City	Substation	Feeder	No. of DTR		HT_Underground (m)		HT_Overhead (m)		LT_Overhead (m)		LT_Underground (m)	
			2011	2015	2011	2015	2011	2015	2011	2015	2011	2015
Bhadohi	33/11 KV Bhadohi	Bhadohi Coloney Indra mill Khushiyara Khushiyara Industrial	194	234	952.71	1311.62	38249.85	46270.62	64145.11	62148.06	85.58	114.25
	33/11 KV Carpet city	Carpet city Jamuni pur	42	68	13.67	52.83	14718.52	19297.88	23482.24	24448.71	0.00	0.00
	33/11 KV Fattupur	Maryad patti Nai bazar Sidhvan	100	131	383.89	646.31	41693.72	45365.33	30819.14	39126.81	0.00	0.00
TOTAL			336	433	1350.3	2010.8	94662.09	110933.8	118446.5	125723.6	85.58	114.25

Table 5. Feeder wise changes of electrical asset in the Bhadohi city during 2011-15

			No. of DTR		HT_underground (m)		HT_overhead (m)		HT Total (m)		LT_underground (m)	
City	**Sub Station**	**Feeder**	**2011**	**2015**	**2011**	**2015**	**2011**	**2015**	**2011**	**2015**	**2011**	**2015**
Bhadohi	**33/11 KV Bhadohi**	Bhadohi	51	52	346.14	320.80	7632.64	6714.08	7978.79	7034.88	24.63	24.41646
		Coloney	12	15	26.87	26.87	2471.59	3053.20	2498.45	3080.07	0	0
		Indra mill	46	60	363.66	449.46	8537.54	10042.19	8901.21	10491.65	0	60.9511
		Khushiyara	85	91	216.04	472.57	19608.07	20121.91	19824.11	20594.49	60.95	28.88109
		Khushiyara Industrial	0.0	16	0.0	41.92	0.0	6339.22	0.00	6381.15	0.0	0.0
	33/11 kv Carpet city	Carpet city (town)	5.0	16	6.86	46.02	2498.74	5933.01	2505.59	5979.04	0.0	0.0
		Jamuni pur	37.0	52	6.81	6.81	12219.79	13364.86	12226.60	13371.68	0.0	0.0
	33/11 kv Fattupur	Maryad patti	78.0	94	166.13	268.78	22435.31	25165.90	22601.44	25434.68	0.0	0.0
		Nai bazar	13.0	19	142.60	302.37	9501.65	9751.041	9644.25	10053.42	0.0	0.0
		Sidhvan	9.0	18	75.16	75.16	9756.76	10448.39	9831.92	10523.55	0.0	0.0
TOTAL			**336**	**433**	**1350.3**	**2010.8**	**94662.1**	**110933.84**	**96012.3**	**112944.64**	**85.58**	**114.25**

In this 4 years, HT network length in Khusiyara feeder in Bhadohi substation is also increased (0 to 6.38km) and it is because of demand for new electrical connections and installation of new DTRs in each feeder. Bhadohi feeders show a maximum reduction in HT and LT network during 2011 to 2015. During the four years, many new carpet industries have been developed in the Bhadohi town which may increase the demand for new electric connection and overburden of electric load and due to this electrical department tried to improve the electric facilities in the industrial area and installed 11 new DTRs in the Carpet city feeder. HT network length in Carpet city feeder is also increased from 25 km to 59.79km respectively while LT length is nominally increased (approximate 1.5km) in this feeder during 4 years. Naibazar feeder of Fattupur substation shown maximum increase of HT length (approximate 3.4km.) while Shidvan feeder shows maximum increased of LT network (approximate 9km) during 2011 to 2015.

In this study, it is found that due to the increasing of population and development of new carpet industries in the Bhadohi, there is an enormous demand for new connection arise while the production rate is not very much improved but electrical department is continuous trying to improve the electrical asset facilities and time to time changing the assets.

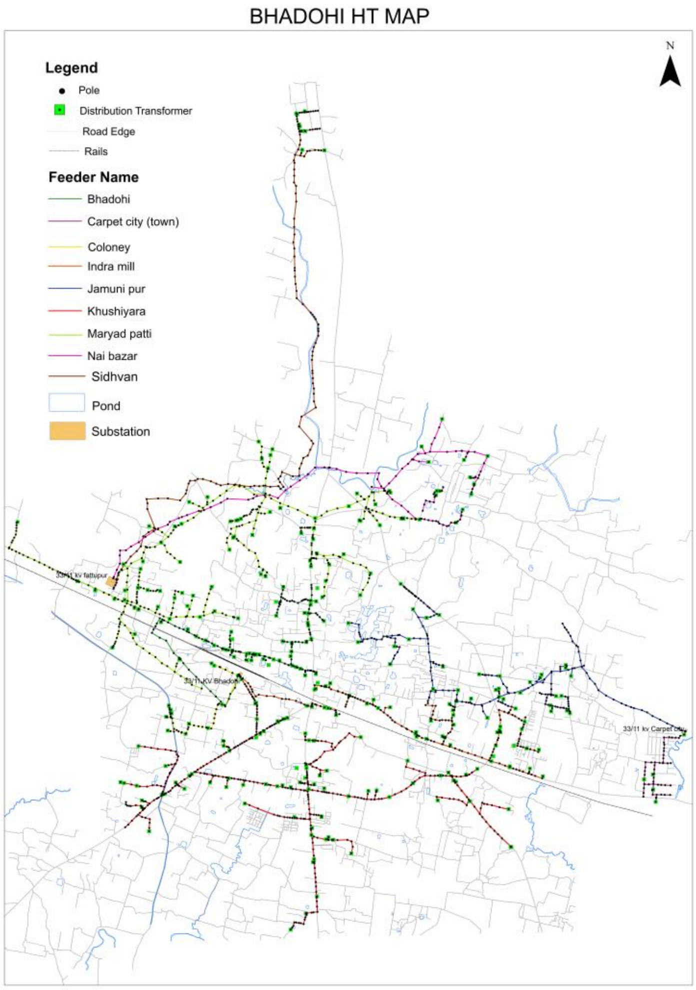

Figure 3. Electrical asset location and HT Network in each feeder in Bhadohi town in 2011.

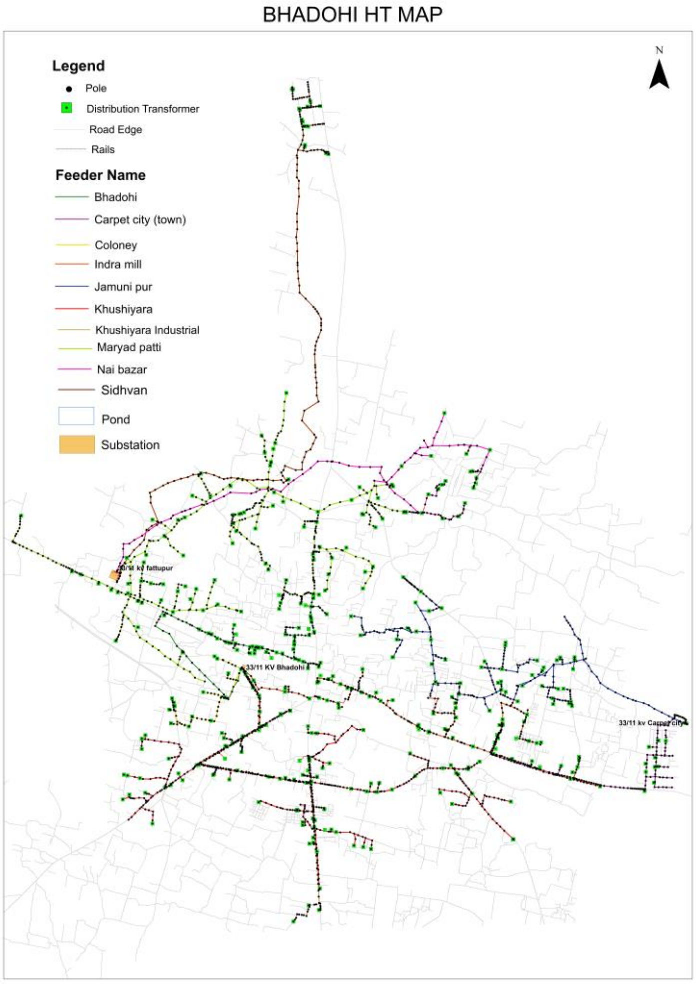

Figure 4. Electrical asset location and HT Network in each feeder in Bhadohi town in 2015.

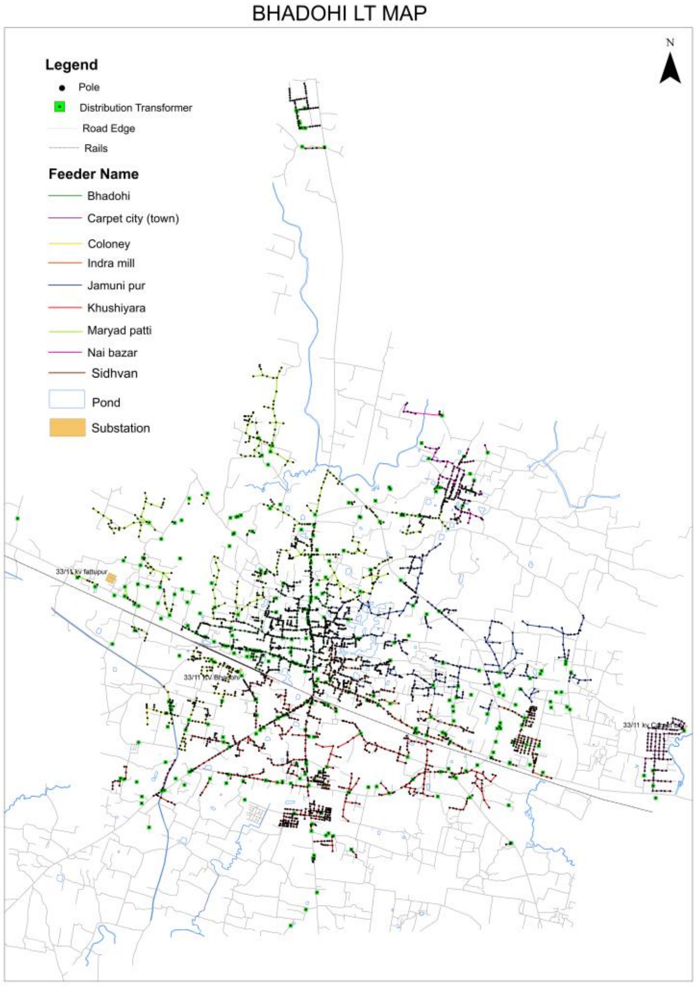

Figure 5. Electrical asset location and LT Network in each feeder in Bhadohi town in 2011.

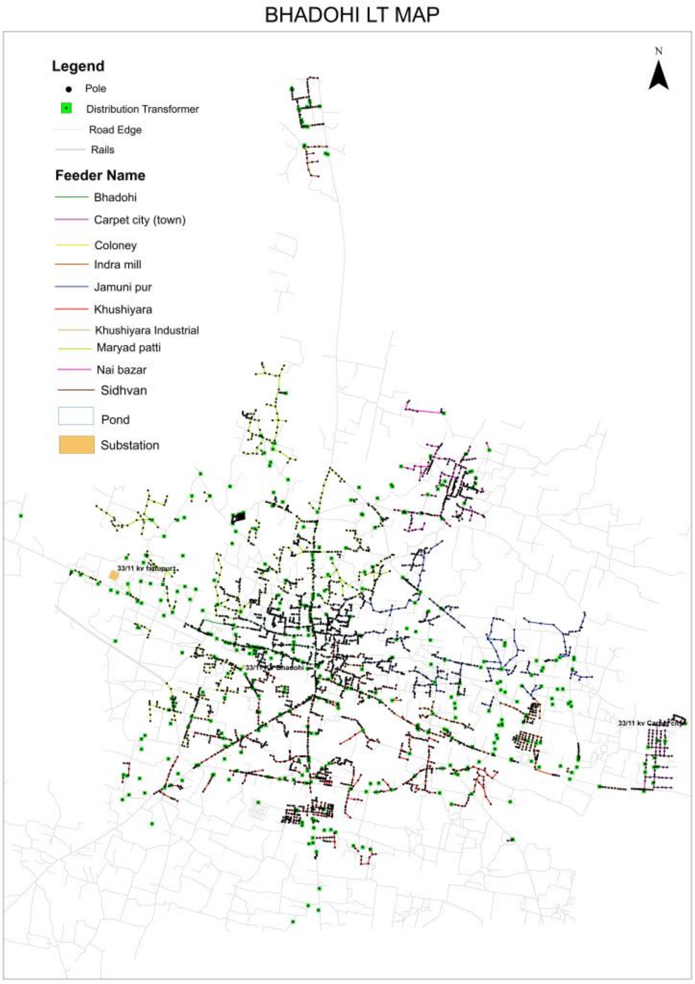

Figure 6. Electrical asset location and LT Network in each feeder in Bhadohi town in 2015.

6. CONCLUSION

In this paper, GIS plays very important role in the electrical system, which is very helpful for energy audit, electric load management, electrical network planning and analysis; determining the optimum and shortest path for power transmission lines; forecasting and predicting the amount of power needed in the coming future in the area which may help to arranging projects, identifying substation property requirements, control the demand growth of each electrical assets. This study is also very helpful to improve the customer complaints, long-standing faults brought to a minimum, to stop power theft (in local language it is called Katia practice), and to provide better facilities to the each consumer. In this study, it is very well found that the continuous growing of carpet industries leads an overload on the electrical system in Bhadohi. The main advantage of this paper is to provide operational efficiencies and customer benefits that exceed traditional GIS and mapping boundaries. This study allows officials of electrical departments to work on the latest technologies by relating the output to the location of load and feeder and providing better long term DTRs and distribution planning network etc.

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